The Dover Bronze Age Boat

edited by Peter Clark

ENGLISH HERITAGE

The Dover Bronze Age Boat

This volume is dedicated to the memory of Edward Wright (1918-2001),
whose contribution to the study of ancient boats and wetland archaeology
since his discovery of the first of the Ferriby boats in September 1937 was immense.
His scholarship, infectious enthusiasm and courteous good humour
won the respect and affection of all those who knew and worked with him.

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Edited by Peter Clark

Illustrations by Caroline Caldwell

ENGLISH HERITAGE

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Foreword

On 28 September 1992 I had a telephone call from an old friend and neighbour, Valerie Fenwick, to ask if I had heard about an ancient boat that had just been found at Dover. I knew nothing about it and, in any case, was convalescing from an illness that prevented me from driving my car. She immediately offered to give me a lift to Dover the next day. When we reached the site, we could look down into the cofferdam and see the work going on to expose the find six metres below. With some difficulty and a steadying hand from one of the excavators I then tottered down a ladder and found myself standing alongside a major part of the boat that was plainly a relative of the three that I had myself found on the Humber at North Ferriby, the last nearly 30 years before. I could thus enjoy again the feeling of awe that comes to the few who have seen such relics undisturbed in their matrix of wet clay when they are first exposed to view. As Keith Parfitt implies in his section, such sights are never matched in subsequent displays however painstaking the restoration; and it has been my privilege to have experienced such a vision in the case of all five of the recorded major finds of Bronze Age plank built boats in Britain, a group so far unique in north-west Europe.

After viewing the work we all decamped to a nearby Portakabin to discuss strategy for the removal of such a large and intractable artefact in the short time that the contractors could allow. The first tentative proposal was to envelop the fragile remains in foam-plastic and try to extract what had been exposed in one piece. I was able to tell the company that twice in my own experience I had attempted just that and with disastrous results on each occasion. Following the strategy pioneered by Sean McGrail in 1984 for lifting the Bronze Age Brigg 'raft' (*c* 820–780 cal BC), I advocated rather the dissection of the remains into manageable pieces that could be transferred to pallets and lifted out of the cofferdam by crane. It was quickly decided to adopt this course and the procedure was carried out with surprisingly little damage and incidentally made it easier to carry out recording and conservation later.

What followed is amply described in the monograph in sufficient detail for anyone to construct an accurate copy of what was found together with the evidence concerning the surroundings necessary to reconstruct the ancient environment. Perhaps the most unfortunate fact of the whole enterprise was that the presumed stern-end had to be left unexposed and is now entombed in steel and concrete with a five storey building on top, although it is acknowledged that it may have suffered disturbance in Roman times or later. Boat archaeologists must however be profoundly grateful that the authorities and the providers of funds enabled a second shaft to be sunk to reveal the bows together with so much of the find.

This was a rescue operation in the true sense of the term and those involved in the cramped and dirty conditions prevailing have confessed that they have never in their lives worked so hard to complete the excavation in the short period permissible. The conserved and now re-assembled remains in Dover Museum are a fitting tribute to the toiling of a dedicated team.

After the full description of the find, the book continues with the specialists' interpretations of the evidence put forward. Where certainty cannot be achieved, plausible hypotheses are advanced to answer most of the questions posed by the incomplete artefact.

Inevitably, debate will go on far into the future over some interpretations, but as a report on so complicated an exercise, the book has been produced with highly commendable promptness and thoroughness.

As one who has been concerned with ancient boats for over 60 years, I can sincerely congratulate the Canterbury Archaeological Trust, the Dover Museum and the Dover Bronze Age Boat Trust on conducting a copybook exercise in the teeth of formidable difficulties. I live in hope that more finds will be made to extend the known distribution of this unique class of Bronze Age boats. Hopefully also it will be possible to fill the gaps in the knowledge of their structure, all the examples found so far being substantially incomplete, and thereby replace hypothesis with fact.

Dr Edward Wright
January 2000

Acknowledgements

In the ten years since the discovery of the boat, many individuals and organizations have contributed to making the Dover boat project a success, either in its excavation, analysis, conservation or display. We attempt to record their names here; our apologies for any omissions. First, we must all recognise the contribution made by Keith Parfitt and Barry Corke in discovering the boat in the first place. Although the boat was a chance find, that chance may have easily been missed were it not for their integrity, hard work and dedication to the archaeology of Dover over many years. Especial thanks should also be given to the staff of Dover Museum; Christine Waterman, Mark Frost, Jon Iveson, Elizabeth Owen, and Margaret Sharp who made Herculean efforts to save the boat for the people of Dover from the day of its discovery. We must also acknowledge the splendid and indispensable support of Mott MacDonald (particularly Bill Cox, John Edwards and John Roe), Norwest Holst (Keith Haddock, Tooraj Ahadi-moghaddam, Colin Evison, Bill Rugg, John Rawlings and Michael Gulwell), Dover Harbour Board (Jonathan Slogget, Bill Fawcus, Colin Hedges and Barry Brown), the Highways Agency (Mr Ron Scales), English Heritage (Jocelyn Stevens and Geoffrey Wainwright) and P&O Stena Line (Steve Bispham).

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Summary

In 1992, the perfectly preserved remains of a large prehistoric sewn-plank boat were discovered buried 6m below the streets of Dover in south-east England. Dated to *c* 1550 BC, the boat is one of the most important and spectacular prehistoric wooden objects ever found in Europe.

The boat was an unexpected discovery. It was found during a watching brief on a deep shaft being excavated for a pedestrian underpass beneath the new road linking the port of Dover with the channel tunnel and beyond. A rapid rescue excavation was undertaken to record and salvage the boat; owing to its position at the bottom of the shaft, it was necessary to cut the vessel into thirty-two pieces and remove them by crane.

A 9m length of the boat was recovered, including one end of the boat, probably its bow. The surviving remains were approximately 2.3m broad, made from huge oak planks hewn into elaborate shapes that fitted together with exacting tolerances. These were made fast with an intricate system of timber wedges and twisted yew withies, the seams waterproofed with pads of moss held in place by thin strips of oak and a stopping made of beeswax and animal fat. Together these elements formed a broad-beamed, flat-bottomed boat of unique design, employing a woodworking tradition now long forgotten.

It was clear that the boat was not a wreck, but that it had been partially dismantled at the time of its abandonment. It was found in association with fragments of pottery, shale, animal bones, chalk blocks and flints, perhaps suggesting a symbolic dimension to the act of disposal of the vessel. The care with which the boat had been taken apart, and the evidence of deliberate damage to certain parts of the vessel, is in keeping with the idea that it had been ritually 'killed' at the end of its working life. It was abandoned in the liminal zone between land and sea, flanked by steep hills and towering white chalk cliffs. In this respect the circumstances of the boat's abandonment is reminiscent of a phenomenon seen elsewhere in Britain and western Europe relating to domestic architecture.

Study of the boat timbers and an experiment in reconstructing a 3m-long mid-section of the hull has provided a wealth of information about the techniques and sequence of construction, the tools used and the sophistication of woodworking techniques in the Middle Bronze Age.

Analysis of the hull form has enabled researchers to postulate a hypothetical reconstruction of the original boat form. Originally the boat would have been approximately 11m long. There was no evidence for a mast or the use of oars, and it seems probable that it was paddled. Speeds of about four knots would have been possible, carrying cargoes of about two to three tonnes. Palaeoenvironmental evidence indicates the boat was abandoned in a shallow, braided river, completely unsuitable for a boat of this size and complexity. It must therefore have travelled on the open sea, perhaps plying along the southern coast of Britain and across to continental Europe. Such voyages were well within the vessel's technological capabilities. Although there was no trace of a cargo in the boat, it seems likely that it would have carried a range of goods, perhaps most importantly bronze, either in the form of ingots or scrap metal. The raw materials for making bronze tools do not naturally occur in south-east Britain.

The timbers were in a superb state of preservation, retaining the marks of tools used in the construction and maintenance of the boat. However, the timbers and other artefacts were very fragile, and urgent conservation was required. It was fortunate that the technique of cutting the boat into pieces to retrieve it meant that the timbers were small enough to fit into a freeze drier. After soaking in a solution of polyethylene glycol for eighteen months, the timbers were transported to the Mary Rose Trust in Portsmouth, where they were freeze dried. The process proved a great success; there was little distortion or shrinkage of the timbers. The boat pieces returned to Dover in August 1998.

Another advantage of having cut the boat into pieces was that many cross-sections through the timbers of the boat became available for study. Analysis of the tree rings and rays revealed in these cross-sections showed the timbers had been significantly compressed during their long burial (by up to 50% in some places). By compensating for this compression, it was possible to postulate the original thicknesses of the oak planks, a crucial factor in understanding the boat's original form.

From the time of its discovery, there was a great desire that the vessel would be preserved and put on display to the public in the place where it was found. A charitable trust was set up to secure funding not only for the conservation, but also for the building of a brand new gallery at Dover Museum, which was to be dedicated to a display of Bronze Age life, with the boat as its centrepiece. Work began on building the new gallery in May 1998.

The task of re-assembling the thirty-two boat pieces on a supportive cradle was complicated by the fact that the outboard (bottom) of the boat could not be recorded during excavation and the minor distortion of the boat pieces during conservation had slightly twisted some of the pieces in relationship to each other. A system was conceived whereby each piece could be offered up to a fully adjustable cradle in such a way that the pieces could be manipulated in three dimensions until a suitable fit could be achieved. Ten months of trial and error were required before the boat was fully re-assembled and sealed into its environmentally controlled display case. The new gallery was opened to the public in November 1999.

The Dover boat is one of a few rare survivals of complex prehistoric boats ever found in northern Europe, and certainly one of the most complete and best preserved. The archaeological record is unequivocal about the importance of water transport to social and economic contact in the prehistoric period, and the study of the Dover boat has given us a unique opportunity to further our understanding of the technological basis of this contact and the implications for the structure of Bronze Age society.

Résumé

En 1992, on découvrit, enfouis à une profondeur de 6 mètres sous les rues de Douvres, ville de sud-est de l'Angleterre, les vestiges parfaitement conservés d'un des objets préhistorique à planches cousues. Datant d'environ 1550 avant J.-C., ce bateau constitue l'un des objets préhistoriques en bois les plus importants et les plus spectaculaires jamais découverts en Europe.

Le bateau fut une trouvaille fortuite, mis au jour par hasard au cours d'une opération de surveillance d'un puits profond que l'ont creusait pour un passage souterrain piéton sous la nouvelle route reliant le port de Douvres au tunnel sous la Manche et au-delà. On entreprit de rapides fouilles de sauvetage afin de répertorier et de sauvegarder le bateau; en raison de sa position au fond de puits, il fallut découper le vaisseau en trente-deux morceaux et les remonter avec une grue. On récupéra 9m de la longueur du bateau, y compris une des extrémités, probalement la proue. Les vestiges subsistants mesuraient 2.30m de largeur, et consistaient en d'énormes planches de chêne traillées en formes élaborées qui s'assemblaient l'une dans l'autre avec des tolérances astreignantes. Elles étaient fixées par un système compliqué de coins de bois et de baguettes d'if tressées, des tampons de mousse maintenus en place par de fines lamelles de chêne et un calfatage fait de cire d'abeilles et de graisse animale assuraient l'étanchéité des coutures. L'ensemble de ces composants formait un bateau à larges baux, à fond plat, d'une conception unique, utilisant une technique traditionnelle de travail de bois depuis longtemps disparue maintainant.

De toute évidence, nous n'avions pas affaire à une épave, car le bateau avait été partiellement démantelé au moment de son abandon. On l'a découvert associé à des fragments de poterie, de schistes, d'os d'animaux, de blocs de craie et de silex, ce qui donne peut-être à penser que la mise à l'écart de ce vaisseau aurait eu une dimension symbolique. Le soin avec lequel le bateau avait été démonté, et la preuve que certaines parties de bateau avaient été délibérément endommagées, s'accorde avec l'idée qu'il avait été 'tué' rituellement à la fin de sa vie utile. Il avait été abandonné dans la zone liminaire entre la terre et la mer, flanqué par des collines escarpées et dominé par les falaises de craie blanche. A cet égard, les circonstances de l'abandon du navire rappellent un phénomène rencontré ailleurs en Grande-Bretagne et en Europe occidentale en matière d'architecture domestique.

L'étude des bois du bateau et une tentative de reconstruction de la section médiane de la coque sur une longueur de 3 mètres ont apporté une abondance de renseignements sur les techniques et la chronologie de la construction, les outils utilisés et la sophistication des techniques de travail du bois au cours de l'âge du bronze moyen.

L'analyse de la forme de la coque a permis aux chercheurs d'envisager une hypothétique reconstruction du bateau dans sa forme originale. Il mesurait à l'origine environ 11 mètres de long. On n'a pas trouvé de témoignage de la présence d'un mât, ni de l'utilisation de rames, il semble probable qu'il était propulsé par des pagaies. Il pouvait attendre une vitesse de quatre noeuds environs et transporter des cargaisons de quelques deux ou trois tonnes. Les témoignages paléo-environnementaux indiquent que le bateau a été abandonné dans une rivière en tresses peu profonde sur laquelle un bateau d'une telle taille et d'une telle complexité n'aurait absolument pas du navigeur. Il doit donc avoir voyagé sur la pleine mer, cabotant le long de la côte sud de la Grande-Bretagne et traversant pour rejoindre l'Europe continentale. Ce vaisseau possédait dans aucun doute les capacités technologiques nécessaires à de tels voyages. Bien qu'on n'ait pas retrouvé de traces de cargaison sur le bateau, il semble probable qu'il ait transporté une variété de produits, le plus important étant le bronze, soit sous la forme de lingots ou de métaux de récupération. Les matières premières nécessaires à la fabrication d'outils en bronze n'existent pas à l'état naturel dans le sud-est de la Grande-Bretagne.

Les bois étaient dans un état de préservation exceptionnel, ils avaient gardé les marques des outils utilisés pour la construction et l'entretien du bateau. Les bois et les autres artefacts étaient très fragiles cependant et il était urgent de prendre des mesures de conservation. Heureuseusement, le fait que l'on ait été de découper le bateau en morceaux pour le dégager signifiait que les bois étaient assez petits pout être déposés dans un lyophilisateur. Après avoir fait tremper les morceaux dans une solution de polyéthylène glycol pendant dix-huit mois, les bois ont été transporté à Porstmouth, à l'association pour la sauvegarde de la Mary Rose, où ils ont été liophylisés. Le procédé se révéla un brillant succès, on a constaté que les bois ne s'étaient que peu déformés ou contractés. Les morceaux du bateau revinrent à Douvres en août 1998. Le découpage du bateau en morceaux offrait un autre avantage, il nous a permis d'étudier de nombreuses coupes à travers les bois. L'analyse des cernes et des rayons d'arbres révélés par les coupes a montré que les bois s'étaient sensiblement comprimés au cours de la longue période passeé sous terre) jusqu'à 50% à certains endroits). En compensant pour cette compression, il était possible d'avoir une idée de l'épaisseur des planche de chêne à l'origine, un facteur crucial pour comprendre la forme originale du bateau.

Dès le moment de sa découverte, on a vivement souhaité que le vaisseau soit conservé et exposé à la vue du public à l'endroit où il avait été trouvé. Une association de bienfaisance fut donc créée dans le but d'assurer la financement, non seulement de sa conservation, mais aussi de la construction d'une nouvelle galerie dans le musée de Douvres, qui serait consacrée à une exposition sur la vie à l'âge du bronze avec le bateau comme pièce centrale. Les travaux de constuction de la nouvelle galerie commencèrent en mai 1998. La tâche qui consistait à réassembler les 32 morceaux du bateau sur une charpente de support se trouvait compliquée par le fait que l'extérieur (fond) du bateau n'avait pas pu être répertorié pendant les fouilles et que la déformation, bien que minime, des morceaux pendant la phase de conservation avait légèrement faussé certaines pièces les unes par rapport aux autres. On conçut un système grâce auquel on pouvait présenter chaque pièce à un support totalement modulable, si bien qu'on pouvait la manipuler dans les trois dimensions jusqu'à ce qu'on obtienne un ajustement convenable. Il fallut dix mois d'essais de tâtonnements avant que le bateau ne soit complètement réassemblé et scellé dans sa vitrine à atmosphère controlée. La nouvelle galerie ouvrit au public en novembre 1999.

Le bateau de Douvres est l'un des quelques rares exemples de bateaux préhistoiriques complexes jamais découverts en Europe de nord, et il est certainement un des plus complets et des mieux préservés. Les données archéologiques sont sans équivoque quant à l'importance du transport fluvial dans les contacts sociaux et économiques pendant la préhistoire et l'étude du bateau de Douvres nous a offert une occasion de faire progresser nos connaissance sur le fondement technologique de ce contact et ses implications pour la structure de la société à l'âge du bronze.

Traduction: Annie Pritchard

Zusammenfassung

In 1992 wurden die perfekt erhaltenen Überreste eines großen prähistorischen Nahtplankenbootes gefunden, welche 6m unter den Straßen von Dover im Südosten Englands vergraben waren. Datiert auf *c* 1550BC ist das Boot eines der wichtigsten und spektakulärsten hölzernen Objekte, welche jemals in Europa gefunden wurden.

Das Boot war ein unerwarteter Fund und wurde zufällig während einer Besichtigung eines tiefen Schaftes entdeckt, welcher für einen Fußgängertunnel unter der Straße gegraben wurde, die den Hafen von Dover mit dem Channel Tunnel und weitergehend verbindet. Eine schnelle Rettungsausgrabung fand statt, um das Boot aufzuzeichnen und zu retten. Durch seine Lage am Grunde des Schaftes war es notwendig das Boot in zweiunddreißig Teile zu trennen und mit einem Kran auszuheben. Eine 9m-Länge des Bootes wurde einschließlich eines Endes, wahrscheinlich des Buges, gehoben. Die erhaltenen Überreste sind ungefähr 2.3m breit und sind von großen in den verschiedensten Formen gehauenen Eichplanken hergestellt, welche auf anspruchsvolle Tolereranzen zusammen passten. Diese wurden durch ein kompliziertes System von Holzkeilen und gedrehten Eibensträngen festgemacht. Die Fugen sind durch mit dünnen Eichenstreifen festgemachten Mooseinlagen wasserdicht gemacht und mit Bienenwachs und Tierfett versiegelt. Alle diese Elemente zusammen formten ein breitseitiges, flachbodiges Boot mit einem einzigartigen Design, für welches Holzbearbeitungstraditionen angewandt wurden, die mittlerweile längst vergessen sind.

Es war deutlich, daß das Boot kein Wrack war, da es schon teilweise während seiner Stillegung zerlegt wurde. Es wurde zusammen mit Fragmenten von Töpfereiwerken, Schiefer, Tierknochen und Feuerstein gefunden, welches eine Art von Ritual bei der Stillegung des Bootes nahelegt. Die Sorgfalt, mit welcher das Boot auseinander genommen wurde, und die Beweise für die absichtliche Beschädigung von bestimmten Teilen des Bootes, geben der Idee eines rituellen „Todes" des Bootes am Ende seiner Dienstzeit mehr Nahrung. Es wurde in der kalkigen Zone zwischen Land und Meer und von steilen Hügeln und turmartigen weißen Kreidesteilküsten umgeben zurückgelassen. Mit Hinsicht auf die Umstände der Stillegung, weisen diese auf ein gleichartiges Phänomen bei domestischer Architektur in anderen Stellen in Großbritannien und Westeuropa hin.

Das Studium der Bootplanken und ein Experiment, welches die Rekonstruktion eines 3m langen Mittelschiffteiles beinhaltete, ergaben eine Fülle von Informationen über die Konstruktionstechniken und –abläufe, die notwendigen Werkzeuge und den Entwicklungsstand der Holzbearbeitungsmethoden des Mittleren Bronzezeitalters.

Eine Analyse des Schiffrumpfes ermöglichte den Forschern eine hypothetische Rekonstruktion der originalen Schiffsform. Das Boot hatte eine ungefähre Länge von 11m. Es gab keine Hinweise für eventuelle Masten oder Ruder, welches Paddel nahelegt. Geschwindigkeiten von 4 Knoten wären mit einer Güterbeladung von 2 bis 3 Tonnen durchaus möglich gewesen. Paläoumweltliche Beweise deuten darauf hin, daß das Boot in einem flachen und verflochtenen Fluß zurückgelassen wurde, welcher für das Boot in seiner Beschaffenheit und Komplexität völlig ungeeignet war. Es muß daher auf dem offenen Meer gefahren sein, wahrscheinlich kreuzte es die Südküste von Großbritannien oder hinüber zu Kontinental-Europa. Derartige Fahrten waren ohne Weiteres im Rahmen der technischen Möglichkeiten dieses Schiffes. Selbst ohne jegliche Hinweise von geladenen Gütern ist es wahrscheinlich, daß das Boot eine Reihe von Gütern beförderte, am wichtigsten davon Bronze, entweder in Barren oder Schrott. Die Rohmaterialen zur Herstellung von Bronzewerkzeugen kamen nicht in natürlicher Form im Südosten Englands vor.

Die Hölzer waren in einem ausgezeichneten präservierten Zustand, und man konnte noch immer die Spuren der Werkzeuge erkennen, welche für deren Instandhaltung und Bearbeitung benutzt wurden. Die Planken und andere Artefakte waren jedoch sehr zerbrechlich, und schnelle Maßnahmen zur Konservierung waren notwendig. Die Methode das Boot in Teile zu zerlegen, um es ungeschädigt zu heben, bedeutete, daß die Hölzer klein genug waren um in einen Gefriertrockener zu passen. Nachdem die Holzteile in Polyäthylenglykol für achtzehn Monate eingeweicht waren, wurden sie zum Mary Rose Trust in Portsmouth transportiert und dort gefriergetrocknet. Dieser Prozess hatte großen Erfolg, da wenig oder überhaupt keine Verzerrung und Verschrumpfung des Holzes zu erkennen war. 1998 kehrten die Bootteile nach Dover zurück. Ein weiterer Vorteil der Zerlegung des Bootes in verschiedene Teile war die Möglichkeit das Boot an vielen Querschnitten durch die Hölzer zu studieren. Analysen der Jahresringe und –strahlen machten deutlich, wie stark das Holz durch seine lange Vergrabung, an einigen Stellen sogar bis zu 50%, komprimiert wurde. Durch Kompensierung für die Verdichtung, war es möglich die originale Dicke der Eichenplanken zu berechnen, ein entscheidener Faktor für das Verständnis der ursprünglichen Bootform.

Seit der Zeit als das Boot entdeckt wurde, bestand ein starker Wille, daß das Boot präserviert und an seinem Fundesort für die Öffentlichkeit ausgestellt werden soll. Eine Wohltätigskeitsstiftung wurde ins Leben gerufen, um die notwendigen Mittel nicht nur zur Konservierung sondern auch zu dem Bau einer brandneuen Austellung im Museum von Dover zu sichern, welche dem Leben des Bronzezeitalters gewidmet ist und das Boot als Mittelpunkt beinhaltet. Die Bauarbeiten für die neue Ausstellung begannen im Mai 1998. Die Aufgabe die zweiunddreißig Bootteile in einem Schutzgestell wiederherzustellen, wurde kompliziert durch den Fakt, daß die Außenhaut am Kiel des Bootes nicht mit aufgezeichnet werden konnte und daß, durch minimalen Verzug bei der Konservierung, die Teile verdreht im Zusammenhang mit anderen waren. Man entwickelte ein System, bei welchem jedes Teil zu einem volleinstellbaren Schutzgerüst gereicht und so dreidimensional manipuliert wurde, bis eine zufriedenstellende Montage erzielt werden konnte. Zehn Monate des Ausprobierens und Lernens waren notwendig bis das Boot vollständig wiederhergestellt und in seiner umweltlich kontrollierbaren Vitrine versiegelt wurde. Die neue Austellung wurde im November 1999 für die Öffentlichkeit eröffnet.

Das Doverboot ist eines der wenigen Überlebenden der komplexen prähistorischen Boote, welche in Nordeuropa gefunden wurden, und ganz sicher eines der vollständigsten und best-erhaltenen Boote. Die archäologischen Aufzeichnungen sind eindeutig über die Bedeutung von Wassertransport beim sozialen und ökonomischen Kontakt in prähistorischen Zeiten. Das Boot von Dover hat uns eine einmalige Möglichkeit gegeben, unser Verständnis der technologischen Grundlagen dieses Kontaktes und deren Einfluß auf die Struktur der Bronzezeitgesellschaft zu erweitern.

Übersetzung: Norman Behrend

1
Introduction

by Peter Clark

In 1992, a small team of archaeologists discovered the hull of a beautifully preserved sewn-plank boat of Middle Bronze Age date (Fig 1.1), buried 6m below the modern streets of Dover and about 200m inland from the present shore. About 9.5m of the vessel was recovered, the northern end of the boat lying outwith the area of excavation.

Figure 1.1
The boat in situ. Here, the astonishing preservation of the timbers can be seen clearly; note the tool marks on the upper surfaces of the bottom planks. When first exposed, the timbers were a golden brown in colour, but turned dark brown or black in front of the excavators' eyes – probably the result of ferrous ions reacting with residual tannins in the wood.

The hull was approximately 2.3m wide at its widest point, and consisted of four sculpted-oak planks, joined together by a system of twisted yew withy stitches, wedges and larger timbers. The design of the boat seems unique, although some technological parallels can be found both in the Ferriby boats, found more than half a century ago in northern England (Wright 1990), and in other fragmentary discoveries elsewhere in Britain (Bell 1993a; 1993b; McGrail 1981; 1997; van der Noort *et al* 1999). This unexpected discovery, at the heart of a major construction programme, the unique and unprecedented nature of the find and its position at the base of a deep, narrow shaft, presented a formidable challenge to all associated with the project – archaeologists, engineers, conservators, palaeoenvironmentalists, curators and a host of others. The boat has now been conserved, presented to the public in a new gallery and the primary results of study made available within eleven years of the original discovery.

It is ironic that an example of one of our earliest sea-going boats should be brought to light during works related to England's first land link with Europe for some 8,000 years. Improvements to the A20 – a major road linking the docks at Dover with the Channel tunnel and the motorway network to London and beyond – had been closely monitored for more than a year by a small team from Canterbury Archaeological Trust. Many important discoveries had been made throughout the course of this project (Parfitt 1991a; 1991b; 1992; 1993b) but, by September 1992, our budget was nearly exhausted, and we prepared to wind up this long campaign of fieldwork. The archaeological monitoring of the excavation for the pumping station at the southern end of Bench Street was to be our last task before the field team would stand down and start collating and assessing the results of their labours. The unearthing of the medieval town wall and the Roman harbour timbers seemed a fitting climax to the project. So it was in a mood of completion and (premature) relaxation that Keith Parfitt made his dramatic discovery (Chapter 3; Parfitt 1993a).

We were completely unprepared for such a find; nevertheless, within twenty-four hours, an emergency halt to the contractor's work had been negotiated, funding made available by English Heritage and a team of specialist advisors assembled on site. There was enormous interest in the boat from the moment of its discovery; archaeologists and conservators arrived at the site from all over the country, while media interest was stirred up around the world. Local people were also caught up in the excitement; a group of Dovorians gathered in the cold and wet to cheer the first piece of boat to be lifted from the shaft – a sound that warmed the hearts of the exhausted and sodden excavation team working 6m below.

At times, the number of visitors at the base of the cramped shaft made it difficult for the team to work, and strict limits were needed on how many guests could be accommodated. As the excavation progressed, staff from Dover Museum set up a closed-circuit television screen to help satisfy the public's appetite for seeing the work advance.

Following excavation, the work of recording, assessment, analysis, conservation, reassembly and display was to continue for eight years. At least 150 individuals have been concerned with one aspect or another of the project, each with their own skills, perspectives, interests, theoretical viewpoints and insights into the meaning and relevance of the boat – a breadth reflected in the range of author contributions to this volume. Unusually for an archaeological project, many authors have examined the same data-set – the boat itself – and have brought to it their own interests and vision. Within the following chapters are similar themes discussed from widely different perspectives; contradictions and disagreement of interpretation; technical determinism and cultural post-processualism; sober minimalism and informed speculation. Here we recognise the rich vein of academic thought, debate and speculation that the discovery of the boat has inspired. No doubt each reader will bring his or her own value systems and interests to the volume; some will find certain chapters too detailed, others too summary. Much more information is held in archive at Dover Museum, where the boat itself may also be seen. There are no simple answers; we expect further debate and discussion to take place, particularly as new discoveries are made. Here, then, are presented the findings of a group of individuals, recorded after several years of study. This volume does not attempt to be a final, definitive statement on the Dover Bronze Age boat; rather, it is a springboard for further study and a resource for the imagination.

From the outset, the programme of study was conceived as a much broader exercise than just a technical analysis of the hull itself. Ancient boats are, of course, at the epicentre of what is known as 'nautical' or 'maritime' archaeology: 'the study of Man's encounter or interaction with the waters of the world – oceans, seas, rivers and lakes' (McGrail 1995, 329). The development of this discipline over the last forty years or so has been a vital one, and has allowed the development of essential specialist skills. Nevertheless, it must be recognised this is a sub-discipline; the relationship of humankind with the 'waters of the world' is but one aspect of the rich tapestry of human cultural experience. Boats must be seen in the context of the lives and histories of the people who built and used them.

We wanted to reflect this in our studies; the Dover boat was an object built by people for a purpose, used by people within a rich, complex social and economic life. We aimed to move beyond the boat as an object and explore its implications for our understanding of the world 3,500 years ago and the people who lived in that world. It is hoped that this aim is well met in the contributions to this volume.

Structure of the report

The report moves through the various contributions in such a way that our horizons of interpretation and inference are broadened. It opens with Keith Parfitt's account of the discovery and excavation (Chapter 3), followed by an account of the recording process (Chapter 4). We study the evidence of the boat itself, in a detailed description by Peter Marsden (Chapter 5), who also examines what inferences about the construction, use and abandonment of the boat can be drawn from a study of the timbers.

We then attempt to visualise the nature of the boat as it was originally, and the immediate socio-economic implications of its original form. On the way, we review the techniques by which we have developed our hypotheses. Richard Darrah examines the way in which the timbers have been compressed, attempting to return to the original form of the planks that have survived (Chapter 6). He then reviews the raw materials used in the boat (Chapter 7), while Damian Goodburn examines the method of construction and the resources (both human and material) needed to build the boat (Chapter 8). The lessons learnt from the reconstruction experiment – in terms of our understanding of the manufacturing processes and the realisation of the original hull form – are discussed by Richard Darrah (Chapter 9). This brings us to the chapter by Owain Roberts, who sets out hypotheses for the original form of the boat and the implications for performance, capacity, and so forth, drawing together the threads of evidence (and speculation) and setting out his own line of enquiry (Chapter 10).

At this point we have arrived at a suggestion of what the boat was originally like, together with ideas of how it was built and what resources were required to construct it. From here, we start to think about the world in which it operated. First, we consider the finds associated with the boat, and the clues they give us about nearby settlement, the dismantlement of the boat, and (possibly) the places the boat might have visited (Chapter 11). The environmental evidence – reviewed by Helen Keeley (Chapter 12) – helps paint a picture of the landscape in which the boat was abandoned and offers clues to the working environment of the boat. A detailed examination of the dating evidence by Alex Bayliss *et al* (Chapter 13) sets out the basis on which one can compare the boat to contemporary evidence further afield.

Now we can discuss the implications of the discovery more generally; Ted Wright examines the affinities and differences of the Dover find with other prehistoric boats (Chapter 14), while Keith Parfitt and Timothy Champion review the cultural setting of the boat (Chapter 15). Returning to the boat itself, Timothy Champion discusses the implications of the abandonment of the boat (Chapter 16), Jacqui Watson sets out the way in which the boat was preserved (Chapter 17), and Christine Waterman and Barry Corke describe the reassembly of the boat and its presentation to the public (Chapter 18). Finally, we present an overview of the project, highlighting the breadth and richness of debate and speculation the boat has inspired (Chapter 19).

2
Glossary

by Peter Clark

Figure 2.1 (opposite) Schematic view of the boat, showing the main structural elements referred to in the text.

Argillaceous: Sediments of silt or clay-particle size.

Athwartship: Lying transversely from one side of a boat to the other.

Atlantic wildwood: The primeval mixed deciduous forest that reached its climax during the warm, wet Atlantic phase, between 5500 and 3000 cal BC (*c* 6100–4400 BP).

Biconical: Of a pottery vessel, a body profile resembling two cones joined together at their widest points, producing a distinct carination or ridge.

Block coefficient: The ratio of the volume displaced by a boat's hull to the product of the waterline length, waterline beam and draught.

Bucking: To cut a log at right angles to its long axis, ie across the grain.

Bulb of percussion: A raised hump on the ventral surface of a conchoidal flint flake, just below the striking platform.

Butt joint: A form of joint where the flat face of one timber is laid squarely against another.

Caulking: Material inserted between two timbers to help make the joint watertight.

Centre of buoyancy (LCB): The fore-and-aft location of the point about which the buoyant forces acting on the hull have no rotational effect ('moment') expressed as a percentage of the distance from the fore end of the waterline.

Centre of flotation (LCF): Geometric centre of the waterline plane.

Centre of gravity: Point through which the weight of a hull may be taken to act.

Chatter marks: Fine ridges across the grain of a timber, left by scraping.

Chine girder effect: Provision of fore-and-aft rigidity in a boat hull by the use of matching iles or hollowed-out logs to effect the transition from (flat) bottom to sides at the bilge.

Cleat: A rounded ridge of timber on the inboard face of a plank perforated to allow a timber (eg a transverse timber) to pass through.

Coccoliths: Minute calcareous plates formed by unicellular planktonic algae.

Cortex: The outer surface of a complete nodule of flint.

Crosscutting: To cut a timber at right angles to its major axis, ie across the grain.

Denticulate: A stone artefact possessing a serrated edge.

Diatom: Microscopic unicellular algae, which live in water and are characterised by their ornamental silica outer shell.

Dihedral: Formed by two intersecting planes.

Displacement: The weight or volume of water a boat displaces when afloat.

Dominant tree: Dominant trees are the tallest trees; they may break through the lower canopy forming broad emergent crowns that enable them to grow faster, producing wider annual rings.

Dovetail: A wedge-shaped tenon.

Downflooding: The uncontrolled entry of water into a boat hull when the angle of heel is such that freeboard becomes negative. Also known as 'swamping'.

Dragon boat: A long, narrow boat paddled at great speed over short distances in competition. First popularised during the Tang dynasty in China (AD 618–907), today Dragon boats are raced around the world. Modern competition boats are about 12m long and 1.2m wide, accommodating 20 paddlers over a course of 450m; larger boats of up to 30m in length were used in the past.

Dunnage: Packing materials placed between items of cargo and hull.

End board: A plank used to close what is presumed to be the forward end of the boat.

Epicormic: Relating to branches that grow out of the main stem of a tree from buds produced under the bark. Severe epicormic branching increases knottiness and reduces lumber quality.

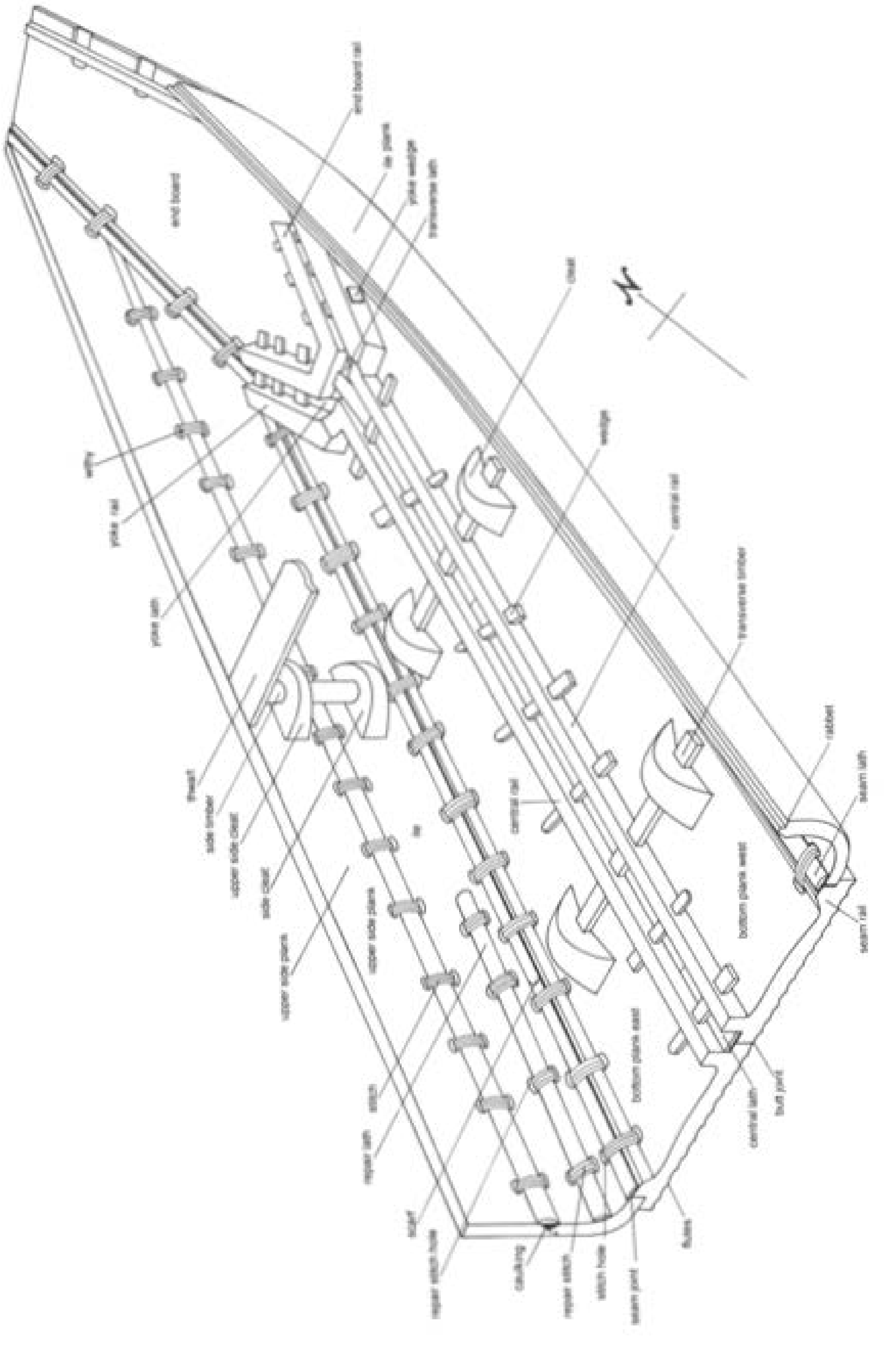
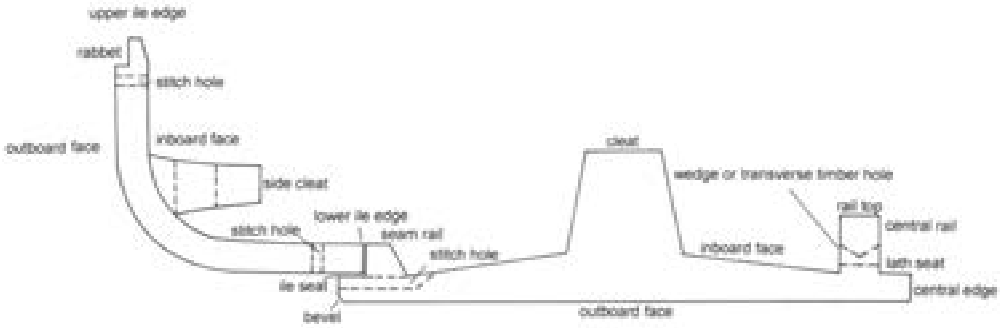

end board rail
yoke wedge
transverse lath
end board
cleat
N
wedge
central rail
transverse timber
rabbet
seam lath
seam rail
bottom plank west
butt joint
central lath
seam joint
stitch hole
repair stitch
caulking
stitch
bottom plank east
thwart

Figure 2.2
Schematic section through a bottom plank and ile, showing the features mentioned in the text.



Equivalent girder: In a boat, the conversion of a complex cross-section into a simplified rectilinear form to facilitate the calculation of the section modulus and the moment of inertia.

Everted: Of a pottery vessel, where the rim of the vessel wall turns outward.

Facet: The general shape, size and form of a surface impression caused by one blow with an edge tool such as an axe, adze or chisel.

Fastigated: Of plants, having erect branches, often appearing to form a single column with the stem.

Fay: To fit closely together.

Flat: A flattened area worked with an edge tool, but having no clear individual facets.

Floor: A transverse member across the bottom of a boat.

Freeboard: The vertical distance from the top of the hull sides to the water line.

Grain: The general direction of the timber fibres relative to the main axis of the tree.

Grog: Ground-up, fired clay or pot sherd added deliberately to the clay fabric of a pottery vessel in order to strengthen the fabric, make it more workable and reduce the risk of thermal shock during firing and subsequent use.

Grommet: A loop, often made of rope or leather, used as a pivot for an oar.

Gunwale: The topmost strake of the side of a boat.

Halophilous: Existing in a slightly brackish environment.

Heel: The angle of inclination of a boat from an upright position.

Heeling moment: A capsizing rotational force – balanced by the righting moment – that brings the boat to a level keel. Heeling moment may be caused by crew movement, wave action or the force of the wind acting on a sail.

Hobblers: Boatmen and their boats that assisted sailing ships to enter and leave harbour safely.

Hogging: The distortion of a boat's hull where the ends droop as the middle is supported on the crest of a wave.

Hydrostatic curves: A graphical display of the values obtained from the displacement calculations.

Ile plank: A transversely curved plank forming the transition from the hull bottom to hull side; also known as the chine girder or the transition strake.

Incut: A line, or sometimes a triangular incision, created by the use of an edge tool at a steep angle to the surface of the worked wood, as in cutting a notch.

Lath: A narrow strip of wood used to cap seams inboard.

Lines: The interrelation of sections in different planes that show the shape of a boat's hull.

Luting: Composition to make joints airtight or watertight.

Matrix: A graphical display of the relative chronological positions of individual stratigraphic units (Harris 1989).

Medullary rays: Layers of parenchyma cells in horizontal strands running out from the centre of a tree towards the circumference.

Mesohalobous: Existing in brackish conditions.

Mesotrophic: An environment with moderate quantities of nutrients, which supports a moderate range of animal and plant species.

Metacentre: The theoretical point at which a line drawn vertically through the centre of buoyancy of a heeled vessel meets the centreline of the boat's cross-section.

Metacentric height: The distance between the metacentre (M) and the centre of gravity (G) of a boat and cargo. This is an indication of a boat's stability; a high value of GM is good; zero GM is unstable.

Moment of inertia: Of a body, a measure of the difficulty of changing its speed of turning.

Monoxylous: Made from a single tree.
Neutral axis: In a bending beam, the boundary between the side that is in tension and the side that is in compression.
Oligohalobous: Existing in a freshwater environment.
Ostracod: Small aquatic crustaceans with a bivalved calcareous shell (carapace).
Pedunculate oak: A species of oak (*Quercus robur*) that supports its acorns on small stalks, native to Britain and north-west Europe.
PEG (polyethylene glycol): A water-soluble wax used to strengthen ancient timbers by replacing lost cellulose.
Phytophage: An animal feeding exclusively on plants.
Pitching: Of a boat, to dip and raise its bow and stern alternately.
Planimeter: A mechanical instrument for measuring the area of an irregular plane figure, such as the area under a curve.
Pot boiler: A heated stone added to a liquid to raise its temperature; usually used for cooking without exposing a pot directly to heat.
Prismatic coefficient: The ratio of the volume displaced by the hull to the product of the waterline length and the largest immersed area of any cross-section of the hull.
Punting: To propel a boat by use of a pole from a standing (stationary) position within the vessel.
Quanting: To propel a boat by use of a pole, placing the pole against the shoulder and walking along the side of the vessel.
Rabbet: A cut or bevel designed to take the end or side of another piece of timber.
Radial splitting: Splitting a log along its medullary rays, producing a timber with a wedge-shaped cross-section.
Rail: An upstanding ridge of timber cut out of solid wood.
Righting lever: The distance measured horizontally between a heeled hull's centre of gravity and its metacentre, or its heeled centre of buoyancy. When multiplied by the displacement, the product represents the righting moment.
Righting moment: The force acting upon a boat to return it to an upright position; equal to the product of a boat's displacement, its metacentric height and the sine of the angle of heel.
Riparian: Of, inhabiting or on the bank of a river.
Roundwood: Generally small stems of wood with a complete cross-section of stem or branch.
Sagging: The distortion of a boat's hull where the middle droops as it lies in the trough of a wave.
Sapwood: The wood just beneath the bark of a tree that consists of living tissue.
Scantling: The size or proportion of a timber.
Scarf: A joint in which timbers with parallel axes overlap longitudinally.
Score: A line of repeated incuts, resulting from the cutting of a notch across the grain with an edge tool. Also used of the notch itself (sometimes called 'weakening cuts').
Scow-form: The fore-end of a scow barge slopes from the hull bottom like a broad ramp almost as wide as the remainder of the hull.
Scribing: Scratching a line as a guide for woodwork, often parallel to the edges of a timber to be close fitted.
Seam rail: A raised ridge of timber at the outer inboard edge of the bottom planks to accommodate the lower edge of the ile plank, perforated for stitches.
Section modulus: A measure of the strength of a beam, used to calculate the stresses produced by loading.
Sessile oak: A species of oak (*Quercus petraea*) that supports its acorns attached directly to the stem without small stalks, native to Britain and north-west Europe.
Shake: A fissure or crack in timber.
Shearing stress: The force tending to make one section of material move across an adjacent section, measured by the force divided by the area of the section.
Sheer: In the profile of a boat, the upward curve towards the ends of the hull.
Sheer strake: The uppermost strake of the hull proper.
Signature: A distinctive pattern of small ridges or striations on a worked surface, created by nicks or dull areas in the blade of an individual edge tool.
Slenderness coefficient: A means of obtaining a relative assessment of the speed potential of various boats.
Snapping: A method of marking lines on a surface by stretching a string (impregnated with pigment) taut across the surface, pulling the string up and releasing it sharply, dislodging pigment onto the surface.

Spanish windlass: A device for exerting tension by twisting ropes between two fixed points.

Spring vessels: Large porous vessels laid down in timber during the spring.

Stability: The strength of a boat's tendency to right itself, expressed in terms of its righting moment.

Standard wave: A wave of a length equal to that of the boat and having a depth one-twentieth of the distance between crests or troughs; the wave has a trochoidal profile.

Stitch: The means of edge-fastening the boat's planks by separate stitches of withies.

Stop mark: Distinct lines, which are often curved, created at the end of a cut made by an edge tool; the lines mirror part or all of the shape of the blade that created them. (Other terms used for this type of feature include, jam kerf, jam curve or jam line.)

Stopping: A waterproofing substance put into stitch holes and seams to make the construction watertight.

Strake: A single plank or course of planks that stretches from one end of a boat to the other.

Strike-orientated: Following the strike direction of the geologic bedding and perpendicular to the dip (which forms an angle to the horizontal).

Striking platform: The surface area on a flint core receiving the force to detach a piece of material. This surface is often removed with the detached piece so that the detached piece will contain the striking platform at the point of applied force.

Sublimation: To change directly from a solid to a gas without first melting.

Summer wood: Wood produced by a plant near the end of the growing season, consisting of small, thick-walled xylem cells.

SWW (saturated wet weight): The weight of a wood sample when totally saturated with water, usually calculated by immersing the sample under vacuum conditions so that all air spaces within the wood are filled with water.

Synanthropic: Closely associated with humans.

Tangential splitting: Splitting a log at right angles to its medullary rays, tangential to its annual growth rings.

Thermocouple: A device for measuring temperature, consisting of a pair of wires of different metals or semiconductors joined at both ends.

Thwart: A simple seat, consisting of a board set transversely across the boat hull.

Tool mark(s): Any mark or group of related marks made by a tool used on the surface of timber or wood.

Transom: A transverse board at the end of a boat.

Transverse timber: A cross-batten of long, squared flat timber that passes through the cleats and helps to give transverse shape and strength to the boat.

Tree rings: The sequence of layers of new wood laid down between the bark and old wood of a tree during each growing season.

Trochoidal wave: The configuration used for the standard wave; it is a curve traced out by a point inside a circle when the circle is rolled along a straight line.

Upper side plank: The missing upper planks of the side, originally attached to the upper edge of the ile planks.

Volume coefficient: Used to assess the higher speed potential of a displacement hull type.

Wadding: Material lain over the junction of two timbers to help make the joint watertight, in contradistinction to caulking or luting, where waterproofing material is inserted between the timbers. In the case of the Dover boat, this material (moss) was held in place and compressed by timber laths.

Wale timber: A particularly thick strake timber, often intended to provide extra longitudinal strength.

Wedge: Short, flat, squared pieces of timber, usually tapered at one end, that were used to pass through holes in the central rails of the boat, so helping to hold the bottom planks together.

Withy: Tough, thin flexible branches of a tree used, after twisting, to stitch planks together.

3
Discovery and excavation

by Keith Parfitt

The site and topography of Dover

During the earlier Mesolithic period, Britain became an island, as rising seas finally broke through the connecting land bridge and separated her from mainland Europe. Since that time, sea-craft have been necessary for travel to and from the Continent across the English Channel (*La Manche*). The town of Dover in south-east Kent is strategically located where the Channel reaches its narrowest point and is therefore well placed for use by those attempting to cross to the Continent. The settlement is situated at the mouth of the River Dour, a small chalk stream flowing north-west to south-east across the dip-slope of the North Downs (Fig 3.1). The river has cut deeply into the Upper and Middle Chalk bed-rock and, where it meets the coast, forms the only significant break in almost 20km of sheer, almost unscalable, cliffs – the world-famous White Cliffs of Dover.

These facts have ensured Dover's standing as a highly important port since the Roman period, or even earlier. On a clear day, the north French coast – approximately 34km (21 miles) across the Strait of Dover – can be seen from the town. However, to comprehend fully Dover's geographical significance, it is perhaps best to view the site from the sea, as if arriving from the Continent. Approaching Dover in the 1st century BC, Caesar's scout Volusenus might have seen towering chalk cliffs stretching away to the west and to the east, but the narrow, steep-sided valley carved out by the Dour would have offered a safe haven and a ready point of access into the fertile hinterland of east Kent.

The River Dour has been central to Dover's very existence, providing both a sheltered haven for shipping at its mouth and a constant supply of fresh water for local inhabitants. The river represents one of the few permanent sources of fresh water in this part of south-east Kent. Its name – meaning 'the waters' (Rivet and Smith 1979, 341) – is of Celtic origin, suggesting that it has been of significance since pre-Roman times. The original river estuary, however, has long since been choked with silt and shingle and much of modern Dover is built across the deep layers of sediment that infill the site of the ancient haven. The valley has been truncated by the formation and subsequent enlargement of the English Channel in the recent geological past, and the river now flows for a total distance of approximately 6km. It must have once flowed further out towards France. Today, the river is a clear, fast-flowing chalk stream, seldom over 10m wide or more than 1m deep. It has been extensively used to power mills since at least the Norman period and consequently much of its course has been modified by the construction of artificial leats, dams and mill-ponds (Horsley *c* 1895).

There are two separate sources of the river, with spring-fed tributaries from Temple Ewell and Alkham joining at

Figure 3.1
Dover's location on the south-east coast of modern Britain.

Kearsney to form the main stream, which appears to follow a fault line in the chalk bed-rock (Shephard-Thorn 1988, 31). The Alkham branch now normally rises some 1.7km from the confluence, which is near Chilton Farm at the lower end of a long dry valley that starts above Folkestone. After extended periods of wet weather, however, the stream sometimes mysteriously rises as the 'Drellingore', its source as much as 4.5km farther up this valley, beyond South Alkham (Harman 1997). Such intermittently flowing 'winterbourne' streams are also known in other chalkland areas (including the Nail Bourne in the upper reaches of the Little Stour valley, a short distance further to the west). The 1km long Temple Ewell branch always used to rise at Great Watersend pond, but in recent years this has sometimes dried up in hot weather (*see* Figs 15.1 and 15.2).

It has long been assumed that there was a major Roman harbour at the mouth of the Dour, and work carried out principally during the 1970s and 1980s demonstrated the existence under the modern town of an almost unique 2nd-century Roman naval fort. In addition, remains of a late Roman Shore fort were found, together with various other buildings and harbour installations (Rigold 1969; Philp nd; 1981; 1989). The prime importance of the site as a port in Roman times is now fully apparent and has always been suggested by the occurrence of the only two known Roman lighthouses in Britain on the hills on either side of the valley. The Roman place-name evidence further underlines the point, with *Portus Dubris* recorded in the *Itinerarium Provinciarum Antonini Augusti* and *novus portus* ('the new port') in the *Geographia Claudii Ptolemaei* (Rivet and Smith 1979, 116; Philp 1981, 100).

The use of the Dour estuary as a port of entry in prehistoric times is highly likely on topographical grounds, but has appeared less certain from the archaeological record. The existence of an Iron Age hill fort under the medieval castle on the eastern heights above the town has been postulated for some time (Colvin 1959; Coad 1995, 16). Although the evidence is still not wholly convincing, Martin Biddle has, nevertheless, established the existence of some sort of Iron Age settlement here (Bayly 1962). More importantly, excavations close to the find-spot of the boat have revealed some quite extensive evidence for prehistoric settlement in the valley, and other finds of prehistoric material have been made on the adjacent downlands (Chapter 15).

Thus pre-Roman occupation certainly appears to have occurred in and around the Dour valley. It is perhaps significant, however, that in 55 BC, Caesar, apparently describing his arrival off the coast at Dover, makes no mention of any settlement here, and he certainly did not consider it a suitable landing place for his large invasion fleet. The narrow river estuary, however, was no doubt always more suitable for the landing of single or small groups of craft. Recent palaeo-environmental work has indicated that the entrance to the haven in prehistoric times may well have lain farther to the south-west than it did during Roman times (Parfitt 1998).

The first tangible evidence that the Dover gap might have been used as a landing place in the Bronze Age came in 1974, when divers of the Dover Sub-Aqua Club recovered a large quantity of bronze implements from the seabed off the Eastern Arm of the modern harbour (Stevens 1976; Muckleroy 1981). In archaeological terms, these implements – now totalling more than 400 individual items – are of great interest, apparently representing scrap material of Continental origin dating to about 1100–1000 Cal BC (Needham and Dean 1987). The most likely interpretation is that these bronzes were the cargo from a vessel that foundered while trying to make the safety of the Dour estuary when sailing from the Continent fully laden. No traces of the vessel itself have been identified and the exact form of the craft has remained entirely conjectural.

The subsequent discovery of the remains of a Bronze Age boat under the town centre in 1992 sharply re-focused attention on the existence of a prehistoric haven at Dover and, indeed, on the nature of Bronze Age shipping and maritime trade in general. A significant amount of apparently domestic rubbish was found in and around the excavated vessel, clearly indicating the presence of some nearby contemporary settlement site. Unpublished prehistoric finds from the Dover town centre excavations of the 1970s and 1980s may well contain further evidence for such Bronze Age occupation in this part of the Dour valley.

The A20 project

Extensive long-term economic growth in Kent is being forecast, with efficient transportation systems being identified as a key to such development. This has led to a substantial number of road construction and improvement schemes across the County, frequently with considerable archaeological implications. Several new roads are now in place, and more are projected.

Early in 1991, plans were put in hand for the construction of a major new highway (A20) to link the Eastern Docks at Dover to the Channel Tunnel terminal at Folkestone. This posed a significant threat to the buried archaeology, particularly within the historic town of Dover. Here, the new road, and its related works, required the large-scale movement and disturbance of earth along much of the town's seaward flank, cutting across the long-silted estuary of the River Dour and through most of the maritime quarters of the old medieval and post-medieval settlement. These key areas of ancient Dover had received little archaeological attention in the past (Wilkinson 1990) and the construction work potentially provided a splendid opportunity to examine a number of unknown areas in detail.

Despite the extent of the works proposed, however, no provision for any archaeological investigations had been included in the original environmental impact assessment; the effect that the groundworks might have on buried archaeological deposits had not been brought to the attention of either the Department of Transport or Southern Water Services, the principal developers. Shortly after the contractors had begun preliminary operations along the road line, and initial demolition work on the route had started, Canterbury Archaeological Trust became aware of this situation and rapidly prepared an archaeological impact assessment (Parfitt 1991a). English Heritage recognised that the likely impact of the scheme, as set out in this report, was of sufficient importance to warrant immediate action and readily agreed to give grant aid to the fieldwork. The Department of Transport made all necessary arrangements for the incorporation of an archaeological element in the works programme and a team from Canterbury Archaeological Trust was assembled, with a wide-ranging brief to observe all groundworks and to undertake investigations wherever and whenever this might prove possible.

The Trust began fieldwork in June 1991. It was clear from the outset that a phased and thoroughly considered programme of research-orientated excavation ahead of the development could not be carried out, owing to the late stage at which arrangements for archaeological investigations had been made. Under the direction of the author, however, a small mobile team, working very much on an opportunistic basis, conducted both formal excavations and watching briefs along a road construction corridor up to 0.5km in width and extending some 2km through the town. This team was fully employed recording a wealth of archaeological evidence for two and a half years. A separate team undertook investigations along the rural section of the road, on the high chalklands to the west of the town, also with some useful results (Rady 1991; 1992).

Along the urban section of the route, investigations allowed the rapid examination and recording of widely distributed remains across the town, ranging in date from the prehistoric period through to the Second World War (Parfitt 1991b; 1992; 1993b). Detailed palaeo-environmental studies of the valley sediments were undertaken simultaneously by Dr Martin Bates of the London Institute of Archaeology (Bates 1999; Bates and Barham 1993a). It was in the context of this complex project that the Dover Bronze Age boat was found. The other, not insignificant, discoveries made along the urban section of the new A20, principally relating to the local palaeo-environment and the medieval and post-medieval town, will be described in a series of reports to be published elsewhere.

The discovery and excavation of the boat

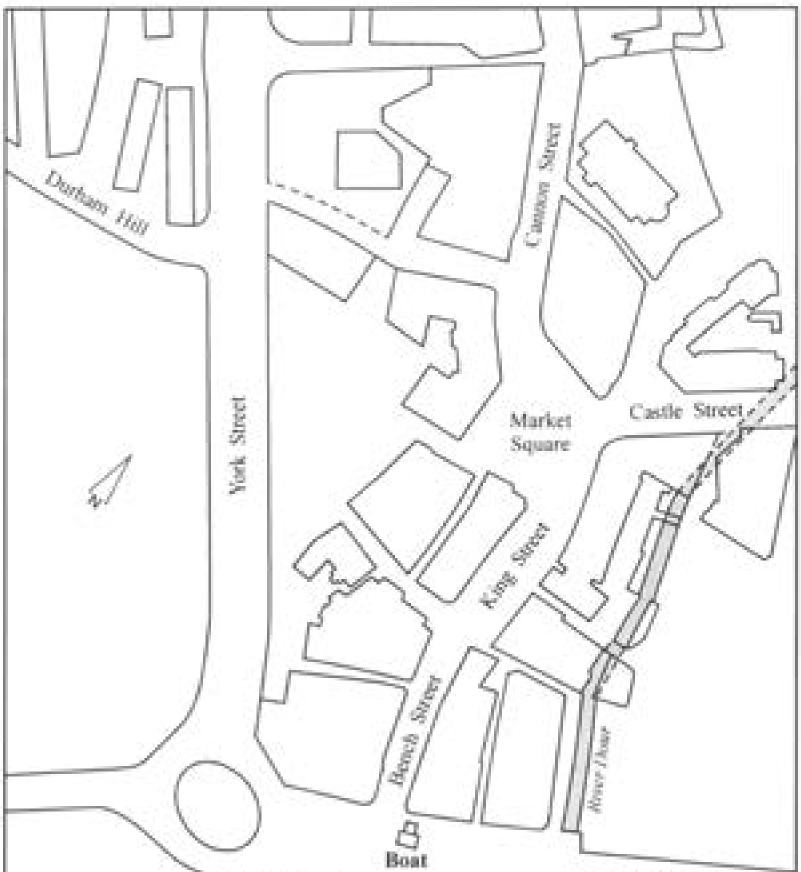
Discovery

From the start of the A20 project it was clear that one of the principal regions requiring detailed archaeological investigation would be centred on Bench Street, within the heart of the old town, about 200m inland from the present shoreline (Fig 3.2). Here, extensive deep excavations for replacement mains sewers and a major pedestrian underpass below the new highway (Townwall Street) were fully expected to reveal some significant remains, as the area lay across an important part of the medieval settlement, adjacent to the seaward defences of the town.

Construction of the new underpass began in the summer of 1992 and allowed the rapid examination and recording of a series of medieval and early post-medieval remains. These included parts of substantial domestic buildings that once fronted onto Bench Street (mostly destroyed when the road was widened in 1836), significant sections of the medieval town wall, and remnants of the contemporary Boldware Gate overlain by the foundations of the late-16th-century Three Gun Battery (Parfitt 1993a; 1993b).

It had long been recognised that the whole of this part of medieval Dover was built across reclaimed land that was formerly part of the river estuary. Some examination of the deeply buried silts in the area was undertaken through deep-core drilling in the early stages of the A20 project, firmly establishing the presence, at depth, of prehistoric sediments.

Figure 3.2
The location of the two cofferdams in present-day Dover.



In September 1992, an opportunity to examine a more substantial exposure of the early valley deposits was provided when the contractors, as a late addition to their original plans, opened a deep shaft at the junction of Bench Street and Townwall Street, NGR TR 3201 4126. This was intended for the insertion of a water pump below the base level of the new underpass. The machine-excavated shaft was lined with interlocking sheet-steel piling and cut across the line of the lost medieval town wall. It was ultimately excavated to a maximum depth of just over 7m below modern street level, revealing an impressive sequence of deposits and structures of great archaeological and palaeo-environmental interest, before terminating at a point 1.30m below modern Ordnance Datum (OD). The standing arrangements allowed for no more than a watching-brief to be conducted as the excavations progressed, but archaeological observation was maintained throughout, in close collaboration with the contractors.

Below ground, the medieval town wall in this area still survived to a height of between 3 and 4m in places and there was clear evidence to show that its southern face had once been washed by the sea or the river. As a result, some sections of the wall appeared to have collapsed, leaving substantial breaches in the masonry that subsequently became filled with loose beach shingle. The contractors took full advantage of one such convenient break, and repositioned their shaft a metre or two to the west of the spot originally intended (where the wall survived). By doing this, they safeguarded a well-preserved section of medieval walling immediately to the east, but, as was to be later revealed, it also meant they had moved across the area occupied by the prehistoric boat.

The first major archaeological structure to be located and rapidly recorded was the base of the town wall, which was still preserved under the thick shingle deposit infilling the breach. The wall survived to a height of about 0.50m and the southern (seaward) side was found to rest upon a line of timber planks, supported on closely spaced vertical timber piles driven into what had presumably been the medieval foreshore or river-bed, consequently preserved by the waterlogged conditions. The base of the wall footing was at +1.00m OD and

Figure 3.3
The first exposure of the boat (Cofferdam I); the damage done by the mechanical excavator can be seen in the foreground.

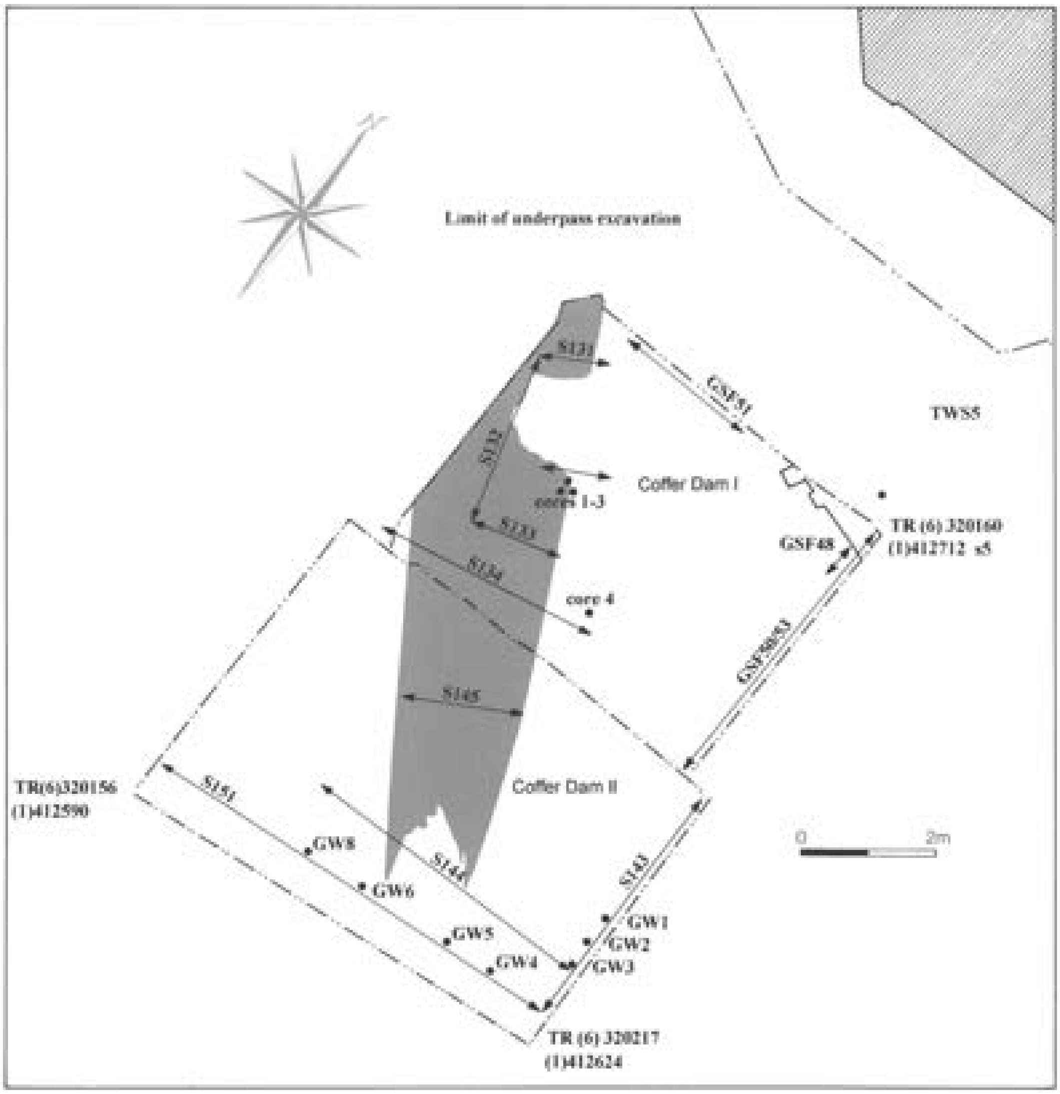


Figure 3.4
The position of the boat in the two cofferdams, showing the position of section drawings and samples.

rested upon a series of fine water-laid silt layers, largely without beach pebbles and quite different to the deep shingle deposits previously removed.

At a slightly lower level, in the north-east corner of the shaft, a short section of an earlier structure built from large timbers was exposed and hastily recorded. This survived to a maximum height of 0.77m. Two massive timber baulks, laid horizontally, one upon the other, and set within a construction trench aligned roughly east-west, formed the main elements of the structure. Horizontal cross-beams had been rebated into these timbers to brace the structure laterally, but it was clear that its upper levels had long been removed, probably by water erosion. The surviving top of the timbers was at +0.56m OD. This unexpected discovery appeared to form the southern side of a massive timber-box-framed harbour wall of typical Roman construction, cut into the bed of the ancient estuary. The details of the construction were very similar to those of a more extensive Roman harbour wall discovered in 1855–6, off Dolphin Lane, a short distance inland (Rigold 1969, 90), but it clearly represented a completely separate structure.

The contractors removed the Roman structure with some considerable difficulty, but the timbers were salvaged – reasonably intact – for archaeological examination. Before they had been completely cleared, however, more ancient timbers were revealed at a slightly lower level, again on the western side of the shaft. Inspection by the author of a de-watering sump dug in one corner of the main shaft revealed a thin band of wood in three sides of the exposed section. In the south face an associated carved, semi-circular fitting (Side Cleat 823) and a piece of twisted fibre 'rope' (later identified as a twisted yew wood withy) were visible. Further examination soon suggested that these timbers must form part of a boat (Fig 3.3), lying some 6m from the modern ground surface. Initial ideas of a Roman vessel sunk alongside the previously located harbour wall were soon discounted. The construction details, together with the nature of the surrounding sediments (which contained significant quantities of calcined flint and struck flint flakes) suggested that these remains were of prehistoric date.

A find of first-rate importance had thus been revealed. The largely informal watching-brief arrangements were now clearly inappropriate for the situation, and so, drawing upon the good working relationship built up over the previous 15 months, senior construction engineers were rapidly contacted in order to request a temporary halt to the works to allow a detailed archaeological assessment of the find to be made.

Figure 3.5
Cutting the boat timbers. The boat was cut into thirty-two pieces with a diamond-tipped rotary saw, each cut carefully positioned to preserve the fragile and complicated seams between the planks.

The excavation programme

Cofferdam I

The discovery of the first boat timbers was made at midday on Monday, 28 September. A direct appeal to Mott Macdonald's Section Engineer, Bill Cox, led to the issue of an order for the cessation of all excavation work in the Bench Street shaft – at least for the rest of the day. (Construction work on this part of the project was running some 19 weeks behind schedule at this time.) Work to expose the timbers, in order to assess more fully their extent and importance, was rapidly begun. The main contractor, Norwest Holst, arranged for floodlighting to be set up around the excavation so that investigations could continue into the night. By 9.00 pm the situation was abundantly clear: running diagonally across the shaft, undisturbed boat timbers extended for the full width of the excavation – a distance of almost 6m (Fig 3.4). The vessel was orientated north-west by south-east, lying almost horizontal and the right way up, about 6m below modern street level, between +0.04m and -0.75m OD. The original de-watering sump had previously removed a length of the structure, more than 1m in length, on the eastern side, but the remaining timbers, without doubt, constituted the mid-section of a very well preserved sewn-plank vessel. It was immediately recognisable as being broadly similar in form and construction to Bronze Age craft previously found at North Ferriby on the Humber estuary (Wright 1990).

It was obvious that further substantial sections of the boat must lie to the north and south of the exposed portion, severed by the sheet piling around the shaft. Early the following morning, the potential significance of the remains were outlined in a meeting with John Edwards, Mott Macdonald's Resident Engineer. In engineering terms, both the positioning and depth of the new water-pumping chamber were critical and it would be impossible to reposition the shaft (for a second time) in order to avoid the boat. Nor – in archaeological terms – could a 'safe' area be confidently suggested for such a deep and costly excavation. It was found that the boat remains lay over 1m above the proposed finished level of the shaft base; the vessel and all its associated sediments would therefore have to be removed. Further detailed archaeological excavation was, therefore, the only option. An excavation team was quickly assembled, including conservators from English Heritage and other specialists, notably Valerie Fenwick.

Figure 3.6
Lifting the boat pieces by crane. The team from Dover Harbour Board were crucial in moving the fast-decaying timbers quickly to the safety of the temporary holding tank.

Up to a dozen people worked under extreme pressure for an average of twelve hours each day to complete the excavation and recording of the boat. The work was supervised by the author and by Paul Bennett, Director of Canterbury Archaeological Trust. Specific tasks were delegated. The recording and sampling of the sediments surrounding and infilling the vessel was the responsibility of Martin Bates, while the excavation and recording of the boat itself was undertaken by staff from Canterbury Archaeological Trust. The author and Barry Corke prepared a detailed plan of the vessel. At the request of Dr

Geoffrey Wainwright, conservators from the Ancient Monuments Laboratory – Colin Slack and Adrian Tribe – came to Dover to help with the safeguarding of the timbers and the lifting of the vessel. (For Cofferdam II they were joined by Julia Park, and further assistance was provided at the end of this stage by Mike Corfield and Glynis Edwards).

Initially, the time that could be made available for the archaeological works amounted to just three days, owing to the delays that would inevitably be caused to the underpass construction programme. With the ready agreement of the Department of Transport, this time was subsequently extended to six days. In all, the investigations in Cofferdam I lasted a total of six-and-a-half days (sixty-seven hours) – from midday on Monday, 28 September to the evening of Sunday, 4 October. The considerable costs of the archaeological work were covered by a grant rapidly made available by English Heritage.

Because the boat had to be removed in order to allow the contractors to complete the shaft, and because time for detailed examination and recording in the ground was very limited, the excavation team decided early on that the craft must be lifted in order to allow more careful study off-site. A group of specialists was hastily called to a consultation meeting in Dover. The question to resolve was whether to attempt to lift the boat in one, or whether to cut it into sections and remove these individually. Opinions were divided, but it was finally agreed that – owing to the limited time available (only one-and-a-half days were then remaining), the fairly fragile nature of the construction and the damage already sustained – the only practical solution was to cut the boat into manageable segments, thereby safeguarding key structural features, and lift these out of the excavation separately for further examination (Figs 3.5; 3.6).

Most of the boat's excavation was completed within the three days allocated, amid intense interest from the media and general public. A subsequent extension of the time available allowed a further two days for planning and some detailed recording of the structure in the ground. The lifting of the main part of the vessel took place successfully on Saturday, 3 October, leaving the final day for completion of palaeo-environmental investigations of the sediments that had been sealed under the boat.

The conclusion of this operation allowed most of the exhausted excavation team to stand down, but the following day (Monday, 5 October), as the contractors resumed work in the shaft, the remaining two members of the standing A20 project team were allowed access to recover a further piece of the boat (Piece J; *see* Fig 4.2). This had been left along the southern side of the shaft and was officially abandoned at the end of the archaeological excavations in Cofferdam I. Piece J had to be salvaged in the twenty minutes available, with the help of the workmen, using a shovel and fork. The cracked and damaged section now provides the crucial link between the first section of the boat and the second, recovered in Cofferdam II.

Cofferdam II

With the salvage operation successfully completed, a short break allowed everyone concerned time for reflection and consideration of the implications of the achievements of the previous week. This culminated in the Department of Transport and English Heritage jointly issuing instructions to open up another excavation, in order to recover more of the boat. Current national archaeological policy preferred the preservation of important remains *in situ* wherever possible, but the decision to undertake further work at Dover was based on the likely effect of the new underpass and its associated pumping device on the local water-table. There seemed little certainty that, if the remaining parts of the vessel were left undisturbed for future generations to excavate and study with improved techniques, the surrounding sediments would have remained sufficiently waterlogged to allow the long-term preservation of the timbers. Therefore, another excavation was planned – with enough time available to arrange a sensible work schedule and to assemble the necessary equipment and specialists.

A second shaft, immediately to the south of the first, was excavated by the main contractors. This was designated Cofferdam II. Archaeological work here lasted a total of nine days (101 hours), from the afternoon of Monday, 12 October, until the evening of Tuesday, 20 October. Another substantial and well-preserved section of the boat was revealed, including one end, and this was fully excavated, recorded and lifted (Fig 3.7). The time available allowed for slightly more detailed recording and palaeo-environmental sampling than in the original excavation.

Figure 3.7
The second part of the boat revealed in Cofferdam II. By an astonishing mixture of luck and judgement, the second shaft uncovered one end of the boat in its entirety. Note the severed withies on the upper edge of the ile plank, evidence for an upper side plank.

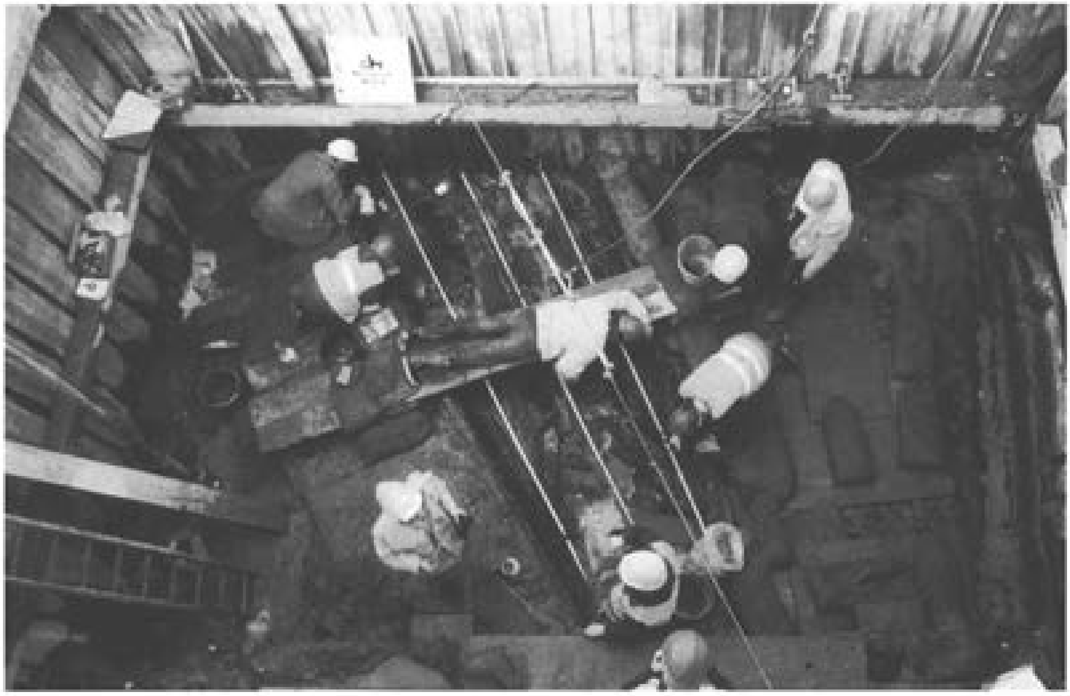


Figure 3.8
Working conditions in Cofferdam II. The addition of visiting specialists, television crews, pouring rain and an ever-shortening timetable meant that the excavation team needed considerable reserves of determination and patience.

The northern end

Despite a letter to *The Times*, signed by several eminent archaeologists, and a very generous offer of additional financial assistance from P&O European Ferries, it was not feasible to recover the final section of the boat north of Cofferdam I. The complex engineering problems associated with supporting adjacent Victorian buildings and the inevitable further delays to the road construction programme, together with the high cost of these works (estimated as being well in excess of two million pounds, exclusive of archaeological excavation) were prohibitive. The northern end of the boat thus lies unseen, well below the base of the new underpass. We cannot presume to know its state of preservation, however, compared

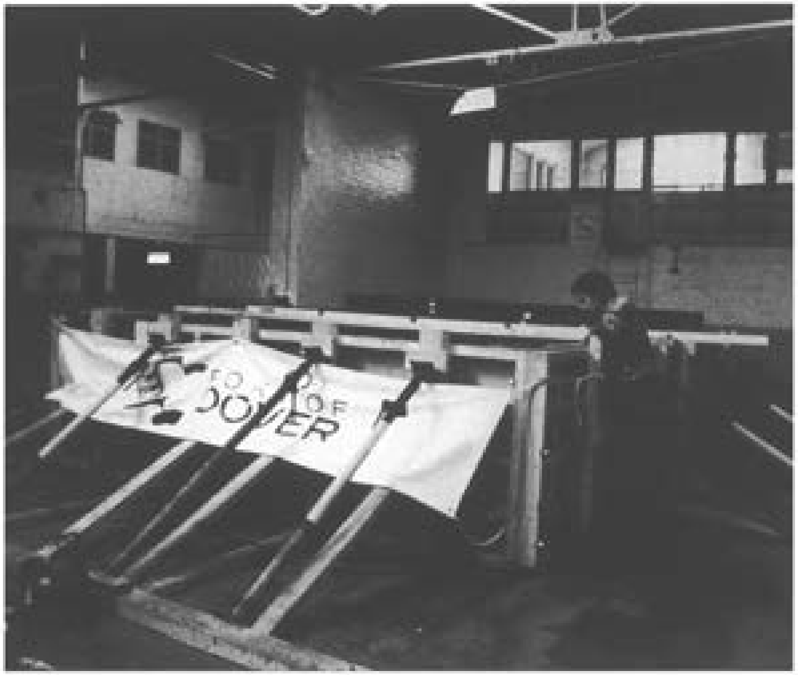


Figure 3.9 (above left) Temporary holding tank. Each boat piece was swiftly transferred to a tank of fresh water to slow decay while a long-term strategy of conservation could be determined.

Figure 3.10 (above right) Primary treatment of boat pieces. Staff from Canterbury Archaeological Trust, Dover Museum, English Heritage and Dover Harbour Board, together with local volunteers, cleaned, supported and consolidated the timbers immediately after their excavation.

to that of the excavated parts of the vessel. The Roman harbour wall (see above) may have cut across it immediately beyond the northern limit of Cofferdam I and may have caused considerable damage to the vessel, perhaps even removing a complete section. Furthermore, the continued waterlogging of the associated sediments cannot now be guaranteed, and any future attempts to excavate the last part of the Dover boat may prove to be poorly rewarded.

Methodology

Excavation and recording

Cofferdam I (initially cut for the water-pumping station) measured some 5m by 6m, while Cofferdam II (dug for purely archaeological purposes) was about 5m by 7m. These adjoining rectangular shafts allowed some 9.50m of the boat to be recovered.

Conditions for archaeological work in both excavations were far from ideal. Problems caused by the lack of time and the unfamiliar nature of the work were compounded by the cramped working space, the need for strict safety procedures and intermittent flooding (Fig 3.8). The boat lay around 3m below modern high-tide level at Dover and, without the aid of large and powerful water pumps, the excavations flooded with fresh water to a depth of over 2m in a short space of time. The water-logged timbers proved to be deceptively fragile in many places and were generally unable to support themselves over any significant length.

The slightly greater timeframe available for the excavations in Cofferdam II allowed a more organised approach than had been possible in Cofferdam I. Again, a machine was used for the bulk removal of infilled modern cellars and the thick deposits of relatively recent beach shingle that covered the bedded silts over the boat. Once the silts were reached, at a depth of about 5m, the mechanical excavation was halted and the deposits were hand-dug, being recorded and sampled as required, until the tops of the boat timbers were reached. Metal excavation tools were then replaced by small wooden implements. The use of a variety of spatulas and sharpened lollipop sticks allowed the exposure of the timbers and sampling of the associated sediments under controlled conditions and limited modern damage to the structure. All the sediment infilling the vessel was kept for analysis in the second excavation, complementing the rapidly collected bulk samples taken during the operations at Cofferdam I.

In Cofferdam II it was again impossible to record fully the complex structure of the boat *in situ*, owing to the limited time available. Only a basic field record was produced, with the intention of undertaking a more thorough examination once the remains had been safely removed from the site.

In both Cofferdams I and II, plans drawn at 1:10 were prepared by means of offsets taken from a series of longitudinal baselines. These provided the basis of the field record. They were supplemented by a set of profiles and sections drawn at the same scale, and by an extensive photographic record. The position of the boat in relation to the surrounding roads and buildings was plotted on a 1:50 base map. Moulds of original tool marks noted on the surface of the timbers were taken in case these deteriorated during subsequent storage of the vessel.

Dover Museum organised and paid for a detailed video film to be made of the progress of the excavation. Museum staff also arranged for a closed-circuit television link to be set up during work in Cofferdam II in order to relay live pictures to people at street level. This proved to be highly popular with passing Dovorians, visitors and off-site excavators alike.

Lifting the boat

It was apparent at an early stage that no matter how desirable it might be to lift the remains of the Dover boat complete, this would be impossible to achieve within the time available. Nor did the well-tried method of dismantling the vessel into its component parts provide a solution, for the methods of joining and caulking the individual timbers appeared to represent probably the most important aspect in the vessel's technology. The eventual decision reached, rather reluctantly by some, was that the craft should be cut up into manageable sections that could be individually lifted from the shaft. Dr Edward Wright, excavator of the North Ferriby Bronze Age boats, was one of the prime movers in advocating this technique, in the light of his largely unsuccessful attempt at a complete lift from the Humber foreshore in 1947 (Wright 1990).

First and foremost, a tool was required to cut the vessel into the required sections. The ideal tool for the job proved to be a diamond-tipped rotary saw of the kind used extensively by the road contractors for precision work. This was supplied, complete with a skilled operator – Michael Gulwell, Norwest's Charge Hand at the Bench Street site. The contractor's carpenters made up a series of stout wooden pallets, on which the freed boat timbers could be supported as they were lifted from the excavation. Urgent enquiries by Dover Museum staff led to the offer from Dover Harbour Board of a heavy mobile crane to lift the boat timbers out of the excavation, and the use of an adjacent warehouse for the safe storage of the timbers after salvage. Harbour Board carpenters were able to design and build two stout storage tanks at very short notice, in which the salvaged timbers could be immersed while their longer-term storage and conservation was planned (Fig 3.9).

Almost the entire exposed full length of the boat, totalling some 9.50m, was lifted in two separate one-day operations, on Saturday, 3 October and Monday, 19 October. The same general procedure was agreed for the lifting of both sections, although continual refinement of the techniques allowed the timbers in the second excavation to be more efficiently removed. The boat remains in Cofferdam I were cut into fifteen planned and lettered sections, mostly of long, plank-like form (*see* Fig 4.2). In Cofferdam II the boat remains were cut into fourteen separate pieces. Despite its great weight, the unusual and highly important swallow-tail end was lifted as one section.

Each boat piece was cut very carefully to a predetermined shape intended to keep joints and key structural features intact. The rotary saw made neat cuts no more than 5mm in width. The timber sections, as well as being very fragile, were found also to be deceptively heavy, and early plans in Cofferdam I to cut the boat into no more than five large pieces were soon abandoned owing to the excessively heavy weights involved.

Freeing the timbers

Freeing the cut timbers from the underlying sediment proved to be a long process, and rather more difficult than expected. The great weight of the overlying deposits, which had included the massive masonry of the medieval town wall and many tonnes of beach shingle, meant that the boat timbers were pressed firmly into the underlying silts. The various methods used to free the timbers developed very much on a trial-and-error basis, and these are worth recording here.

In Cofferdam I, wooden boards measuring about 600mm by 250mm, and about 20mm in thickness, with specially bevelled leading edges were originally planned to be gently tapped under the timbers. This technique soon had to be abandoned, however, as it was found to send shock waves through the ancient timbers, causing cracking and dislocation. Approximately 300mm of sediment needed to be penetrated, and driving in the boards horizontally proved difficult. Small stones often stopped the progress of a board and were sometimes forced up into the base of the ancient timber, causing it to split. Subsequent experiments with steel plates and a hydraulic ram encountered similar problems, although the damaging shock waves caused by individual hammer blows were, at least, eliminated.

The use of expanded polyurethane foam to give support to the exposed boat timbers during the lifting process also had to be abandoned at an early stage because it obscured the ancient wood and made it impossible to observe any detrimental effects caused by the lifting procedure. Moreover, the buoyant foam had to be cut away before subsequent immersion in the water tanks was possible.

A much improved, but slower, technique of loosening the boat timbers from the underlying sediments employed a variety of long-bladed implements and a fine water jet to undercut each piece. The same wooden support boards, closely spaced, could then be progressively eased into the excavated void, leaving about 10–20mm of undisturbed sediment attached to the base of the ancient timber. Once a timber was completely free and fully supported on the wooden boards, it was manoeuvred onto a larger baseboard, slid underneath the support boards. Additional packing in the form of plastic foam, mini sandbags and mud-silt that was readily to hand, was then added as required. Once everything was supported, the loaded baseboard (clearly marked with an identifying code letter and North point) was moved onto a lifting pallet and this was attached to the crane.

The timbers were then lifted clear of the excavation and taken by a Harbour Board lorry to the nearby storage facility where they were received by a second team, including staff from Dover Museum, English Heritage and Dover Harbour Board. Members of the reception team cleaned the loose sediment from the individual timbers, carried out emergency first-aid work on damaged sections, wrapped each timber section in plastic sheet and immersed them all in the storage tanks (Fig 3.10). Work to prepare the boat timbers for immersion continued late into the night on both lift days.

As a technique for lifting ancient timbers, the methods employed at Dover proved to be moderately successful. The great majority of the damage caused during the lifting process was as a result of the force needed to free the timbers from the underlying sediments. The following points may be of help to workers faced with a similar emergency in the future.

By far the safest method of loosening the ancient timbers was found to be by physically excavating under them; but since the boat was lying on the base of the shaft, there was often little space available in which to work. The operation was found to be quite time consuming and the difficulty in 'tunnelling' under ancient timber more than a few centimetres in a confined space did not become apparent until it was attempted. As the sediment was removed from under the boat, it had to be replaced quickly by supporting boards or other materials in order to prevent the collapse of the timber under its own weight. After a timber had been freed, the subsequent phases were found to be fairly straightforward and relatively risk free. Many hands, giving complete overall support to the piece, were required to move it onto the main baseboard ready for lifting. The key to this operation was close support all round – any unsupported areas were found to crack or collapse.

The relative preservation of the boat remains in Cofferdams I and II

The timbers of the boat when first exposed appeared to be in a very good state of preservation, though fragile. Nevertheless, as excavation and recording work progressed there was some slight, but noticeable, deterioration. The rapid removal of the great weight of deposits overlying the vessel is likely to have been one significant factor. The deterioration, however, was more marked in the hastily mounted Cofferdam I excavation; a variety of different reasons must account for this and should be recorded here.

In Cofferdam I, the boat had been initially hit by a mechanical excavator, which ripped out a large section on the eastern side of the vessel. The bulk of the timbers in Cofferdam I were excavated on the first day, leaving them exposed for six more full working days. Although the excavations were flooded by fresh water every night, to a depth of over 2m, there was not enough time to prepare an efficient spray system during the day, and some areas of the exposed wood were allowed to dry out a little too much once the shaft was pumped-out. Owing to the position of the boat (hard against one side of the excavation), access was severely limited and all excavation and recording work had to be conducted from either outside the eastern edge of the vessel or from within it. Sandbags were hastily filled and used to provide some cushioning from direct (underfoot) pressure and gave some protection for the exposed wood, but, once waterlogged, these were too heavy.

The excavation required the services of a large commercial water pump to keep it de-watered, as it lay well below the present-day water table. Water came into the excavation on all sides, particularly from the south (seaward) side. More importantly, a number of small springs forced their way up through cracks in the base timbers of the boat.

The methods used to free the boat from its underlying sediments were initially fairly brutal, requiring a 7lb hammer to tap in the lifting boards. This caused some splitting and movement in the ancient timbers. Piece J, rapidly salvaged with the aid of workmen after the main excavation had been completed, is quite severely cracked and damaged.

In contrast, the excavation at Cofferdam II was conducted under rather more control, being better planned, of longer duration and drawing upon the experiences gained in Cofferdam I and also upon more specialist advice, particularly from English Heritage. The presence of the end of the boat, and its central location within the excavation, allowed easy access from three sides and also the erection of overhead planking for vertical working. A more efficient spray system was set up, which allowed the wood to be kept constantly wet. Standing directly on the ancient timbers was kept to an absolute minimum, protective padded plastic bags representing a great improvement on the heavy sandbags employed in the first excavation. Continued de-watering of the area meant that, once the excavation had been pumped out, no springs forced their way through the base timbers of the vessel. Most of the boat timbers were exposed for only five days and the lifting techniques, tried and tested in the first excavation, were now greatly improved to allow a rather more gentle lifting procedure. The torrential rain, which fell throughout the day of the lift, proved to be highly beneficial in keeping the boat timbers wet.

The context of the boat

When first discovered in Cofferdam I, most of the boat was still sealed by some 0.40 m of fine, light-grey-brown bedded silt interleaved with lenses of granular tufa. Broadly similar deposits infilled the vessel and also separated it from a compact basal freshwater peat layer, which had a somewhat pitted surface apparently caused by water erosion some time prior to the deposition of the silts (Chapter 12).

The Dover boat always appeared as an extremely impressive structure (*see* Fig 1.1). The details of the construction readily made it clear that the vessel must have been the product of a master boat-builder working within a long established tradition. Indeed, the complexity of the craft served as a startling object lesson to all those excavators with previous experience only of dry-land prehistoric sites, devoid of any surviving timber remains. Exactly as Ted Wright found with the Ferriby boats, 'to convey adequately the astonishing intricacy and craftsmanship' as first revealed, is extremely difficult (Wright 1990, 195).

Examination showed that the boat had been largely constructed from just four main timbers. The two curved side planks were attached to the base planks by individual stitches of twisted wood fibre. Moss padding was clearly visible between most of the joints. The two large base planks had been held together by means of transverse timbers and wedges, driven through cleats and a pair of central longitudinal rails carved from the base timbers themselves. Careful inspection of the timbers revealed an extensive series of original tool marks still preserved on the wood surfaces.

Evidence for a number of repairs to the vessel were also observed, most notably on the eastern side, where a long split had been held closed by an additional row of lashings. A row of deliberately cut stitches, together with a neatly shaped rebate along the top of the side timbers, indicated that the vessel as found was not complete and that parts had been deliberately removed at the time of, or soon after, its abandonment. Clearer evidence for this could be seen at the southern end of the vessel. Here, a large section of the end structure had been cut away and removed from the site, leaving intact the ends of the side planks and producing the distinctive swallow-tail.

It therefore became clear that the boat was not an accidental wreck; it seemed that the vessel had been deliberately abandoned and partially dismantled in a shallow backwater of the River Dour. A scatter of cut stitches and other small wood fragments in and around the boat provided evidence that the deliberate breaking-up of the vessel had taken place on the site. About a dozen water-rounded chalk boulders and twenty large flint beach cobbles – without doubt deliberately brought to the site and most probably collected from the nearby seashore – were found scattered on the peat surface, especially around the southern section of the boat (Fig 3.11). There were no similar sized stones either within or under the vessel. It seems most likely that these stones were deposited after the boat had been abandoned. They are too few in number to be regarded as forming a true 'hard' for the regular landing of vessels and they perhaps represent temporary 'stepping stones' placed in the shallows to aid the demolition team's removal of the boat timbers. It is unlikely that they represent ballast removed from the vessel – there seems no logical reason for doing this if the vessel was to be abandoned, and, in any case, the form of the boat does not suggest the need for ballast.

The general absence of any evidence of a cargo, or of major detached structural elements in and around the boat, indicates that anything of use had been stripped out soon after the vessel was abandoned and taken away from the site, leaving an empty, derelict hulk. Presumably, the end-section of the boat was the last element to be removed, allowing water into the vessel and leading to its rapid infilling with sediment.

The riverine sediments underneath and surrounding the boat contained significant quantities of human occupational debris. This included animal bones (some with butchery marks), struck flints, much fragmented calcined flint and three potsherds – all indicative of contemporary prehistoric settlement nearby. The largest potsherd recovered consists of a rim fragment from either a collared or biconical urn (Chapter 11). Two small fragments of sandstone might be derived from domestic quernstones or rubbers.

A number of artefacts – mainly struck flints and burnt flints, unworked flint and bone – were also found within the filling of the vessel. Some of these objects were discovered resting on the floor of the boat and these were plotted *in situ*. Most numerous were small, unworked, natural flint pebbles and flint lumps (20), struck flints (14), cores (4) and calcined flints (2), small chalk lumps (13), occasional animal bones (5) and shells of Dog Whelk (2). Of more particular interest was a small piece of Kimmeridge shale (Chapter 11). In addition, many small pieces of wood and yew stitch were located, scattered above the floor of the vessel, and these must relate to the period when the boat was dismantled. It is not clear if the flints, animal bone and other material recovered actually relates directly to the period of the boat's use, or whether it had washed in at a slightly later date. Study of the sediments infilling the boat suggested that, following abandonment, the vessel infilled quite rapidly with deposits of granular tufa and was then sealed by a thick layer of silt (Chapter 12). It was noted that a number of the individual tufa pellets had formed around a small fragment of calcined flint, indicating that the deposit was actually being laid down at this time.

4
Recording

by Peter Clark and Barry Corke

Field recording

The cramped, noisy conditions at the base of the cofferdams, coupled with the extreme pressure of time and physical discomfort of flooding, rain and fumes from the site machinery made recording the boat *in situ* rather difficult (Fig 4.1). Plans were drawn at 1:10 by taking offsets from a series of longitudinal baselines; these provided the basis of the field record, supplemented by a set of profiles and sections drawn at the same scale, and an extensive photograph record. The accuracy of the site drawings was confirmed by subsequent checking against the boat timbers themselves. Dover Museum arranged a video record of the excavation process. A simple numbering series was used for all components of the boat, which were labelled using Dymo tape attached by stainless-steel map pins. The timber numbers were marked on a copy of the 1:10 plans (however, during post-excavation analysis, it became clear that there were more elements than originally seen during the excavation, and the numbering sequence was subsequently revised; *see* Chapter 5).

There was no opportunity in the drama of those few days to arrange for a photogrammetric survey of the boat *in situ*, such as had been carried out in the research re-excavation of the Brigg raft (Atkinson and Wickens 1981, 35–42) and strongly advocated by Valerie Fenwick at the time of excavation. This was most unfortunate; such a record would have been invaluable in the subsequent study of the boat. With hindsight, such a survey would be viewed as an essential element in the recording of prehistoric boats.

The boat was cut into twenty-three pieces to allow its removal from Cofferdams I and II; these pieces were each identified alphabetically. Subsequently, several of the pieces separated along the seams between their constituent planks, and the resultant pieces were further identified by numbers and/or cardinal points. Eventually the boat consisted of thirty-two pieces, identified as Ai, Aii, Aiii, Bn, Bs, C, Di, Dii, E, F, G, H, I, Ji, Jii, Jiii, K, L, M, N, O, P, Q, Re, Rw, Rwii, S, T, U, Ve, Vw and W (Fig 4.2).

Each piece was removed by crane, supported on wooden pallets and propped with sandbags. All the pieces were transported to a nearby store, where the inboard surfaces were cleaned by staff from Canterbury Archaeological Trust, Dover Museum, English Heritage and other volunteers. They were then placed in specially built storage tanks, immersed in fresh water.

Figure 4.1
Recording the boat in situ. Working at night under floodlights in torrential rain made the process difficult, although the rain was very helpful in keeping the boat timbers wet.

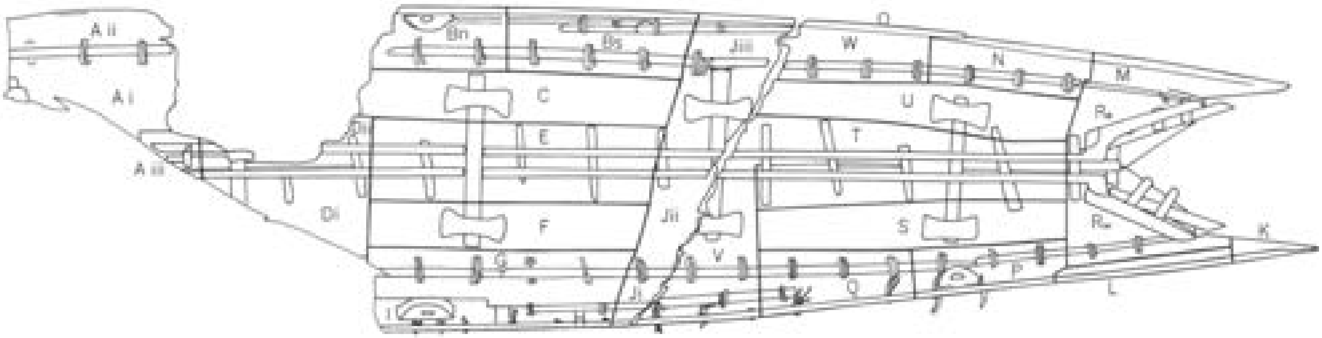


Figure 4.2
A 'piece plan' of the boat, showing the thirty-two pieces into which it was cut, together with their letter codes.

Assessment

After the excitement of discovery and excavation, the future of the Dover boat was considered carefully and in some detail. It was clear that the find was of monumental importance for the prehistory of north-west Europe, but its unique nature meant that there were few, if any, models for its study and preservation. With advice and financial assistance from English Heritage, a group of experts was brought together in Dover for two weeks late in November 1992 to view the boat pieces and debate the way forward. This allowed a proposal for the primary recording and assessment of the boat's research potential to be prepared (Clark 1993a). It was generally agreed that the primary recording should be undertaken as soon as possible, before any significant degradation of the boat timbers could take place. Work started in March 1993 in the cold and unwelcoming warehouse where the boat timbers were stored. Although scheduled to take seven months, the primary recording was completed in January 1994 (Clark 1993b; 1994), eleven months later.

Drawing the timbers

A comprehensive record of all the boat timbers was made at a scale of 1:1 during the assessment, while the timbers were still relatively fresh and prior to any conservation work being undertaken. Each boat piece was removed from its water tank, still on the plywood board used during the excavation, and prepared for recording. This was not straightforward, as many pieces had opened up or 'relaxed' during their recovery, or were lying at a different orientation to that when *in situ* and, although the complex joints were preserved for study, this also meant that some features were obscured.

Each boat piece was recorded in detail, both by photography and by 1:1 drawings including plans, sections and profiles (Fig 4.3). The timbers had to be placed in their correct position, as found at the time of excavation. The original baseboards, while providing an excellent support during the retrieval of the boat, did not adequately support or follow the profile of the pieces and, consequently, the timbers had moved or had been dislodged. A system of shaped wooden supports, foam covered wedges, jiffy foam and new sandbags was used to prop the pieces into position.

The system for recording the boat sections depended on the size and shape of the timbers. The large base planks, being generally flat, required the simplest method; a wooden frame was constructed over the boat piece, (as near as possible to the surface of the boat), onto which a piece of thin Perspex sheet was laid. Mylar film was laid on top of the Perspex, allowing the detail to be drawn from above. The recording of elevations of upstanding features (such as cleats and rails) (Fig 4.4) was aided by the use of small plumb lines, a spirit level and a custom-built mini-recording frame. Section drawings were made at each end of the boat piece, and selected profiles, using an extra-length template comb, at several points along its length.

The curved side planks presented more of a problem. If the timbers were recorded in the upright position – as they were in the ground – the detail of the upper side would have been invisible in plan, owing to the timbers' near-vertical position. Moreover, the detail below the side cleats would be

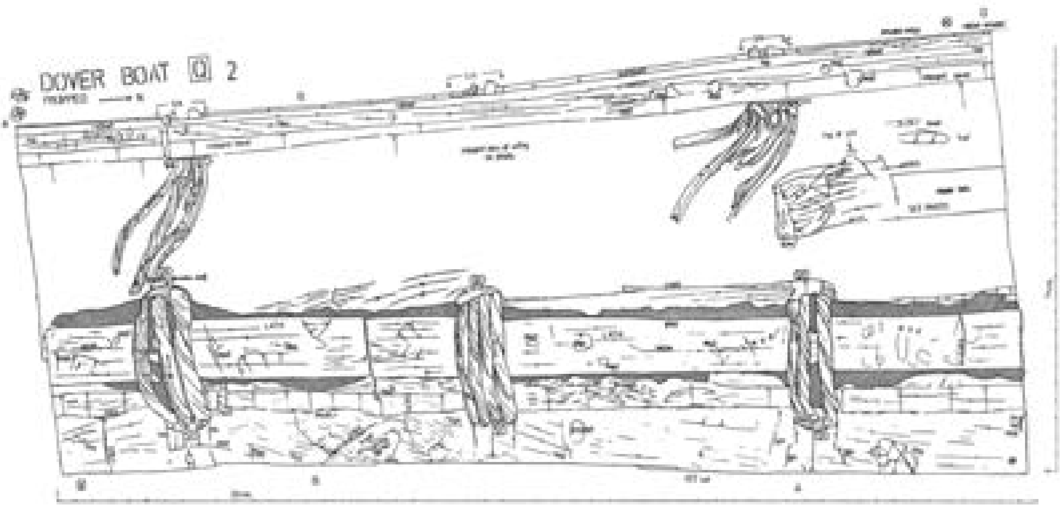


Figure 4.3
An example of an original-piece drawing. Seventy-five life-size plans were prepared, together with over 750 overlays showing constructional details and 126 sections through the boat timbers.

obscured. Another view had to be attained, in addition to the upright version, to enable the full detail to be drawn. The ile pieces were propped in a rotated position such that both the upper and lower edges were approximately at the same height, forming a U-shaped profile.

The recording time for each boat piece varied enormously – from a matter of hours for some, to about five days for the most complicated sections. If the drawing extended beyond a day's work, the piece had to be re-propped to the same position the following day for work to continue. It was not possible to leave the timbers exposed overnight as they had to be returned to the water tanks to prevent drying out and decay.

In addition to the main drawings, contact drawings were made. This involved laying smaller pieces of Mylar film against the boat in the relatively inaccessible areas that contained specific detail that could not be recorded in the normal way. This information was then transferred to the main drawings. More than 750 individual contacts were made during this stage.

With the drawn record of the inboard

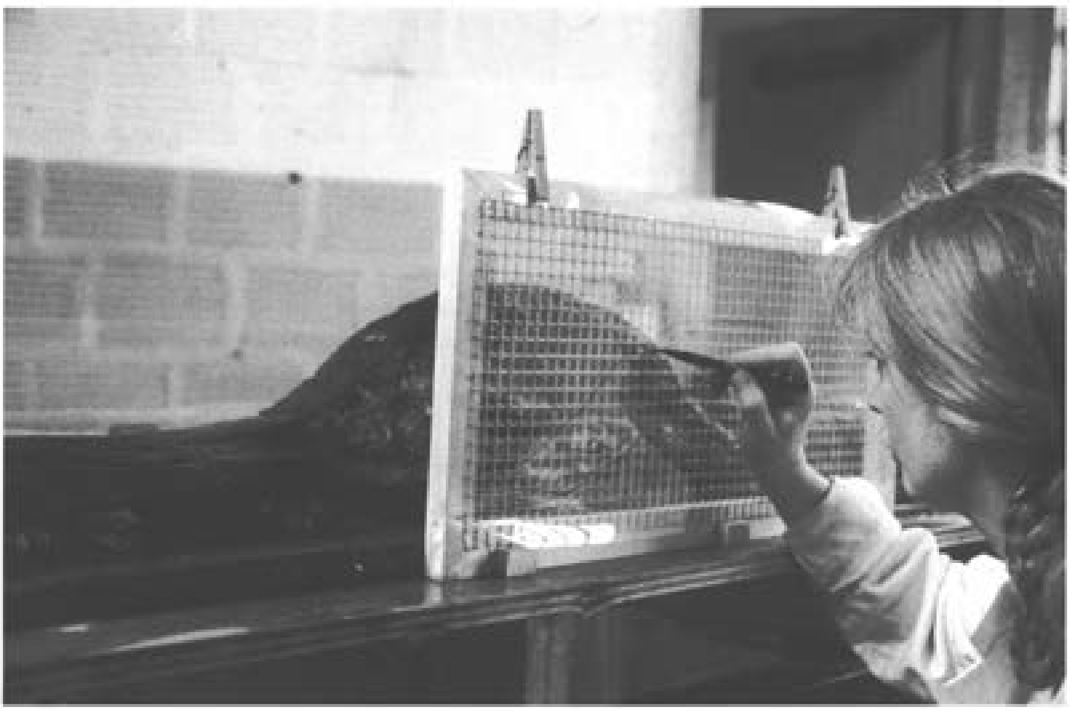


Figure 4.4
Drawing the boat pieces. Here, Caroline Caldwell uses a custom-built mini-recording frame to draw the profile of one of the bottom cleats accurately.

face complete, attention turned to the outboard of the boat. Nobody had yet seen the bottom of the boat, which was still covered with a thin layer of sediment. Inverting the pieces so this sediment could be removed and the outboard face recorded presented a substantial challenge. Unless fully supported during the inversion process, the timbers would be vulnerable to damage, and the pieces would open up, disrupting the complex jointing and destroying the integrity of the boat piece. After much planning, a system was devised that allowed the boat pieces to be inverted successfully. This method is described below.

Inverting the pieces

Essentially, a box was created around each boat piece and filled with expanded polyurethane foam. This followed the technique developed by Gregson for the Brigg raft (Gregson 1981). The foam was applied in liquid form; as it expanded and hardened, it took on the exact contour of the inboard face of the timbers, providing suitable support. The box, containing foam support and boat piece, could then be inverted safely and the outboard surface revealed. Each box was constructed in such a way that water could be added to keep the inverted timbers waterlogged.

Each boat piece was supported with foam and covered wooden wedges to reduce the bulk weight, and the baseboard was cleaned of any loose sediment. The boat timbers were kept damp throughout the inversion process. Flush with the four outer edges of the baseboard's underside, a 50mm × 50mm batten was added, to increase the depth below the boat timber. After the foam was added and re-inverted, this created an upstand above the timber for the addition of water.

At this stage, the baseboard supporting the boat timber was placed centrally on a row of pallets, allowing a sufficient space around the outside for a series of weights and supports.

The flat sections of boat offered no major problems, but the curvature of the side timbers varied from piece to piece; their propping had to reflect these variations. It was determined that these pieces could not go through the process in their 'natural' upright positions, as this would create abnormal or additional pressures on their lower edges. The pieces were laid in a more horizontal posture and rotated about an imaginary lateral centre line so that their original upper and lower edges were approximately at the same height. To protect the outer edges of the boat timbers, sheets of wet paper towel were rolled, shaped and pressed gently against the wood from the upper edge outward towards the baseboard. Any undercuts in the timber, including the holes through the cleats, were filled and covered with a combination of wet paper towel and foam to prevent the expanding polyurethane foam being forced into crevices or stitch holes. All the edges of the timber were covered, including the top and sides of the cleat.

A thin PVC membrane was then laid over the timber, extending beyond the edges of the baseboard. The film prevented water loss from the boat timber, particularly important during the exothermic reaction of the expanding foam. A covering of aluminium foil was then placed over the plastic membrane, again extending about 70mm to 120mm beyond the edge of the baseboard. The function of the foil was to reflect heat from the curing foam away from the boat timbers. The final protective layer – a sheet of 120-grade polythene sheeting – was then placed over the foil.

Four strips of correx (corrugated plastic) were cut about 60mm to 80mm longer than the baseboard, and were lined on one side with PVC film, fastened on the reverse with parcel tape. (The PVC film was added to stop the expanded foam from sticking directly to the correx, thereby facilitating its re-use.) The correx was scored lightly on the reverse and creased to make the corners. Smaller pieces of the same height, scored, creased and taped on the outside of the corners acted as strengthening. When taped together, the four strips created four sides of a box, slightly larger than the baseboard. Placed around the boat timber, the cling film, foil and polythene extended beyond the correx box. These were then turned up and taped to the outside of the correx to stop any foam escaping.

Heavy weights were placed against the outside to prevent any movement or outward pressure distorting the box. Two large timbers, longer than the box, were placed along each edge and roped together at the ends to stop the top of the box flaring outwards under pressure.

The two active ingredients of the polyure-thane foam were mixed together and, as the resultant mixture immediately started to expand, it was poured quickly into the box, where it took on the contours of the timber under its protective plastic and foil before hardening or 'curing'. The curing time lasted approximately thirty minutes, during which time it expanded above the top of the box. It was not prudent to be near the foam, owing to the toxic vapours.

The excess foam, once cooled, was cut off with a handsaw to be level with the top of the correx box. All weights and supports were removed, together with one of the four pallets. The other pallets were carefully moved along to leave gaps underneath the box, approximately 0.80m from each end. These gaps allowed turning clamps to be inserted beneath the baseboard for the inversion process.

The turning clamps were simple in design; two lengths of stout timber, nominally 50mm × 50mm × 700mm, were drilled at each end, using a 10mm bit. Through one end of each timber, a 500mm length of threaded rod was passed with washers and nuts added to each end of the rod. The timbers were pulled apart as far as the nuts would allow. One timber was passed under the box (through one of the gaps between the pallets), and the other over it. Another rod was joined to the other ends of the timbers and, again, washers and nuts added to form a 'box clamp'. An identical clamp was made and placed at the other gap in the pallets. Between the upper clamp timbers and the foam, two cross planks were laid which prevented the timbers from cutting into the foam. The upper nuts were gradually tightened until neither clamps nor cross-planks could be moved.

With the clamps in place, the box was slid, on its baseboard, to one side of the pallets. Using the clamps as handles, the box was rolled over onto its side and again onto its top – now the base. The 180-degree rolling manoeuvre, albeit in two stages, was performed smoothly, with no awkward jerky movements (Fig 4.5).

The clamps and original baseboard were removed to reveal the underside of the boat timber, sediment uppermost. All the paper towelling and wedges were removed, their supporting function now complete, and the correx box was peeled from the foam casing. The foam box could now serve as a watertight storage container.

The sediments adhering to the boat were selectively sampled from noted positions where they were undisturbed. The

Figure 4.5 (above) Inverting the pieces: turning the support.

Figure 4.6 Inverting the pieces: the outboard surface revealed.

Figure 4.7
Creating the fibreglass support cradle.

remaining sediment was then removed and kept as a bulk sample, revealing the outboard surface of the timbers, which could now be recorded (Fig 4.6). Water was added to the box to keep the timbers waterlogged.

Other records

Complementing the 1:1 drawings of the boat timbers, a detailed preliminary description of the boat elements was prepared, recorded in notebooks, annotated plans and sections and sketch drawings. This was supplemented by an extensive photographic record and a detailed study of the tree rays and rings revealed in the cut sections of the boat pieces (Gale 1994). By the end of the assessment phase, seventy-five 1:1 plans of the inboard and outboard surfaces of the boat had been prepared, supplemented by:

- more than 750 1:1 overlays;
- 126 1:1 sections;
- 1,540 monochrome photographs;
- 2,850 colour transparencies;
- 20 large-format monochrome photographs;
- four hours of video footage;
- extensive descriptive notes; and
- the 'Tree Study'.

Together, these elements formed the basis for an assessment of the potential of the boat and a proposal for a programme of detailed analysis (Clark 1994).

Preparing for conservation

With the recording of the boat timbers complete, thought had to be given to how they were to be stored and ultimately conserved. By now, it had been decided that the pieces were to be conserved by polyethylene-glycol (PEG) replacement and freeze-drying (Chapter 17). The expanded foam boxes were clearly unsuitable for storage, transport or conservation. The pieces needed to be returned to their original position, and a mechanism devised so that they could be moved and stored safely, and could successfully undergo conservation. The solution to this was to create a series of strong, fibreglass supportive cradles, custom-built to match exactly the shape and outboard contour of each boat piece.

Building the cradles

Most of the water was removed from the foam box to reveal the upper surface of the boat timber. A piece of 10mm open-celled foam was cut to shape and laid directly on top of the boat timber, with a layer of polythene over this to prevent water loss.

A layer of fibreglass matting was laid on the polythene sheeting and resin applied with a paintbrush, stippled into the mat. A sheet of coremat (a bulking material) and a further sheet of fibre were placed over the coremat and more resin applied, taking care to remove all air bubbles (Fig 4.7). After curing, the primary, load-bearing cradle was complete.

A fibreglass flange was added to the base of the primary cradle to provide a stable base when inverted; also to reduce flexibility and obviate the need for reinforcing strips. A strip of correx (*c* 75mm wide) was cut and laid at about 45 degrees to the base, some 50mm in from the edge. The correx was trimmed to the irregular contour of the cradle, and support pieces were taped to the back. Further strips were added along the other side and at both ends to complete the arrangement. Three layers of glass fibre and one of coremat were laid inside to form the flange; two cross-braces of the same material were added for extra strength (Fig 4.8). The joint between the flange and the cradle base was coated with resin to prevent delamination during the PEG treatment and freeze-drying.

Once completely cured, the cradle was trimmed of excess glass-fibre material with a hand-held angle cutter, and the edges were protected with a polyfoam fabricate. This edging strip was essentially a safety precaution, as the outer edges of the glass fibre were still fairly sharp. Also, it would protect any exposed boat timbers on other cradles nearby from any accidental contact, while also reducing abrasion of the tank walls during PEG pretreatment.

The cradle was then replaced onto the inverted boat timber and trimmed to the correct shape and size. A number of holes were drilled through the base of the cradle to allow for the uniform saturation of PEG, and carrying handles were incorporated into the flange. A piece of 'Netlon' (a shrink-wrap netting) was cut to fit on the cradle, and two pieces of open-cell foam – one coarse and one medium – were added to protect the timbers from the glass-fibre surface of the cradle.

The technique for returning the boat timbers to their original position on their respective cradles was broadly similar to that of their inversion. The foam box was lifted off to reveal the boat timber sitting on the cradle, covered in tissue paper, plastic sheet and aluminium foil. These layers were removed and the timbers rinsed with fresh water before being returned to the main water tanks to await conservation (Figs 4.9; 4.10).

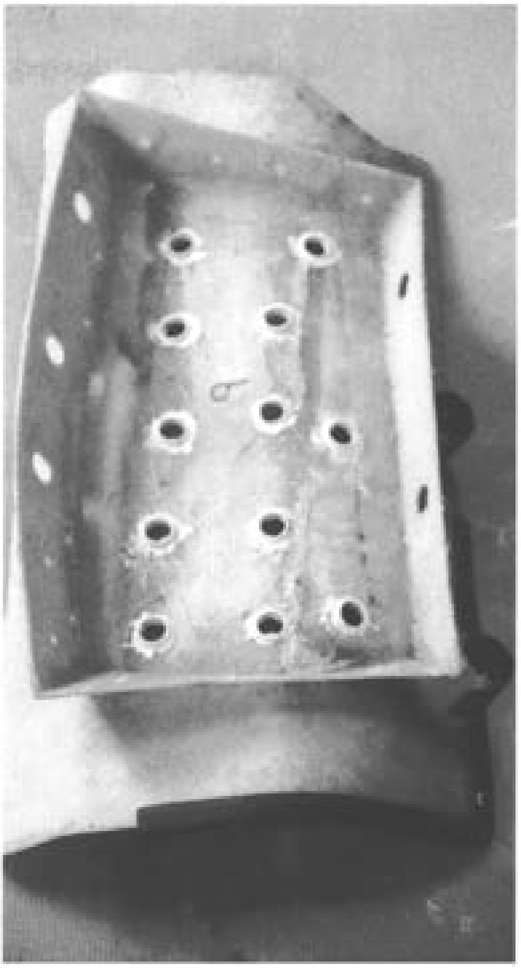


Figure 4.8
An example of a fibreglass support cradle. The cradle is shown upside down, showing the supporting flange and the holes cut through the fibreglass to facilitate the penetration of polyethylene glycol during the primary conservation phase.

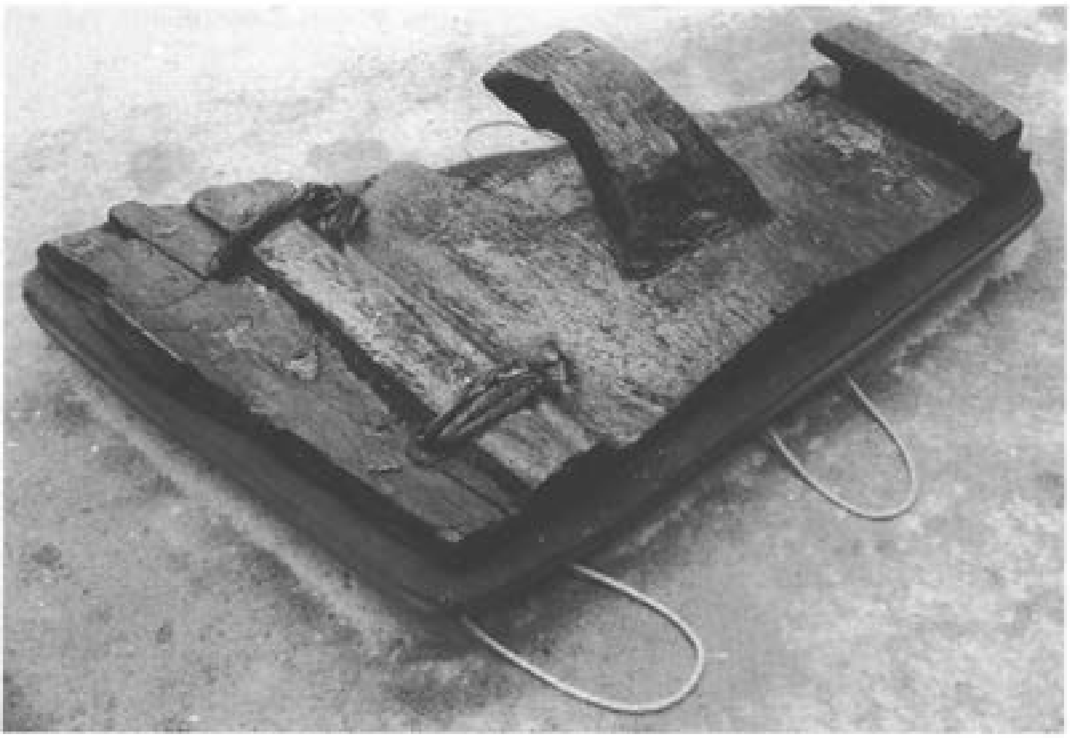


Figure 4.9
A boat piece (V) on its fibreglass cradle.

Figure 4.10
A boat piece on its fibreglass cradle, showing the undulations of the original plank.

Analysis

Further recording of the boat took place during the programme of analysis, following conservation (Chapter 17). As study of the primary records had progressed, new hypotheses and questions had emerged, and the opportunity was taken to enhance the primary record. The boat pieces were re-examined in great detail, and extensive annotated sketch drawings were prepared for each piece, together with many measurements (Fig 4.11). The amount of shrinkage and distortion of the pieces during the conservation process was found to be negligible. The opportunity was also taken to dismantle one of the boat pieces (Piece Q) to examine the nature of the waterproofing of the seams. It was during this process that the previously unpredicted seam stopping was found pressed into the ile seam (Chapter 5, pp 74–5). This final stage of recording was of great benefit, not only in clarifying interpretative and descriptive details of the boat, but also informing the difficult task of integrating the individual boat piece drawings into a coherent picture of the whole vessel (*see* Fig 5.1).

The records of the boat thus compiled form the primary resource for study of the boat, and were essential in the production of this volume. They were also critical in the re-assembly of the boat in its new home in Dover Museum (Chapter 18). All the records are now held in archive by Dover Museum.

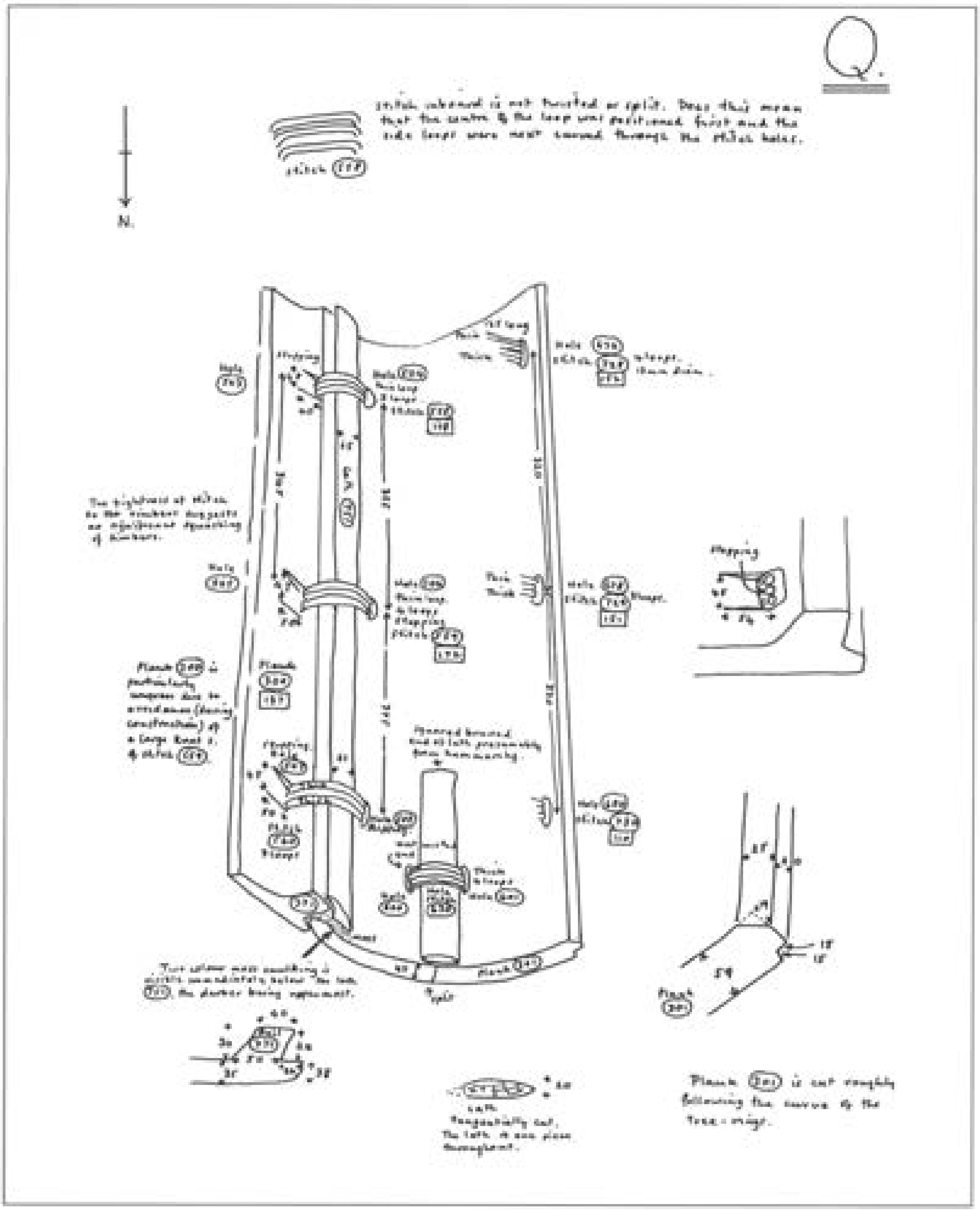


Figure 4.11
One of the many annotated drawings of the boat pieces produced following conservation.

5
Description of the boat

by Peter Marsden

Introduction

From the outset, it was clear that the structure of the Dover boat was incomplete and distorted, and that two levels of study would need to be undertaken: to record, analyse and describe the vessel as found, and then to reconstruct what it was probably like when originally built. The latter required reconstructing what the recovered timbers were originally like before they had suffered from compression and distortion, and reconstructing the missing parts of the vessel. It would then be possible to examine how those alternative hypothetical reconstructions of the vessel might have been used, bearing in mind their estimated stability and load-carrying abilities.

The process of recording the boat is described in detail in chapter 4. Here, it is pertinent to highlight that the boat was recorded by several different people, at different stages of the boat's recovery. The initial recording, in the difficult conditions at the base of the cofferdams, was undertaken by Peter Clark, Barry Corke, Valerie Fenwick and Keith Parfitt. Caroline Caldwell and Valerie Fenwick carried out detailed recording of the boat pieces after excavation, with the attendant problems of the pieces 'relaxing' and seams opening up. This was supplemented by study of the tree rays and rings by Alison Gale and further observations by Richard Darrah, Owain Roberts and Damian Goodburn. Further detailed recording was carried out by this author following conservation. Identification of the timber and moss species, together with chemical analysis of the stopping material was carried out by Andy Fairbairn, Jon Hather and S Wales (Fairbairn 1993; Hather and Wales 1993).

Most of the structural recording was undertaken before the timbers were conserved, though some details were recorded subsequently. Checks made of certain features before and after conservation showed that distortion owing to conservation was mostly minimal. Although every care had been taken, it was found that some of the most fragile features – especially the stitches, laths and caulking (all located at plank edges) – were occasionally damaged when the boat pieces were lifted from the site and subsequently moved during cleaning and conservation. In spite of every precaution, it was impossible not to damage the timbers, as each piece of the boat was very heavy and to lift and turn the pieces over for recording resulted in occasional movement that could damage the fragile joints. The result is that a few details, concerning only a few features, remain uncertain.

Description of the boat structure and form

Structure of the boat, including missing pieces and materials used

Superficially, the boat resembled the lower part of a large, modern plank-built river punt, with a flat bottom, vertical sides and a wide sloping south end (*see* Fig 5.1). Its surviving structure was approximately 2.30m wide and more than 9.2m long, its north end having not been excavated. It is possible that originally the vessel was as much as 15m long.

The boat was constructed from planks fastened together edge to edge, by rather complex methods. The shape of the hull was maintained by the great thickness of the planks, by longitudinal 'rails' of upstanding timber, by curved planks, which acted as 'girders' forming the corners between the flat bottom and the upright sides, and by transverse timbers, which acted as frames.

The result was a very strong vessel whose weakest points were the fastenings holding the planks together edge to edge.

Planks

Four planks were found: the bottom plank west (300), the ile plank west (301), the bottom plank east (303) and the ile plank east (304).

Evidence of three further planks was also found, although they were missing: the upper side plank west (302), the upper side plank east (305) and the end board south (306).

Another plank may also have existed, although this too was missing: an end board north (unnumbered).

The planks were all of oak (*Quercus* sp.).

Transverse timbers

These oak timbers were embryonic frames across the bottom of the boat.

Wedges

These oak wedges were the fastening mechanism used to hold the bottom planks and the end plank together.

Stitches

Twisted yew branches were used as fastenings to hold together side and bottom planks.

Laths

Long, narrow slats of wood were used to cover the caulking inboard. All but one of these slats were of oak; one was of hazel.

Wadding/caulking

Pads of moss covered the plank seams inboard.

Stopping

The stitch holes were made watertight with a stopping, probably a mix of wax and resin, and possibly combined with animal fat (Hather and Wales 1993, 11–16).

Shape of the boat as found

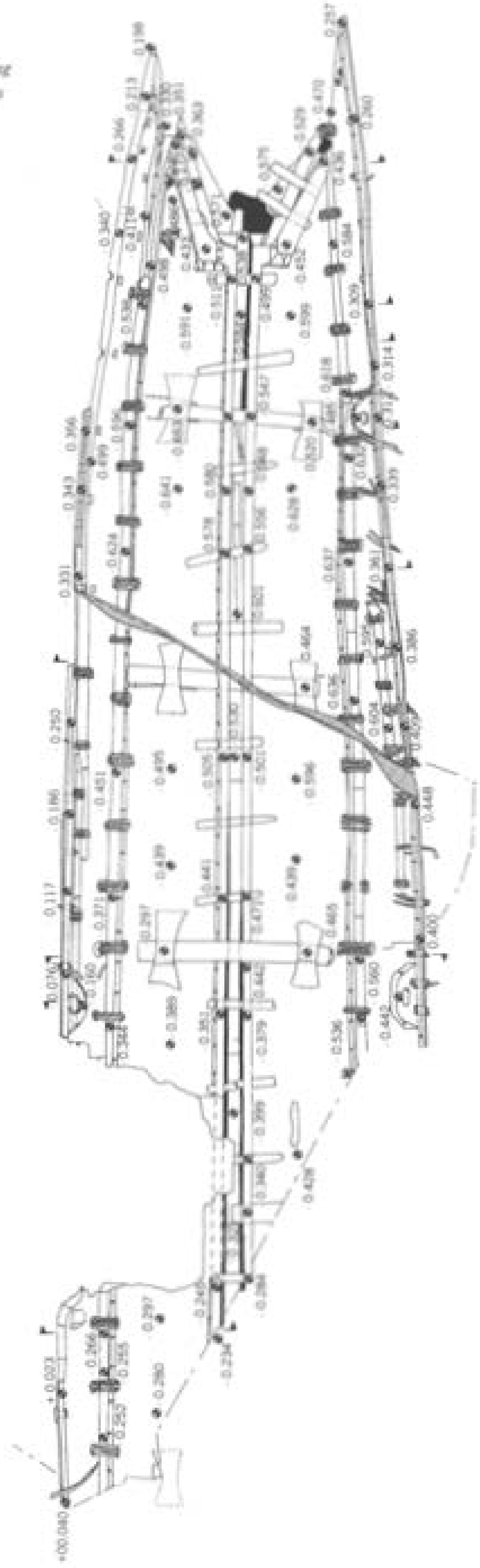
The shape of any boat is represented by a series of transverse and longitudinal profiles of its *outboard* face, but it was not possible to record these *in situ* when excavating the Dover boat, because they remained buried. Consequently, all that could be seen of the outboard face of the vessel was the top of its sides, its south end, and its profile seen in the single cross section of the vessel drawn while *in situ* (Fig 5.2).

The excavators tackled this problem by recording the boat's shape *inboard*, with many spot levels taken relative to Ordnance Datum (*see* Fig 5.3), so that, once the boat was removed from the site, it would be possible to add the thickness of the planking and so extrapolate the outboard shape in any direction. The result is represented by two drawn long profiles, one along the eastern central rail adjacent to the centre line of the boat, and the other along the top of the west ile plank (*see* Fig 5.5). Cross-profiles were also drawn.

Some transverse distortion is clear; the west side of the boat was lying a little lower than the east side, as if the vessel had taken the shape of the uneven ground on which it lay, and that the ground had a slight slope down from east to west (Fig 5.4). This slope might account for the better survival of the stitches at the top of the ile plank on the west side, as they were either more deeply buried than the comparable stitches on the east side, or were below any later truncation of overlying sediments.

Figure 5.2
The cross section through the boat revealed in section (Piece J). This was the last piece to be excavated in Cofferdam I, removed in just twenty minutes with the help of a shovel and fork.

Figure 5.3
A plan of the boat showing the spot heights (in metres OD) recorded during excavation.



The two long profiles show longitudinal distortion. The top of the east rail (360) curved down to its lowest point about 3m from the south end of the boat, and then upwards towards the north end. The top of the ile also curved down to a low point, but this was at about 5m from the south end, and then it inclined upwards. Even though the two long profiles were only about one metre apart, their two lowest points missed each other by about two metres. This, together with the fact that the top of the west ile had sunk below the level of the east central rail, thereby twisting the shape of the vessel, indicates clearly that the boat had taken up the shape of the ground upon which it lay (Fig 5.5).

Construction of the boat

The bottom

The bottom of the boat was fundamental to the safety of the entire vessel, as it carried both the weight of the upper part of the boat and the load of crew and cargo. These loads created *internal* stresses on the bottom structure, which were compounded by the *external* stresses caused by the buoyancy forces of water when afloat, and the stresses caused by running aground, particularly in waves breaking on the shore. Consequently, the boatbuilder had to ensure the boat would be able to absorb stresses from various directions simultaneously, while maintaining the flat shape of the bottom and keeping it watertight. For reasons of safety, there could be no margin of error.

We can learn a good deal about the limits of Middle Bronze Age technological thinking from looking at how these practical problems were solved. Many of the difficulties encountered would have been overcome by using nails – either of wood (treenails) or of metal – to fasten timbers together. That apparently simple development in boatbuilding technology was centuries away (when it occurred, it would transform boatbuilding methods). Nevertheless, the bottom structure shows embryonic developments that, in time, would lead to the invention of the keel and keelson, to give longitudinal strength and shape, and frames, to give transverse strength and shape.

Longitudinal strengthening

Essential longitudinal strengthening features were incorporated into the shaping of the two bottom planks. The western

Figure 5.4
The boat in situ (Cofferdam II). Two of the large chalk blocks placed around the southern end of the boat can be seen in the bottom right of the picture.

plank (300), traced for a distance of 7.26m, was 680mm wide at its south end, widening to 770mm farther north. The eastern plank (303), traced for a length of 8.71m, was 685mm near its south end, widening to 820mm farther north. This means that the bottom of the boat narrowed slightly towards its south end, suggesting that this was the bow (*see* Fig 5.1). The thickness of the planks ranged from 15mm to 69mm – owing, in part, to the unequal compression of the timber (Chapter 6).

The longitudinal shape and strength of the bottom planks was maintained by several means, in addition to the considerable thickness of each plank. First, each bottom plank had an upstanding longitudinal rail, square in section, next to the centre line of the boat. These two rails were about 57mm wide and up to 70mm high. Where the planks abutted at the centre line, these rails were only 10cm apart, with a slot for caulking the central seam between them (Figs 5.6; 5.7).

Another longitudinal rail, the 'seam rail', lay by the outer edge of each bottom plank inboard to provide a seating for the ile planks at the bottom of the sides, as well as to give some longitudinal strength. These two rails were about 37mm wide at the top, but widened below, and stood up to 55mm above the plank face.

Additional longitudinal strength was provided by the shaping of the inboard face of each bottom plank. These were slightly rounded and were thickest along the plank's centre line. As the planks had suffered

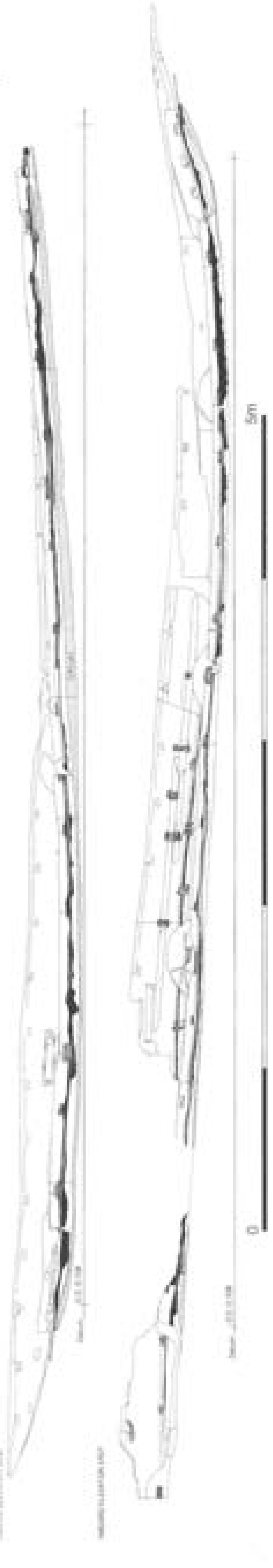


Figure 5.5
Longitudinal sections of the boat as found, showing the curvature taken up by the hull as it settled on sloping ground.

Figure 5.7
Detail of the central seam, showing how the central butt joint had opened up after abandonment. The upstanding central rails flanking the seam can also be seen.

Figure 5.8
An overhead shot of the boat in Cofferdam II, showing the transverse timbers and wedges running under the bottom cleats and central rails.

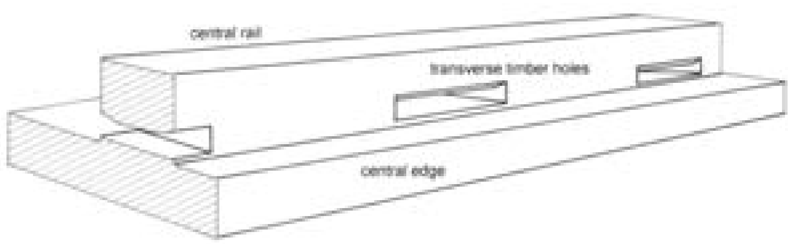


Figure 5.9
Detail of the central plank edge.

considerable compression, it is difficult to judge the original thickness of the centre of the planks compared with the sides.

The inboard rails were fashioned entirely from the shaping of the logs from which the planks were cut. Tool marks of axe or adze blades, both inboard and outboard, generally appear as longitudinal rows of shallow hollows in the plank faces.

Fastening the bottom planks together

The two central rails had another function – as part of the process by which the two bottom planks were attached to each other (Fig 5.8). Slots had been roughly cut by axe through each rail to enable a series of oak 'wedges' to be inserted to fasten the rails to each other (Fig 5.9). These were at average intervals of 501mm. The shapes of the wedges showed that they had been driven into place in pairs from opposite directions. On their own, these would probably not hold the bottom planks together in rough water, but the boatbuilder cleverly inserted them at different angles, effectively 'locking' the bottom planks to each other at the centre line.

Making the central seam watertight between the bottom planks must have been difficult, particularly when the planks flexed in relation to each other in rough water. The solution – once the bottom planks had been fastened together – was to place layers of moss on the inboard face of the seam, to press down these layers under a series of thin laths of oak (about 74mm wide) and then to hold down these oak laths using wedges (Fig 5.10).

Transverse strength

The flat bottom was maintained by 'transverse timbers' of oak, which acted as embryonic frames or ribs (Fig 5.8). These timbers were on average about 115mm wide, about 35mm thick, and spaced about 1.68m apart from centre to centre. A highly elaborate mechanism was used to fasten the transverse timbers to the bottom planks, which meant that the timbers, although quite wide, had to be relatively thin. The mechanism was to slot the transverse timbers through a roughly cut hole in a rounded 'cleat' left standing on the inboard face of each bottom plank. These bottom cleats were carefully carved and, in general, each was 372–460mm long, 110mm wide and about 120mm high in the centre, with 'fish-tail' ends about 190mm wide. As each transverse timber

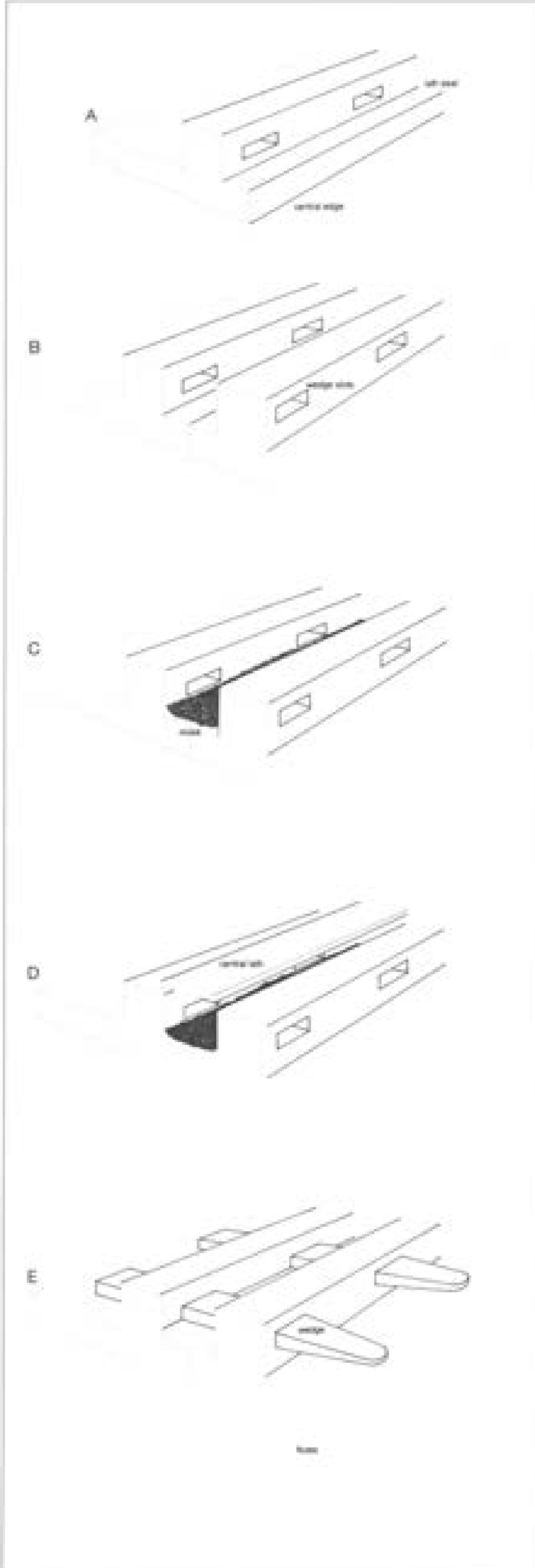
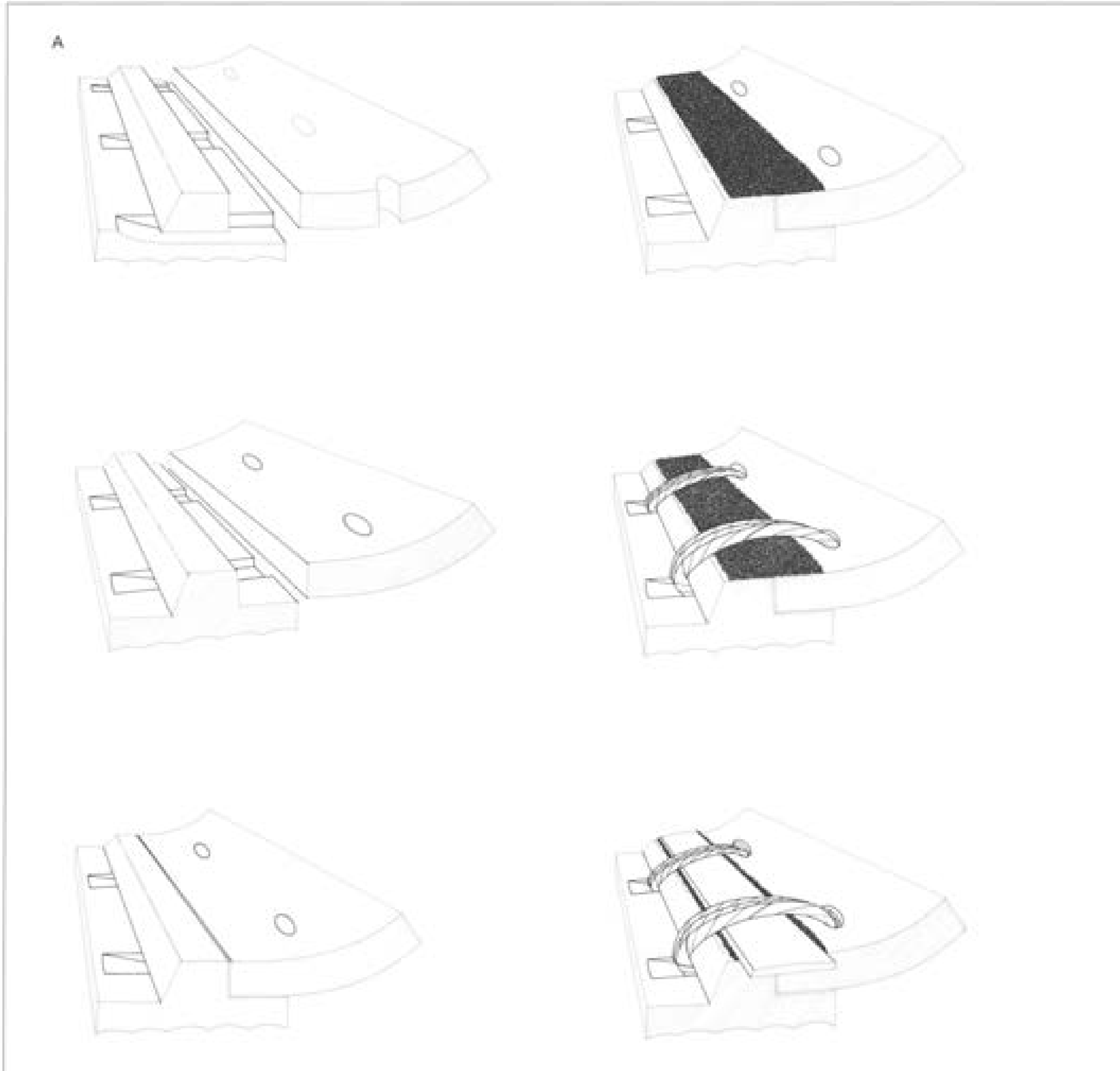


Figure 5.10 Diagram to illustrate the principle of caulking of the central seam. A: central edge of bottom plank. B: bottom planks brought together, showing how wedge slots align. C: moss wadding placed above central butt joint between central rails. D: oak laths inserted above moss. E: wedges and transverse timbers hammered through wedge slots over central lath, thus compressing the underlying moss.

was flat, and as the centre of each bottom plank was slightly domed, it was necessary for the boatbuilder to cut a transverse slot into the upper face of the domed plank. Slots were also cut through the central rails of the bottom planks to accommodate the transverse timbers, with the result that each timber was held to the two bottom planks at four places.

There are two clues to show how effective the transverse timbers were at creating a rigid bottom. First, the wear from grounding on the outboard surface of both bottom planks exists only away from the centre line, showing that the buoyancy force when the vessel was afloat had slightly arched the bottom at the centre line. Second, a piece of flint had been placed between one transverse timber and the bottom plank, as if to stiffen the timber against the slots in the cleat and central rail.

Figure 5.11
Diagram to show the method of attaching the ile and upper side planks. A: inboard view of attaching ile plank to bottom plank. B: outboard view of attaching ile plank to bottom plank. C: inboard view of attaching upper side plank to ile plank.



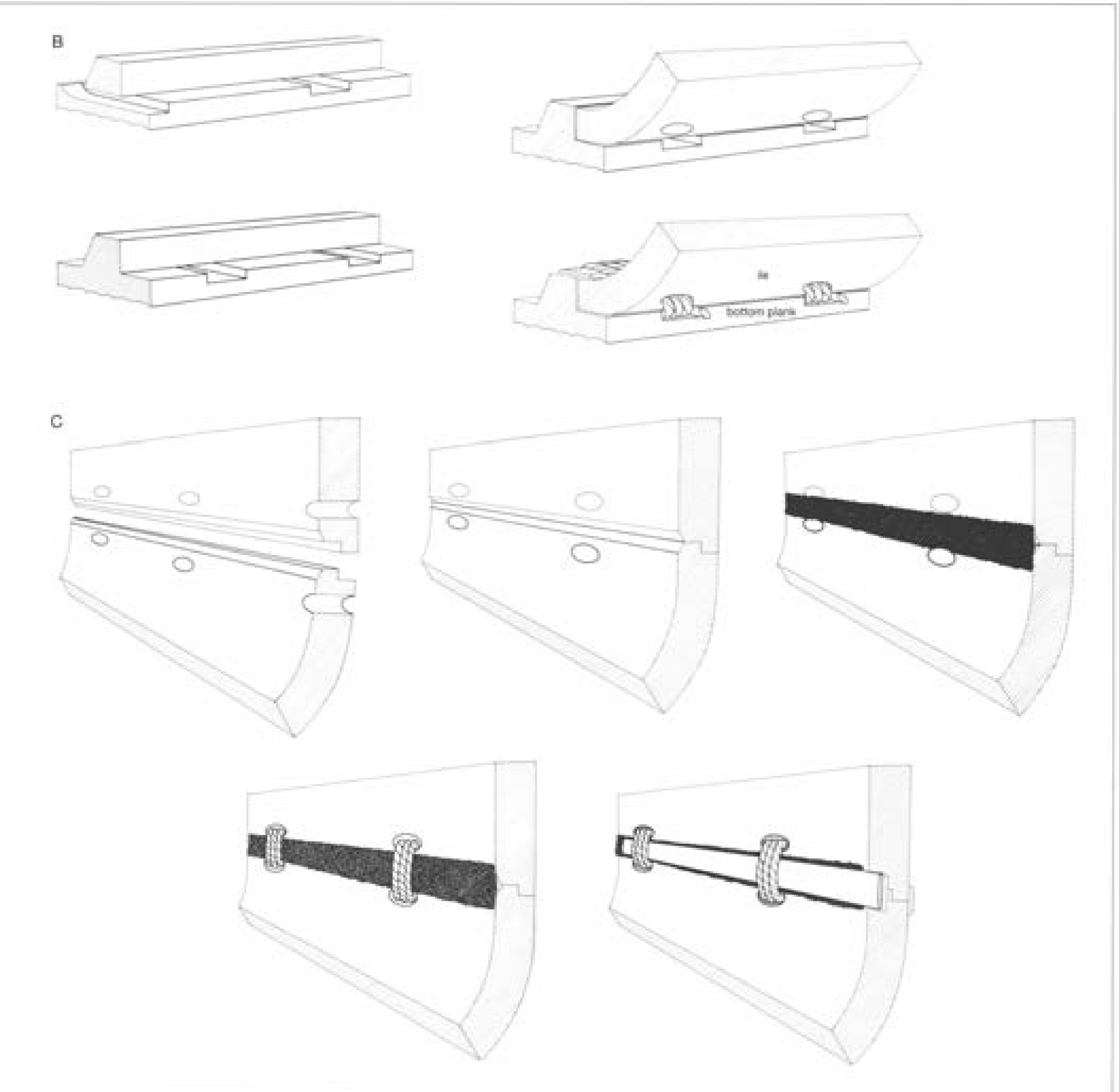
The sides

There were at least two planks on each side of the boat, but only the lower (the ile) had survived in either case. This lower plank was curved in section to form the junction between the flat bottom and the vertical side. The longest surviving ile plank, on the east side of the boat, was more than 9.22m long, and they both varied in thickness between 32mm and 67mm, the lower edge being the thinnest. The lower edge of each was slotted onto the upper ledge formed inboard next to the side rail of the bottom plank, and was held in place by stitches of yew withies.

The ile planks had excellent tool marks of axes on their inboard surface, showing how they were cut from the log and shaped to follow the curve of the tree rings.

Fastening the sides to the bottom

The stitches holding the ile plank to the bottom planks were threaded through a



series of holes cut both into the lower edge of each ile plank and into the outer edge of each bottom plank. The opening of each stitch hole was about 30mm long by 52mm wide, but it narrowed inside and was curved round through the ile plank, and, in the bottom plank, was slotted under the side rail so as not to expose the stitches to wear outboard.

The stitches were of yew withies and were spaced at intervals averaging about 380mm from centre to centre. Having been made malleable by being twisted to separate the fibres, each withy was threaded through the stitch holes from outboard. It was then turned through three or four loops and the thin end was tucked down into the stitch hole. Each stitch was started at the north end outboard of the stitch hole and was looped through from north to south. The thick end of the withy outboard was not malleable and had usually been left projecting out from the boat, showing that this must have been the starting place of the stitching process (*see* Figs 5.11; 5.12).

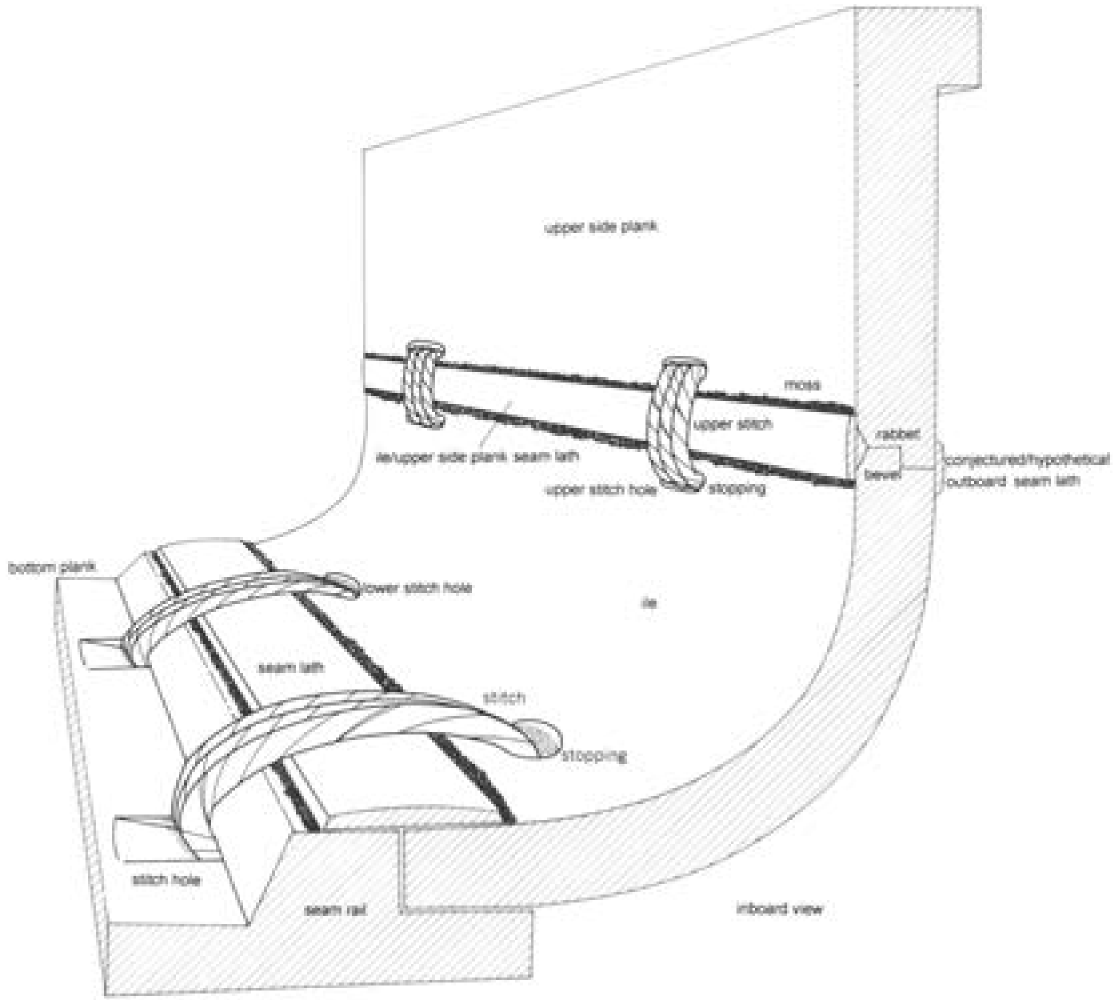
As the stitch holes were below the waterline, they would leak if not filled with a watertight stopping. This stopping had been pressed into the stitch holes, and on analysis has been found to be a mixture of wax and resin, possibly combined with animal fat (Hather and Wales 1993, 11–16).

Making the junction of the sides and bottom watertight

The lower edge of the ile plank, carefully shaped to be level with the top of the side rail of the bottom plank, formed a flat seating for a lath to hold down pads of moss once the lath had been placed under the stitches (Fig 5.13).

The waterproofing material was moss, like that on the central seam, but, unlike the caulking in the central seam that had been placed over the seam *after* the bottom planks had been brought together,

Figure 5.12
Schematic view of the side of the boat, showing the main elements mentioned in the text; the form of the upper side plank is, of course, conjectural.



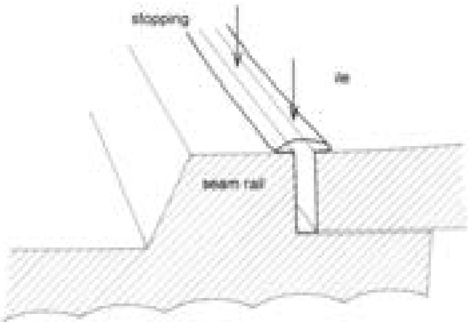


Figure 5.13
The ile planks were faced up to the bottom planks without any waterproofing material between the timbers; a 'stopping', of uncertain composition, was pressed down into the seam after the timbers were in place.

here, some had been placed into the junction between the ile and bottom planks *before* the planks were brought together. The rest was placed on top of the inboard face of the seam, and then was held in place by laths inserted under the stitches.

Complete laths were more than 1.30m long and about 70mm wide, with their ends overlapping each other, suggesting that they had been slotted into place from north to south.

Fastening the upper edges of the ile planks

The upper edge of each ile plank had an L-shaped recess on its outboard corner. The inboard corner was bevelled (*see* Fig 5.14). It is not clear how the missing upper plank was once fastened to the ile, but it is certain that there was a plank there because some of the stitching that once held it remained. These uppermost stitches lay in oval-shaped holes cut near the upper edge of the plank, and, as the curved upper end of one stitch had survived, it is clear that the stitch holes in the missing upper plank lay 100mm above the seam with the ile plank.

These upper stitches were spaced at intervals of 336mm on average, and the few that were sufficiently intact on the west side of the boat all showed that the stitching had been started from outboard working from north to south. No trace of moss was found, but the evidence may simply not have survived. The inboard bevel may have been part of a V-shaped recess to contain moss held in place under a lath below the stitches, but this is entirely conjectural.

Giving vertical shape to the sides

Cleats projected from the middle of the curving inboard face of the ile planks, and these were pierced by holes that apparently once contained vertical timbers. These vertical timbers – or rather their holes in the cleats – were spaced at 3.80m intervals on the east side of the boat. The west side was

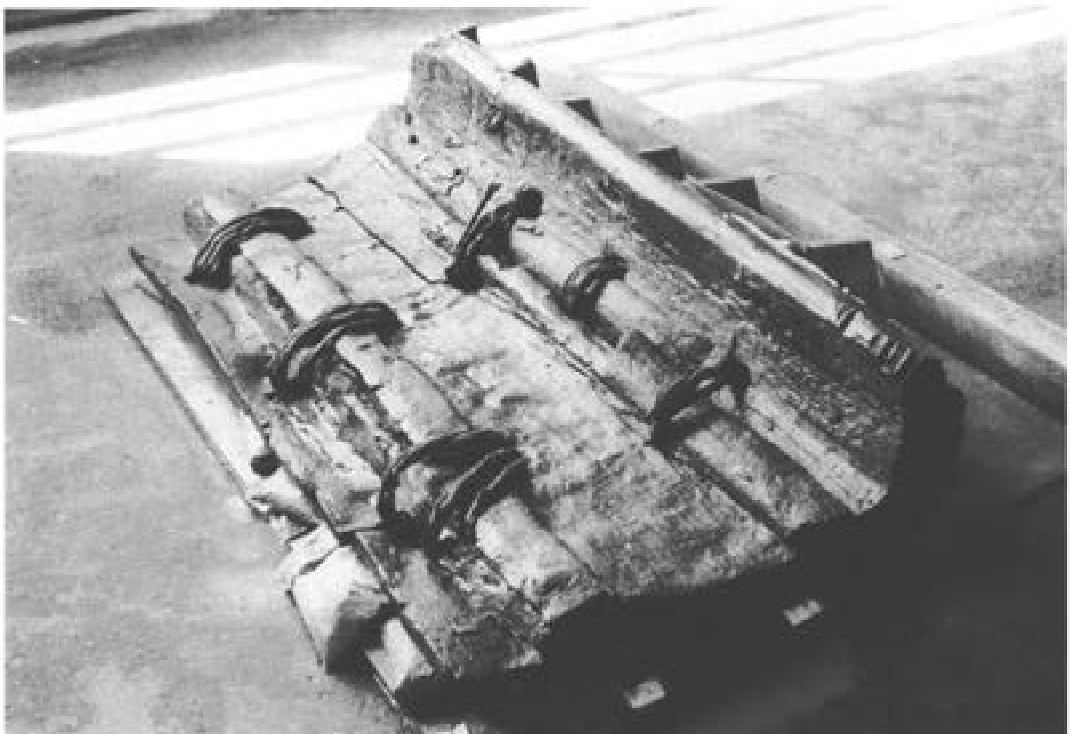
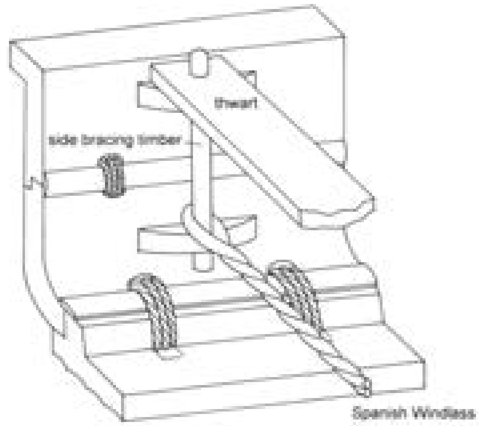


Figure 5.14
Piece B (S), showing the rebate on the upper ile edge.

Figure 5.15
Hypothetical reconstruction of the side bracing timbers, evidenced by wear patterns on the ile timbers, together with parts of a conjectural thwart and Spanish windlass, which would have helped hold the sides of the boat together.

insufficiently excavated to show the spacing, but is presumed to have been similar. That they did contain vertical timbers is certain, for there were wear marks on the face of the ile plank immediately below each cleat.

The extent to which the upright posts supported the sides of the vessel is uncertain, for they were so thin, the three surviving cleat holes averaging 87mm (fore and aft) by 40mm. It seems probable that there was a cleat above each in the missing upper plank; this would make sense of the fastening process. The small dimension of the upright posts could indicate that a purpose of the side timbers may have been to provide a fixing for a tie across the upper part of the boat to help support its sides (Fig 5.15).



The south end

The south end of the boat, thought most likely to have been the bow, was originally formed from a flat sloping board attached both to the bottom planks and to the side planks. Although this board was missing, the impression of its lower end was preserved in the caulking and fastenings at the south end of the boat (Fig 5.16). At that point, it was up to 1.15m wide and at its edges was 25mm thick. A hypothetical reconstruction is shown in Fig 5.17.

Fastening the end board to the sides and bottom

The lower edge of the end board was originally fastened to the ends of the bottom planks by what seems to be a remarkably elaborate scarf that, on its outboard face, continued upwards the smooth hydrodynamic outboard shape of the hull. Inboard, however, it had a complex yoke-shape structure.

The scarf is essentially simple in its design, but, owing to the technological limitations of the boatbuilder, it is heavy in constructional terms. The bottom of the

Figure 5.16
The southern end of the boat, showing the complex arrangement of rails, wedges and laths that held the conjectural end board in place.

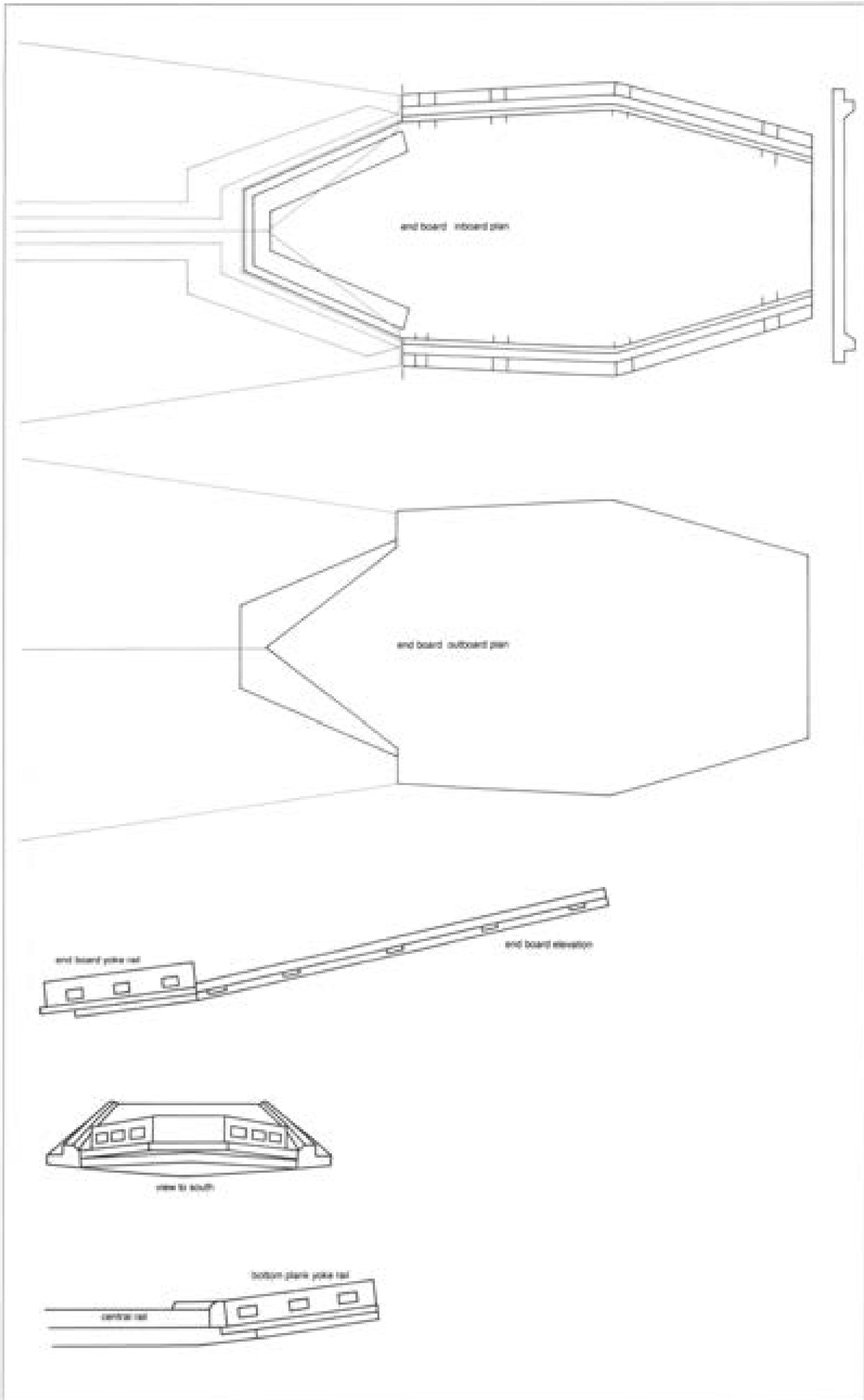


Figure 5.17
A conjectural reconstruction of the missing end board, showing its possible articulation with the bottom planks.

end board was slotted onto ledges cut into the south end of the bottom planks, and then was held in place by wedges of oak. To make this possible, however, it was necessary for the boatbuilder to create a sufficient thickness of timber at the south end of the planks. This was done by fashioning rectangular rails cut from the tree, at the south end of each bottom plank, and, below these, to cut the ledges that supported the end board.

Making the south end of the boat watertight was made possible by placing moss caulking onto the ledges before laying the end board there. Next, laths of oak were laid over the edges of the end board to press it down, and oak wedges were then driven through holes cut through the end rails of the bottom planks. These wedges were much thicker than those used to hold the bottom planks together across the centre line, presumably to withstand any impact to the end of the boat caused when grounding on the shore. The use of wedges implies that the bottom of the end board also had a rail into which the wedges were inserted. Such a rail would have greatly strengthened the lower end of the end board.

Higher up, where the ile planks met the end board, the attachment between those planks and the end board was by means of stitches. It is presumed that moss, held by laths, would have sealed that joint, but this did not remain.

Propulsion and steering

No evidence of fittings connected either with propulsion or steering was found.

Evidence of wear and repair

Wear and damage

There is extensive evidence of wear and damage to the boat. On the outboard face, both bottom planks have had their surfaces worn away towards the sides of the vessel, leaving the centre line unworn (*see* Fig 5.18). The result is that tool marks survive only in the unworn area. That wear pattern shows that the force of buoyancy had slightly arched the bottom planks so that only their outer parts ran aground. A possible impact point was noted on bottom plank 303.

Wear also existed on the outside of both ile planks, but here the marks are mostly scored lines at various angles. A possible point of impact was noted on ile plank west and another at the south end of ile plank east. The latter may have caused the plank to split, needing repair.

This evidence all points to the vessel having run aground and possibly having been moored beside a waterfront.

Repairs

The flexing of the hull, and the impacts, evidently caused leaks, and all the repairs relate to stopping up leaks in the hull.

Extra stopping was added to the central seam between the bottom planks, as these planks were not held as tight together as was needed. The flexing of the bottom planks was evidently a problem and the planks were tightened in two ways: by extra moss caulking being stuffed into some wedge holes, and by a flint flake being pushed under a transverse timber.

The stresses on the hull caused both ile planks to split longitudinally. This not only weakened those planks but also caused some seepage of water into the vessel. The solution was to caulk the splits, but to do this required an elaborate procedure of cutting stitch holes in each plank on either side of the split, and to let the stitches of yew hold a moss caulking in place under the wooden laths. The average spacing of the stitch holes in ile plank 301 was 453mm from centre to centre, and in ile plank 304, the stitches in two splits were spaced at 354mm and 412mm. These different spacings, together with the fact that the stitches were not consistently in one direction, suggest different occasions of repair, perhaps by different boatbuilders.

Dismantlement

When the boat was abandoned, it had seen considerable service and showed signs of leaking. In many ways, however, the structure of the vessel appeared to be quite sound; there were no traces of wood rot or of marine organisms infesting the timber, and many of the tool marks were still very fresh. This evidence appears to indicate that the boat could have been repaired instead of being abandoned. The condition of the missing upper parts of the vessel remains unknown, however, and these parts may have been in a poor enough state to have caused the boat to be abandoned. Or the vessel may have been superseded. Whatever the cause of its abandonment, it is clear that the boat was deliberately broken up – the purpose of demolition presumably being to reuse some of the timbers.

The board at the southern end had been removed after some of the wedges holding it in place had been hacked apart by an axe; both upper side planks had been removed after the stitches holding them had been cut, presumably by an axe; and the thin upright side timbers had also been removed. It is possible that damage to the central rails was done when attempting to remove transverse timber 342, but, as this timber was itself damaged, the attempt to remove it was abandoned.

Method

After the boat had been recorded *in situ*, it was cut up into thirty-two manageable pieces (*see* Fig 4.1). These formed the core of the subsequent recording process, as they allowed the parts of the vessel to be examined in detail.

The main record took five forms:

1 the 1:1 tracings on film by Caroline Caldwell;
2 the initial description written by Valerie Fenwick;
3 the annotated sketches of each piece, described by Peter Marsden;
4 the study of the tree-ring and ray patterns by Alison Gale; and
5 the examination of the tool marks by Damian Goodburn.

The description of the boat given in this chapter is primarily concerned with the vessel as found and not as reconstructed. As the boat was cut into pieces, however, it was not always possible to take direct measurements from the centre of one feature – such as a stitch or wedge – to another. Consequently, some measurements (shown in square brackets) have been taken from the scale drawing of the assembled pieces and, therefore, may be slightly imprecise. Direct measurements are shown without brackets. The measurements given here are all of features as they were found, and do not take account of any distortion or compression. There are also compression hollows caused by the overlying deposits, but these are post-burial features that have no relevance to the use of the boat.

Coding system of timbers, ends and side

It was necessary to number and letter many elements and constructional features during the excavation and initial recording of the boat. This took place randomly, as the need arose, and many features were not numbered. Although adequate for the initial stage of the recovery and recording, the coding was not sufficient for the full analysis and description, so, during the final recording of the boat, the old system was replaced by a new, all-numerical system, commencing at number 300 (*see* Fig 5.19). Gaps in the numbering system allowed for others to be inserted later if needed.

Principles used in investigating the boat

In the investigation and description of the Dover boat, the aim (as it would be with the investigation of any ancient boat) was to try to establish five key attributes:

- its original shape;
- its weight distribution;
- its construction;
- its method of propulsion;
- its method of steering.

The shape and weight distribution mainly determined the boat's stability when afloat. The construction mainly determined its strength and how the vessel was built. Although many different methods of construction will give a strong, stable vessel, it is the method of construction that is often a clue to the technological achievement and cultural background of the community that built the craft.

All of these attributes relate both to the environment in which the boat was used, whether at sea or in inland waters, and to its purpose, whether for carrying people or cargoes, or for warfare. In addition, the boat was conceived within a tradition of boatbuilding that must have influenced the nature of the vessel, along with the cultural perceptions embodied in the society that produced it.

When dealing with an incomplete and distorted vessel from the remote past, it is necessary to recognise that there are limits to the evidence and, therefore, it is important to keep unverified assumptions to a bare minimum and accept that the hypotheses with the fewest assumptions are to be preferred. It is important not to confuse facts with their interpretation, or to limit interpretation to only one possible view. This section of the Dover boat report describes the hull as found and tries to reach minimum conclusions. More developed interpretations are discussed in Chapters 6, 8, 9, 18 and 19.

Detailed description

Surviving planks

Each bottom plank and each ile plank had been fashioned from a single log, including the inboard features: stitch holes, wedge holes, cleats and transverse timber holes cut through both cleats and into the inboard face of the planks. The shaping of the plank edges is particularly important, as these joined neighbouring planks and needed to form watertight seals. Evidence of how the timbers were fashioned is obtained from surviving tool marks and is discussed in Chapter 8. Some evidence of compression is also included, although this is described in greater detail in Chapter 6.

Bottom plank west (300)

Shape and size

This large oak plank was traced for a length of 7.26m, its south end terminating at the scarf with the end board (306), but its north end lay beyond the edge of excavation (*see* Fig 5.20). The plank had been fashioned from a tangential cut through the heartwood of an oak tree, with the pith originally below the outboard face. The grain is fairly straight, with few knots. Near the south end, the plank is 680mm wide, increasing northwards to 770mm at cleat 314. Although the plank varies considerably in thickness, there is a general pattern in its shape that shows that it is thicker along its middle line than near its edges (Fig 5.21). Random thicknesses taken on the west and east sides of the plank, and in the middle, give the following averages: west side 28mm; centre 62mm; east side 32mm.

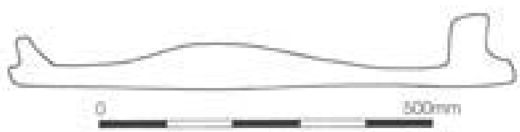


Figure 5.21
Section through the bottom plank showing variation in thickness.

The plank had been fashioned with a flat outboard face, and an inboard face that had the following features, all of which had been cut from solid timber.

First, there are raised cleats, perforated to take transverse timbers, situated at intervals along the centre of the plank (*see* Fig 5.6).

Second, there are upstanding rails located close to the longitudinal edges of the plank, the rail next to the centre line of the boat being perforated with rectangular slots to take transverse timbers and the wedges that joined the plank to its neighbour (303), and the rail furthest from the centre line of the boat having holes cut under it for stitches to attach the adjacent ile plank (301).

Third, the variations in plank thickness that were intended, and are all inboard, are reflected by the horizontal slots cut across the centre of the plank at the cleats. These slots are straight and flat-bottomed to accommodate transverse timbers 340–343 and, in all cases, the slots are cut deepest in the thick centre of the plank, and tail off towards the thinner sides. At cleat 311, the maximum depth of the slot is 10mm and at cleat 313, the slot is 15mm deep.

Fourth, there are many traces of tool marks (Figs 5.22; 5.23), but few clearly reflect the entire blade of the cutting tool. The outboard and inboard flat faces of the plank have long, roughly scooped hollows aligned fore and aft, each about 50mm wide, with slightly raised ridges between. It would appear that they represent the tooling by adze, working in lines along the plank from end to end. The tool marks outboard have a series of small depressions along the flanks of the ridges at intervals of roughly 17mm, suggesting the distance hewn by each axe cut (*see* Fig 5.24). The tool marks on the outboard face are particularly interesting as they exist only near the former centre line of the boat, and appear to have been worn away at a distance from the centre line. This pattern of wear also exists on the outboard face of the adjacent bottom plank (303). There are also curved blade cuts, up to 64mm wide, which reflect the width of the blades used to shape the sides of the slots for the transverse timbers, particularly under cleat 315.

The cleats

Three cleats were found (311, 313, 315; *see* Table 5.1; Figs 5.25–5.28), and the position of a fourth (317) is inferred from the position of transverse timber 343. A fifth cleat (319) may also be postulated as a twin

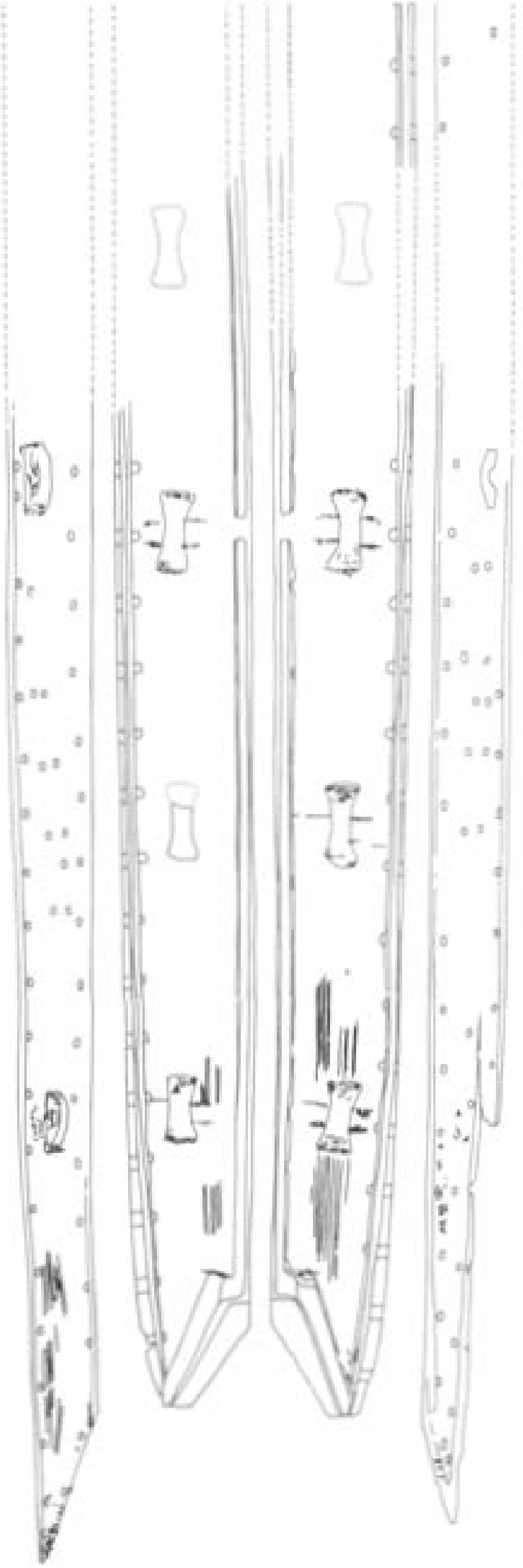


Figure 5.22 Plan of tool marks (inboard).

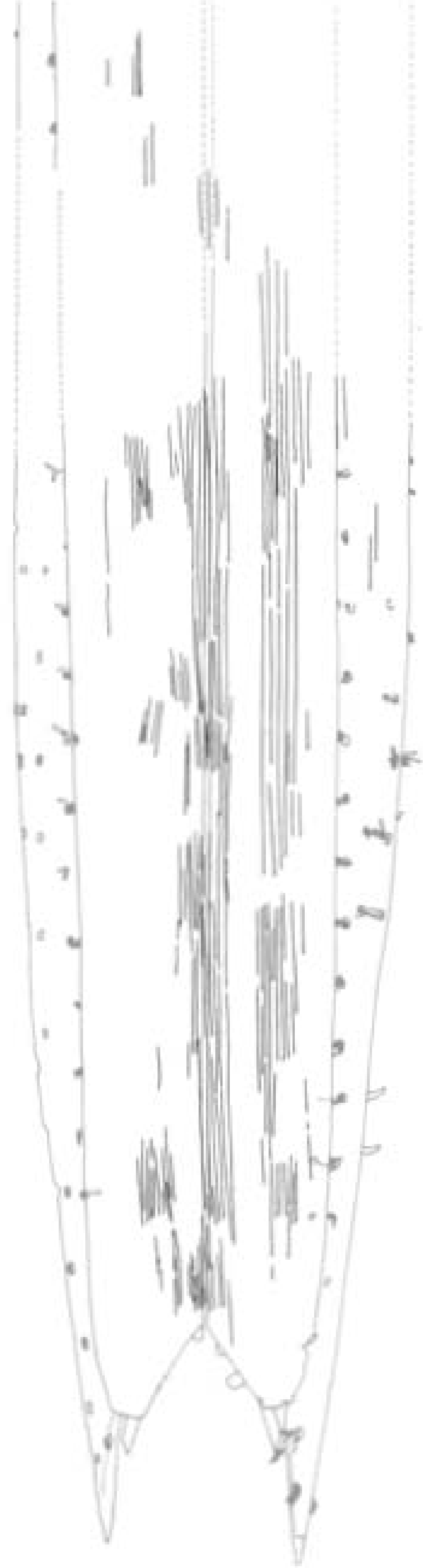


Figure 5.23 Plan of tool marks (outboard).

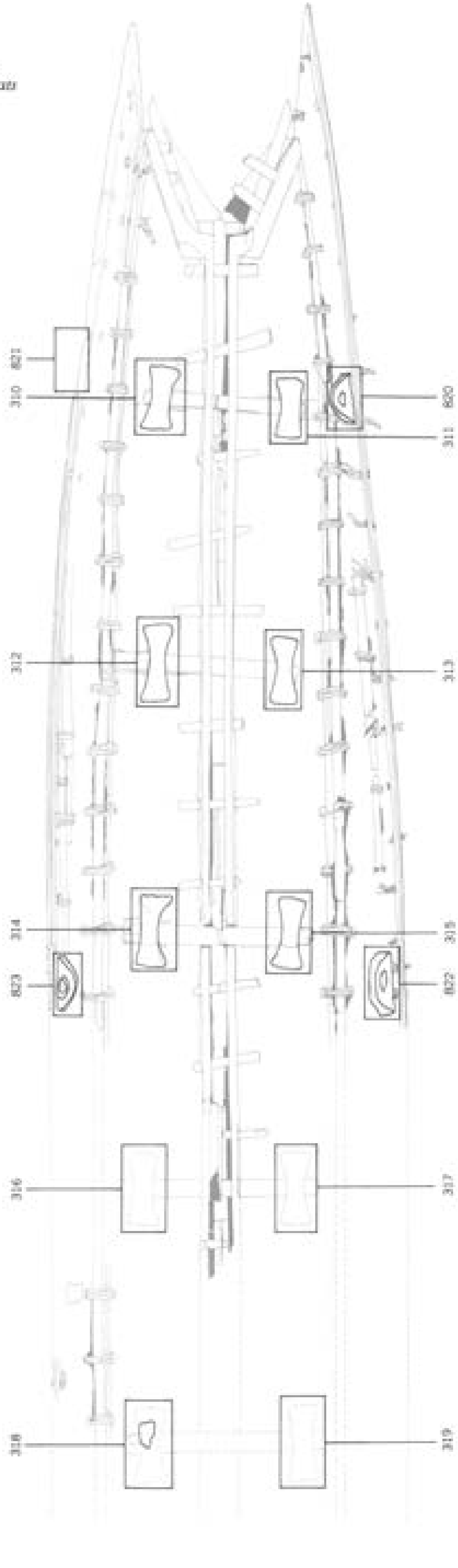


Figure 5.25
Key showing the position and numbering of the cleats described in the text.

to cleat 318. Cleat 313 is incomplete, the northern part having been broken away when found. All three discovered cleats are an integral part of the log from which plank 300 was fashioned. They are all rounded lumps aligned fore and aft along the centre of the plank, and each has a narrow waist in the high centre and broad 'fish-tail' shaped ends on the plank face (*see* Fig 5.29). Through the centre of each is a roughly cut hole to take a transverse timber.

That the cleats were fashioned by axe and adze is shown by the many cuts in their central holes, although the outside surfaces of the cleats are smooth and mostly they have no tool marks except at the fishtails. There are vertical cut marks in the hole through cleat 313, and cut marks in the sides of the slot for its associated transverse timber.

Transverse timber slots under cleats 311, 313, 315

The hole through each cleat is just part of a larger slot cut in the upper face of the plank to accommodate the transverse timber (*see* Fig 5.20).

The slot at Cleat 311 is 110mm wide and up to 35mm high under the cleat. It is to take transverse timber 340, which is 90mm wide and 26mm thick.

The slot at Cleat 313 is 150mm wide and up to 67mm high under the cleat. It is to take transverse timber 341, which is 105mm wide and 38mm thick. The slot is recessed up to 15mm into the inboard surface of the plank.

The slot at Cleat 315 is 150mm wide and up to 42mm high under the cleat. It is to take transverse timber 342, which is 108mm wide and 31mm thick. The slot was shaped by axe or adze and there are clear marks of the blade. These tool marks are slightly curved, one being 37mm long but incomplete, while another is 64mm long.

East side of plank inboard

Central rail (362)

The rail is a longitudinal feature fashioned to stand above the inboard face of the east side of the plank. It is set back 35–45mm from the edge of the central seam of the boat, and is essentially rectangular in cross section. It stands 65–70mm above the plank, and is 53–63mm wide at the top. At their junction, the vertical faces of the rail and the flat surface of the plank are partly angled and partly rounded, but these may have been distorted by compression.

Table 5.1 Dimensions of cleats on bottom planks: height above plank is measured from the general upper plank face and is not taken from the bottom of the transverse slot (in mm).

cleat number	*length*	*height above plank*	*width of fishtails*	*width of waist*
310	405	125	195, 204	122
311	372	100	185, 170	116
312	460	137	185, 200	102
313	?450	62	205, –	110
314	455	113	203, 205	107
315	455	*c* 60	180, 180	105
318	193+	?	125 + ?	–

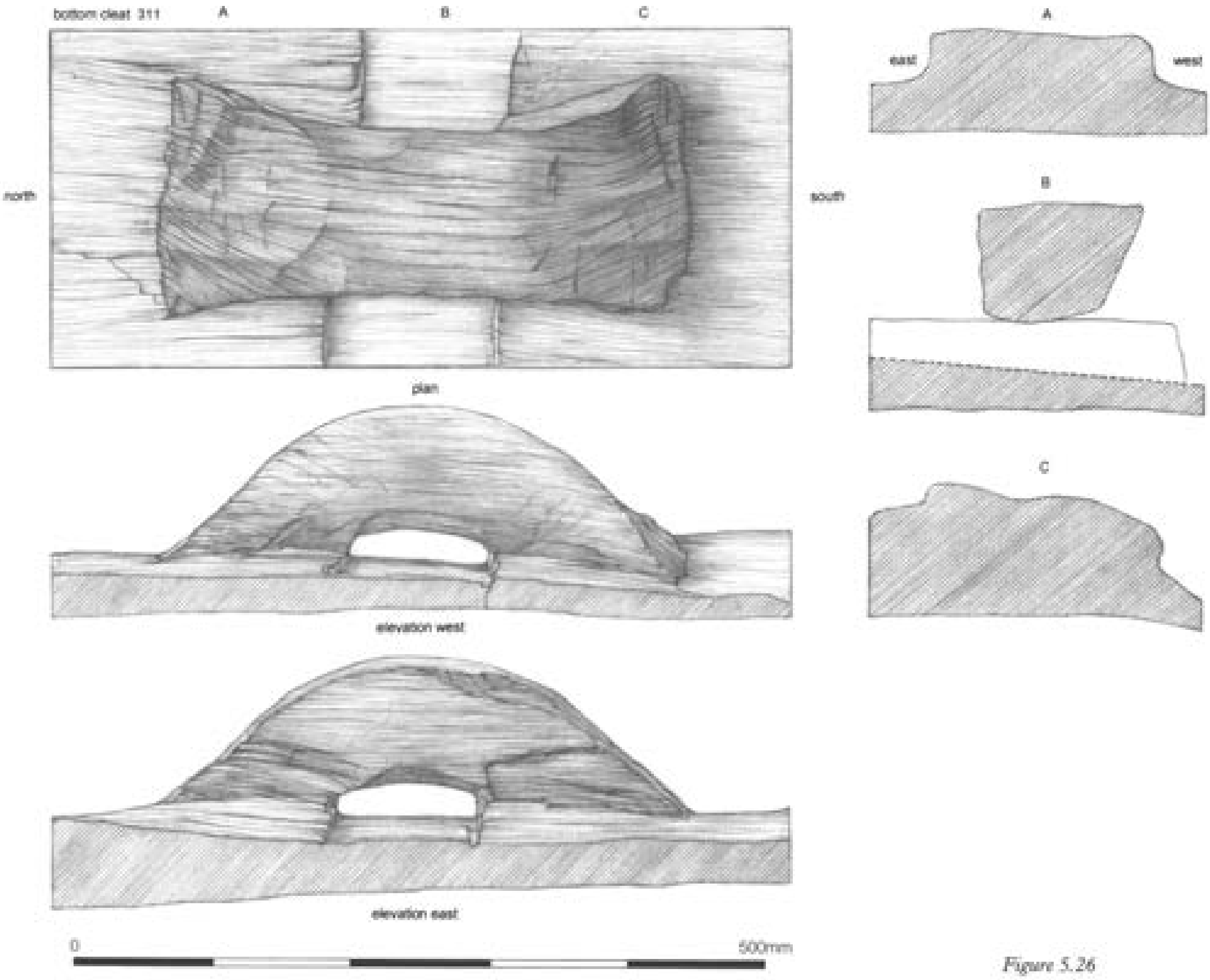


Figure 5.26
Cleat 311.

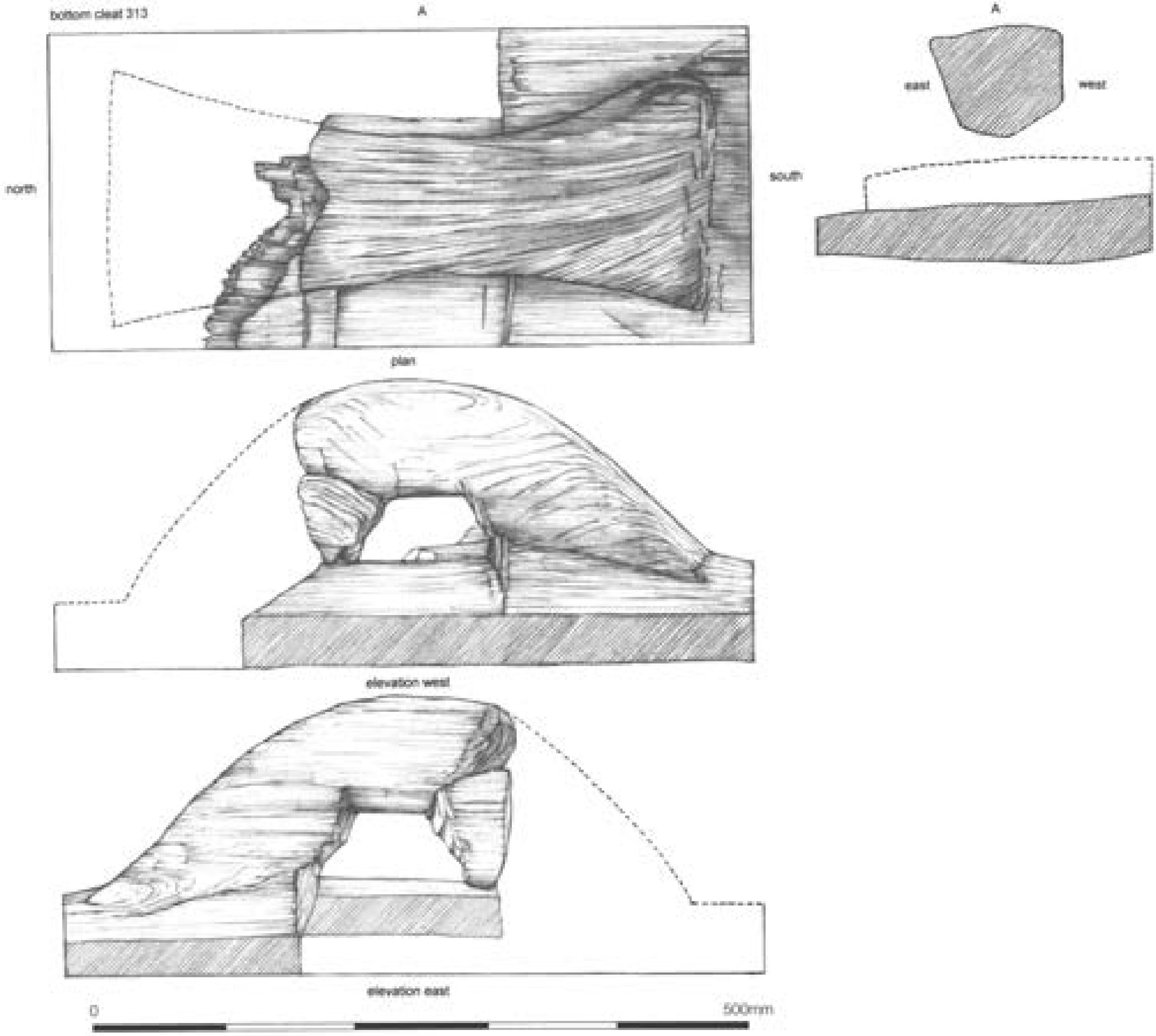


Figure 5.27
Cleat 313. Its northern end was damaged by the sheet piling between the cofferdams.

Wedge holes in the central rail (408–419)

The rail is pierced by roughly rectangular wedge holes (*see* Table 5.2; Fig 5.6). The holes were presumably intended to reflect the relative sizes of the timber wedges that were to pass through them, although the interior of each wedge hole is smaller than the opening. The presence of the wedges makes it impossible to measure the interior of the holes, although the centre of hole 413 was found to be 15mm high.

Transverse timber holes

Four transverse timbers crossed the bottom of the boat, passing through the roughly rectangular holes in the central rail (381, 383, 385, 387; *see* Tables 5.3; 5.4; Fig 5.6). The spacing of the wedge holes (W) and the transverse timber holes (T) from centre to centre are given in Table 5.5.

East plank edge

The central edge of the plank – where it abuts plank 303 to form the central seam of the boat – appears to have been squared off and was originally vertical. The top corner, however, has distorted tree rings, indicating deformation by pressure, so that, whereas the plank is 44–70mm thick (averaging at 54mm), next to the rail it is only 20–55mm thick (averaging at 38mm) at the plank edge.

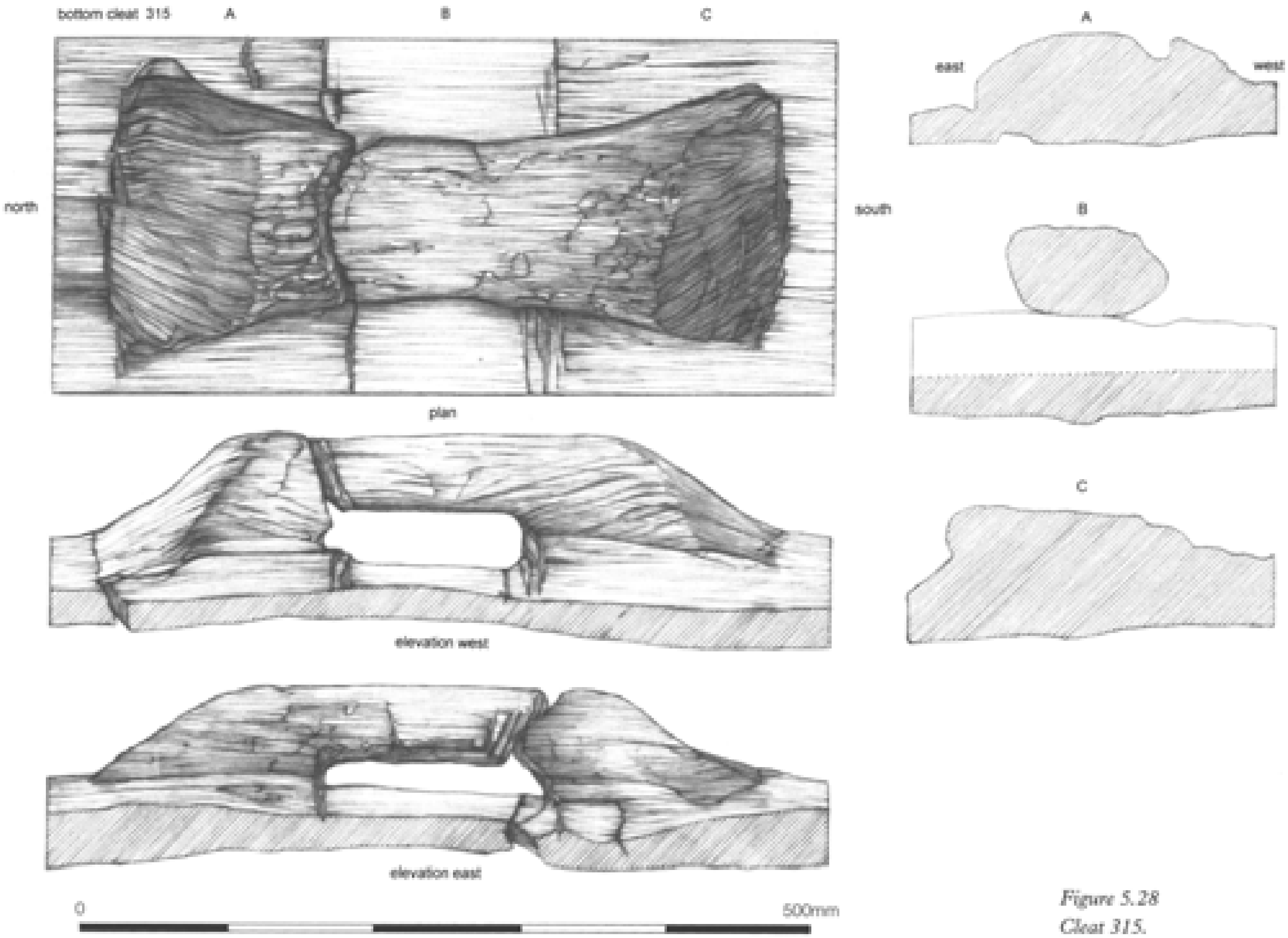


Figure 5.28
Cleat 315.

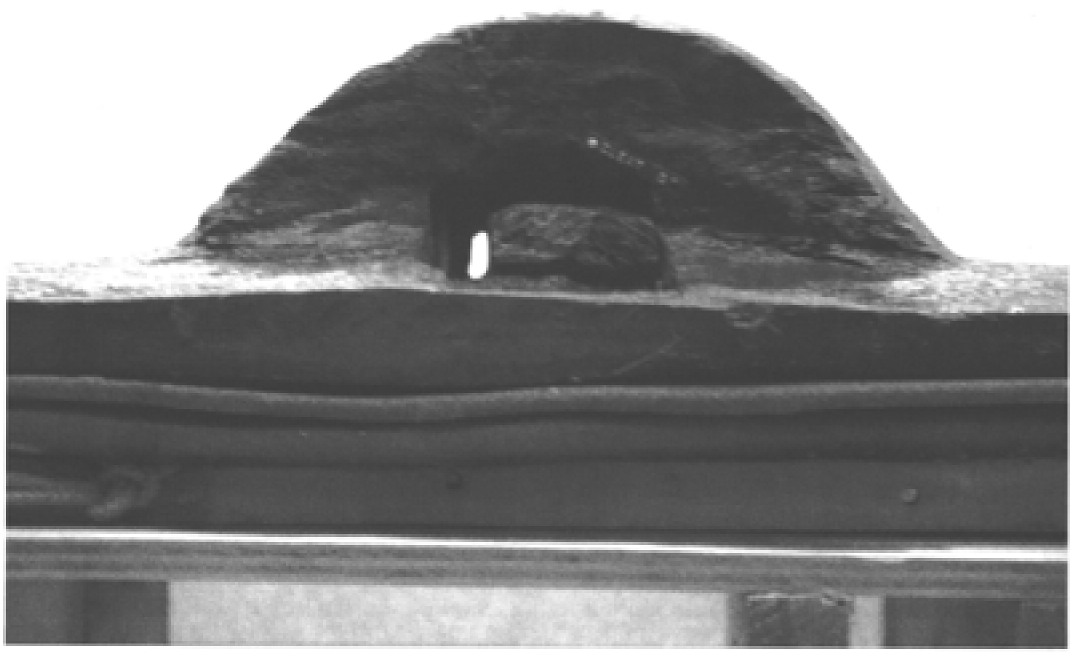


Figure 5.29
An example of one of the bottom cleats (310).

West side of plank inboard

Seam rail (371)

This rail is fashioned from the edge of plank 300 and forms an L-shaped rabbet or seating for the bottom of the ile plank 301. Stitches, passing through holes under the rail and through the lower end of plank 301, held the two plank edges together in the seating. The rail is roughly rectangular in section, but slanted over towards the outer or western edge as if it has been pushed towards the seam with ile plank 301. The flat top of the rail is 36–8mm wide, and stands 32–8mm above the inboard face of plank 300, and 24–5mm above the seating for ile plank 301.

Stitch holes

Seventeen stitch holes were cut into the top of the western edge of the plank and passed beneath the rail to emerge at the outer edge of the plank (491, 493, 495, 497, 499, 501, 503, 505, 507, 509, 511, 513, 515, 517, 519, 521, 523; Tables 5.6; 5.7; Fig 5.30). Each stitch hole started with a D-shaped scoop into the top of the plank beside the rail and passed under the rail as a hole about 20mm high and 58mm broad. This breadth is about the width of one axe, as represented by blade cuts in the wood in parts of the boat, and was perhaps marked out by axe initially. The stitch hole passed immediately below the seating for the ile plank 301, leaving a thin portion of plank between the stitch hole and the outboard face of the boat, ensuring that the stitch was protected from damage when the boat ran aground.

West plank edge

The outer edge of the plank, just beyond rail 371, provides the lower seating for the ile plank (301). The seating is 24–5mm deep against the rail and 15–32mm wide at its base, the outboard corner of the plank being rounded as if having been worn by

Table 5.2 Dimensions of wedge holes in the central rail of plank 300 (in mm)

wedge hole	*size (length × height)*
408	67 × 27
409	80 × 43
410	75 × 34
411	83 × 25
412	77 × 24
413	86 × 25
414	80 × 20
415	80 × 20
416	77 × 20
417	76 × 18
418	75 × 28
419	–
average	77 × 25

Table 5.3 Dimensions of transverse timber holes in the central rail of plank 300 (in mm)

transverse timber hole	*size (length × height)*
381	113 × 41
383	?
385	140 × 25
387	145 × 30

Table 5.4 Spacing between transverse timber holes in the central rail of plank 300 (centre to centre; in mm)

transverse timber holes	*distance*
381–383	[1710]
383–385	[1740]
385–387	[1650]
average	1700

Table 5.5 Spacing between wedge holes and transverse timber holes in the central rail of plank 300 (centre to centre; in mm) T = transverse timber hole; W = wedge hole

	holes	*distance*
W–W	408–409	[480]
W–T	409–381	373
T–W	381–410	330
W–W	410–411	510
W–W	411–412	510
W–T	412–383	[350]
T–W	383–413	[370]
W–W	413–414	[500]
W–W	414–415	505
W–T	415–385	353
T–W	385–416	335
W–W	416–417	[490]
W–W	417–418	490
W–T	418–387	345
T–W	387–419	[350]
average		498

Table 5.6 Dimensions of stitch holes on plank 300 (in mm) breadth = fore-and-aft measurement on the plank face; length = across the boat

stitch hole	*breadth*	*length*
491	–	–
493	55	40
495	65	30
497	–	–
499	–	–
501	50	–
503	48	40
505	47	50
507	45	50
509	58	52
511	50	45
513	55	48
515	56	41
517	52	30
519	56	34
521	–	–
523	–	–
average	53	41

Table 5.7 Spacing between stitch holes on plank 300 (centre to centre; in mm)

stitch holes	*distance*
491–493	[540]
493–495	363
495–497	[360]
497–499	? 345
499–501	355
501–503	[360]
503–505	345
505–507	363
507–509	[360]
509–511	364
511–513	[350]
513–515	[380]
515–517	390
517–519	380
519–521	380
521–523	–
average	375

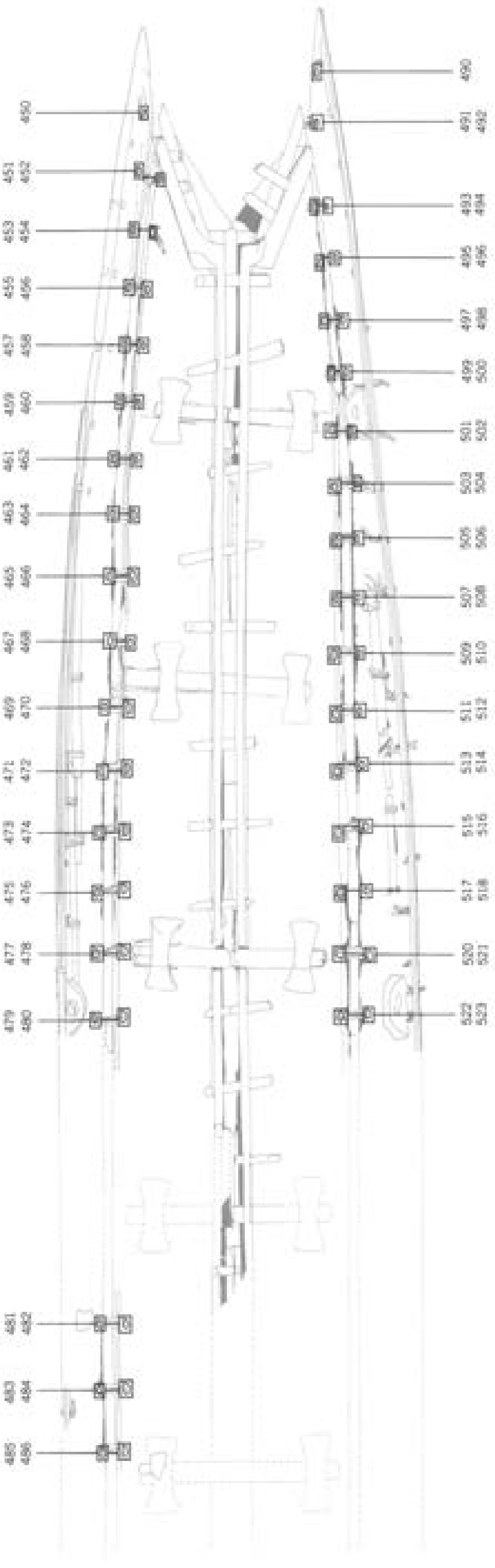


Figure 5.30
Key showing the position and numbering of the lower stitch holes described in the text.

grounding, though this may have been a deliberately made bevel. As the plank edge is traced to the south end of the boat the height of the seating against rail 371 remains about 30mm high but becomes up to 62mm wide. The edge of the plank varies from 24mm to 28mm thick, whereas the plank's thickness next to rail 371 is 34mm.

South end of the plank inboard

The south end of this plank is fashioned to a complex shape as part of the watertight yoke-shaped scarf between the bottom planks and the end board. The extreme end of the plank has been shaped to form a thin shelf, 5–10mm thick at its edge and thickening to 25mm in its interior, to support the lower part of the end board. Beside this is a rail (363), through which there were wedges to hold the lower edge of the end board (306).

Yoke rail (363)

This rail is a diagonal extension of rail 362 along the east side of the plank, forming the east side of the yoke-shaped scarf at the south end of the boat. It is approximately squared in section with a flat top, 110mm wide near its north end, narrowing to a point at its south end. Its north end stands 106mm above the general inboard face of plank 300 and gradually narrows down to less than 65mm high. It is pierced by three wedge holes (405–407).

Rail wedge holes (405–407)

Rectangular rail wedge holes have been roughly cut through rail 363, the sizes of the openings not being quite the same on either side of the rail. The wedges are still in place in holes 406 and 407, so it is not possible to measure the size of the interior of the holes (Tables 5.8; 5.9).

Bottom plank east (303)

Shape and size

This bottom plank of oak was traced for a distance of 8.71m from its intact south end; its northern end lay outside the area of excavation (*see* Fig 5.20). Part of the plank had been destroyed recently near the north end, leaving the remote possibility that it might have comprised two planks joined endwise in the missing area. The destroyed section mostly lay between stitch holes 480 and 481, leaving a gap of only 390mm. It is most unlikely that this coincided with a plank joint. The width of the plank is 685mm near its south end, and 820mm just north of cleat 316 near its north end, and it has a thickness ranging from 12mm to 69mm.

The shaping of this plank is a mirror image of bottom plank 300. Consequently, although there is considerable compression, the thickness does show a consistent pattern with a greatest thickness along the centre line of the plank, the middle being roughly twice the thickness of the plank near its sides. As its outboard face is flat, it is clear that the variations in thickness all existed inboard. This is shown by the slots for the transverse timbers at the cleats, which are cut into the thick centre of the plank only. The plank has been tangentially cut from the tree with the pith below the outboard face, and it has a fairly straight grain with few knots. The plank is therefore very similar in all respects, but as a mirror image, to the adjacent bottom plank 300. On its centre line inboard are upstanding cleats with transverse slots below to hold transverse timbers, and next to both outer edges are longitudinal, fore-and-aft rails of upstanding timber. To the west, the central rail contains wedge holes and transverse timber holes, and under the side rail to the east is a series of stitch holes.

Outboard face

The outboard face is flat, with longitudinal adze-tooled hollows surviving in the western half nearest the centre line of the boat as found in bottom plank 300 (*see* Fig 5.24). The other half is worn flat.

Table 5.8 Dimensions of wedge holes in the yoke rail of plank 300 (in mm)

wedge hole	*size (length × breadth)*
405	75 × 20
406	108 × 37
407	85 × 27

Table 5.9 Spacing between wedge holes in the yoke rail of plank 300 (centre to centre; in mm)

wedge holes	*distance*
405–406	193
406–407	223

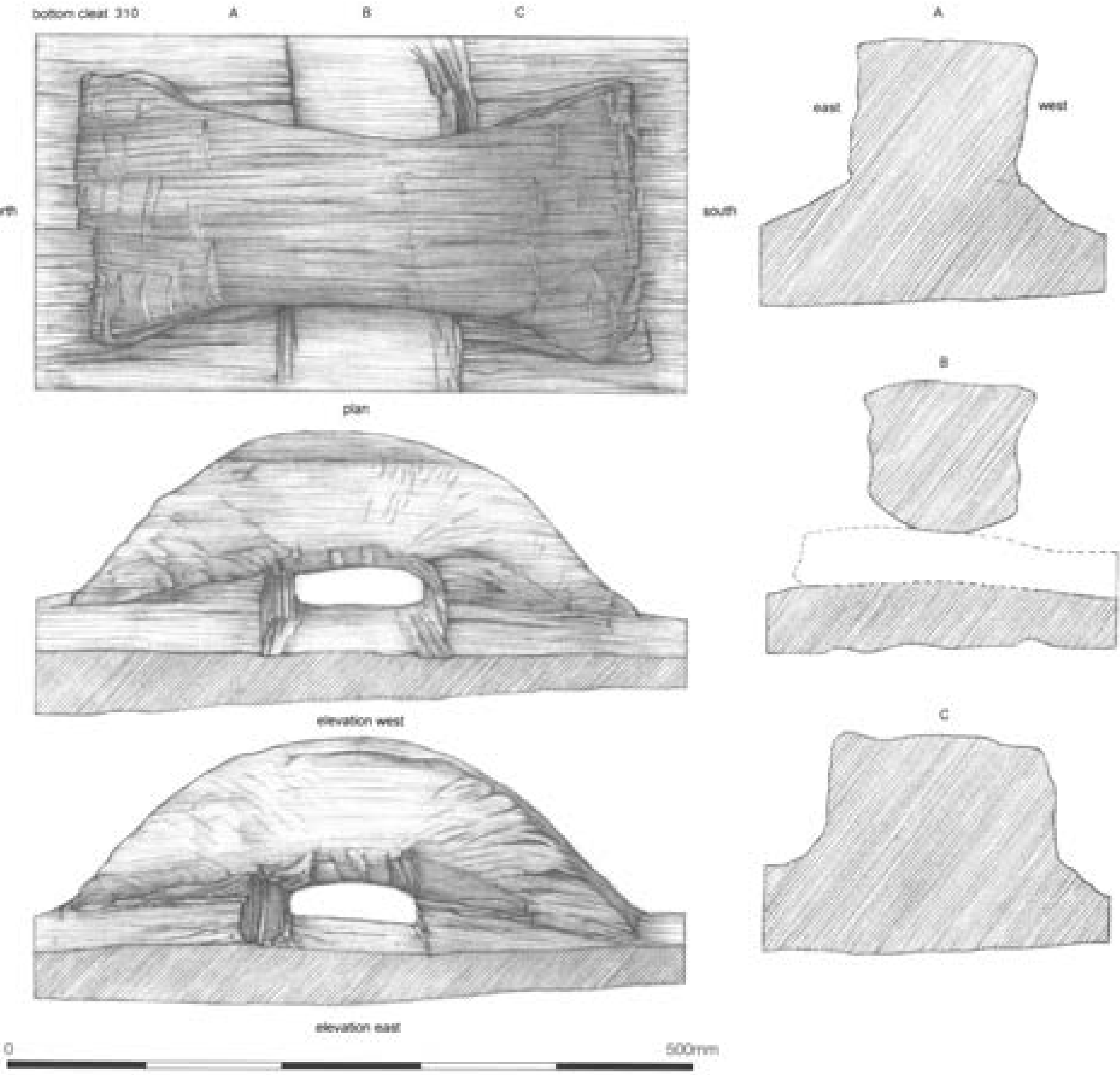


Figure 5.31
Cleat 310.

The cleats

Four cleats were found (310, 312, 314, 318; *see* Table 5.1; Figs 5.25; 5.31–34). Cleat 318, however, was so badly damaged and incomplete that it could not be measured. The cleats, which are an integral part of the plank, lie along its centre line and are aligned fore and aft. Each is rounded fore and aft, with a high narrow central 'waist' descending to wide fishtail-shaped ends. A hole is roughly cut through the centre of each cleat to take a transverse timber.

The cleats were apparently fashioned by axe, but their surfaces were mostly smoothed over. However, near the bottom of the fishtails were some cut marks from the tools used. There were faint cut marks on both fishtails of cleat 314, but no marks were seen on cleats 310 or 318. The clearest marks exist on the north fishtail of cleat 312 where three cuts each 60mm long curved down by 12mm in the centre.

Transverse timber slots under cleats 310, 312, 314, 318

Slots cut through the cleats and into the inboard face of the plank were to take transverse timbers (*see* Fig 5.20).

The slot at cleat 310 is 127mm wide and up to 94mm high under the cleat. It is to take transverse timber 340, which is 90mm wide and 35mm thick. The hole through

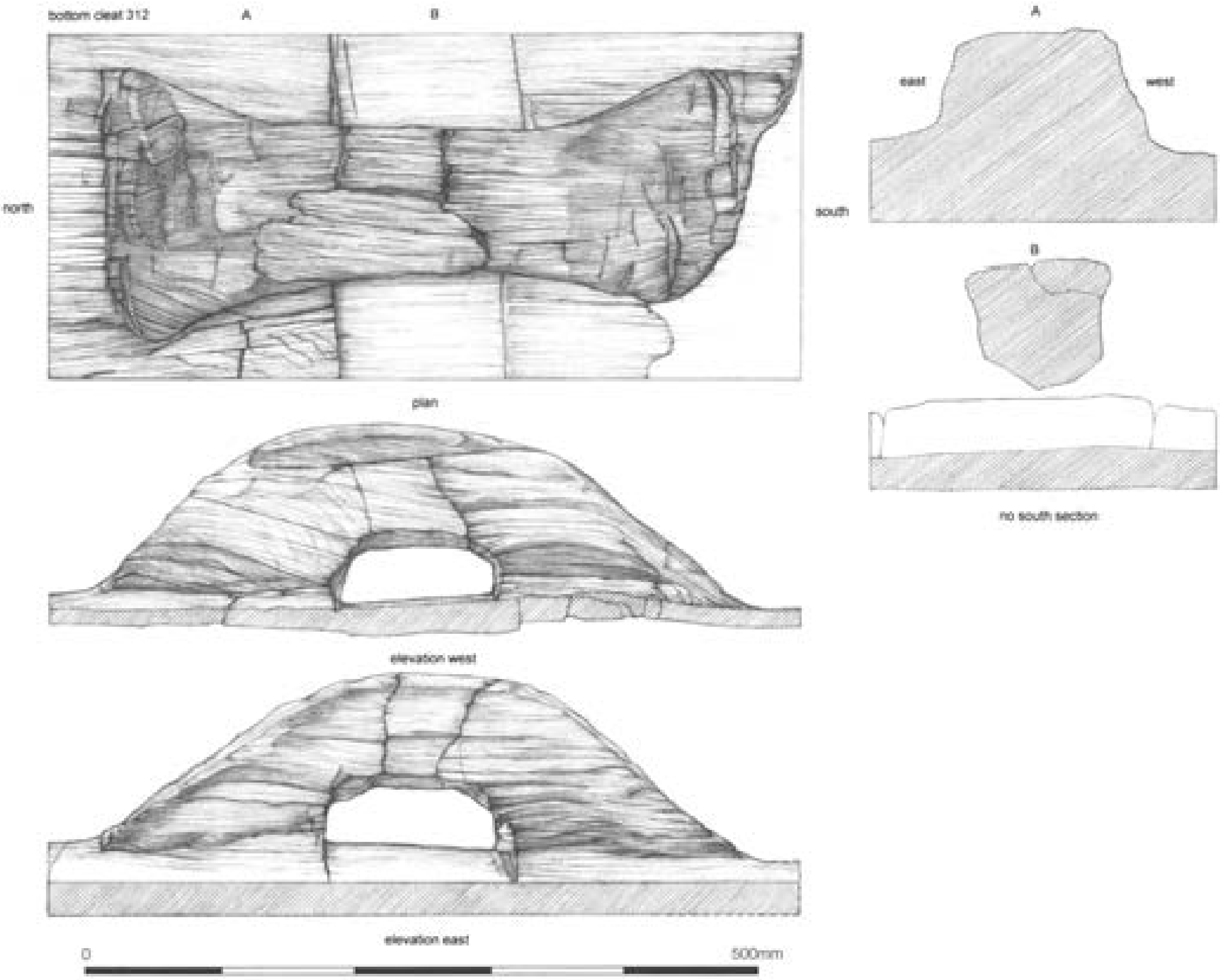


Figure 5.32 Cleat 312.

the cleat has vertical axe stop-marks in the roof of the slot that go about half way under the cleat, to a depth of about 60mm from each side, and show that the hole was cut from both sides of the cleat.

The slot at cleat 312 is 127mm wide and up to 48mm high under the cleat. It is to take transverse timber 341, which is 110mm wide and 38mm thick. The slot is recessed up to 7mm into the inboard surface of the plank.

The slot at cleat 314 is 147mm wide and up to 26mm high under the cleat. It is to take transverse timber 342, which is 127mm wide. Axe cuts exist along the sides of the slot.

The slot at cleat 318 is more than 75mm wide under the cleat, but because of modern damage, it was not possible to judge its original width. It is recessed up to 5mm into the surface of the plank.

West side of plank inboard

Central rail (360)

This rail extends along the entire length of the western side of plank 303, but is set back about 30mm from its edge. The rail is essentially rectangular in cross section and between 50mm and 55mm wide at the top and at its base. It stands generally 64–80mm above the inboard plank face on its east side, but, on occasion, is only 40mm high or as much as 94mm high. The reasons for the variation may be due in part to compression of the timber. Sometimes the junction of the plank face and the rail is angular, and other times it is rounded.

Wedge holes in the central rail (390–404)

The rail wedge holes that were cut through rail 361 are roughly rectangular, but narrow

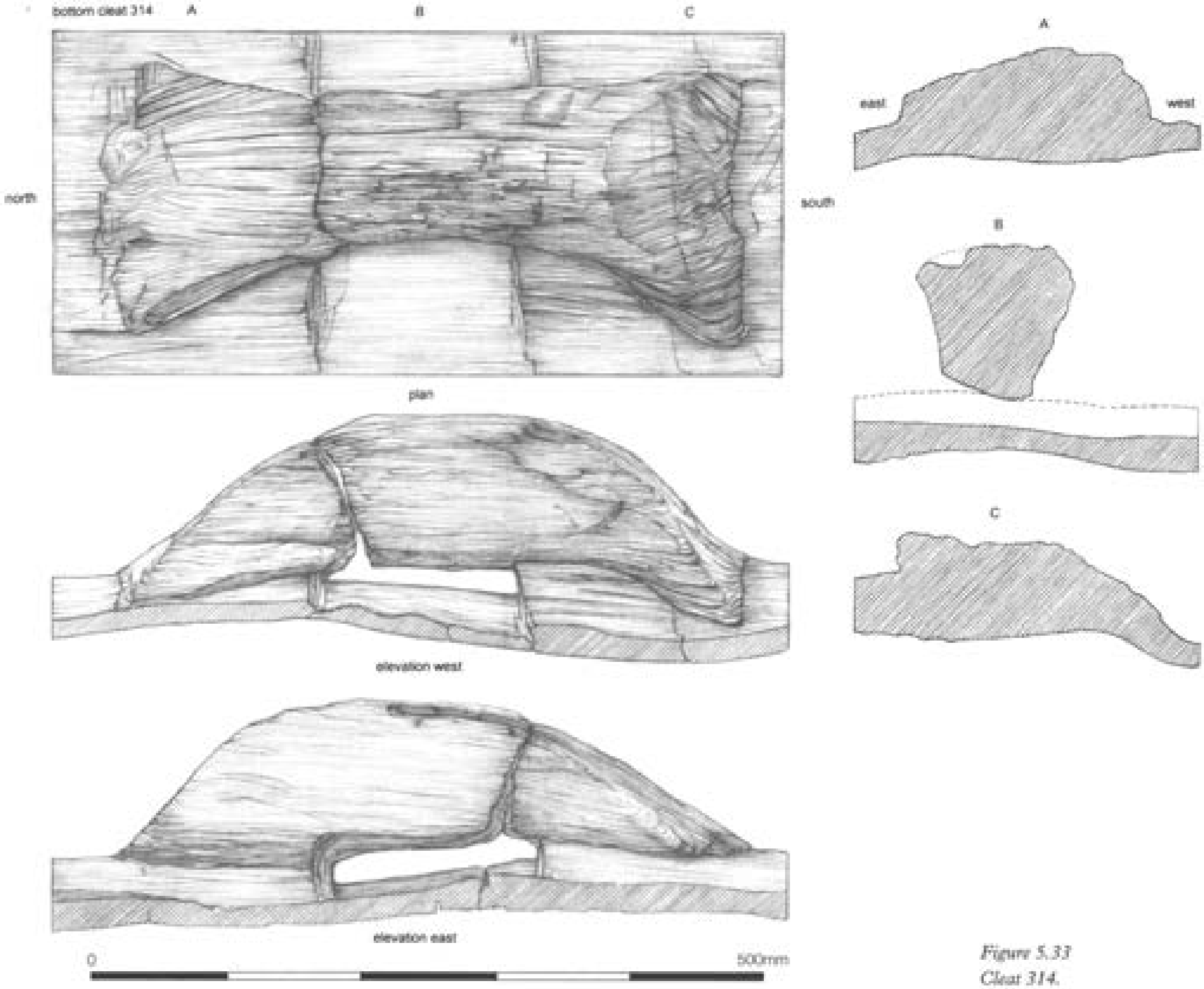


Figure 5.33
Cleat 314.

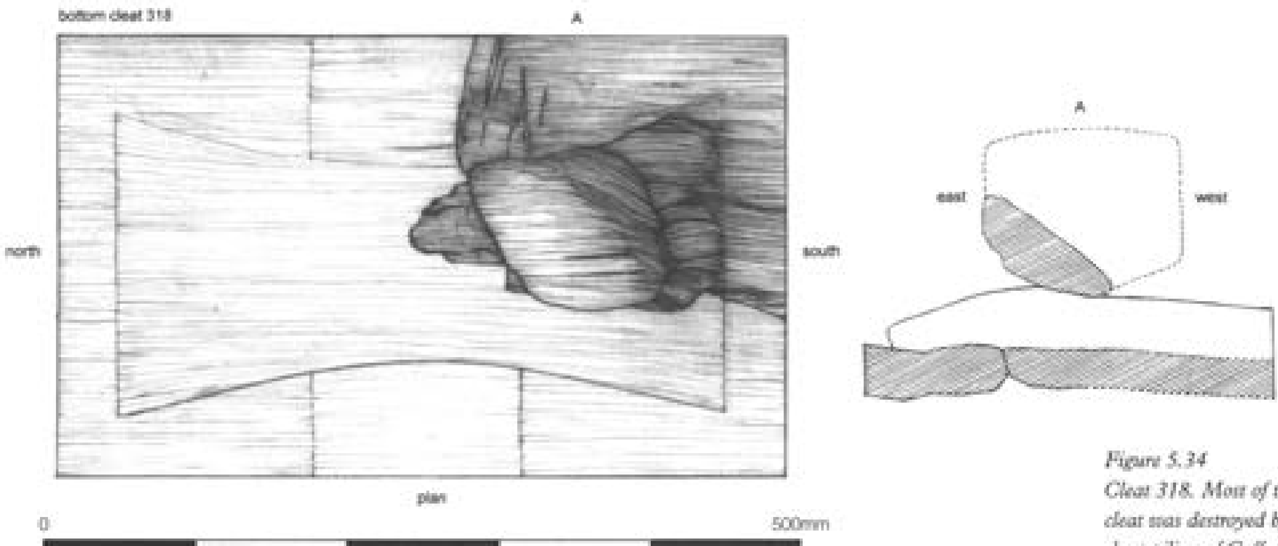


Figure 5.34
Cleat 318. Most of this cleat was destroyed by the sheet piling of Cofferdam I.

inside their openings (Tables 5.10; *see* Fig 5.6). The size of the openings may be a rough indicator of whether there was any standardised system of fashioning the fastenings that they held.

The average size of the wedge hole openings is 76mm × 28mm; although it is not possible to measure their interiors, there are indications that they narrow under the rail.

The spacing between centres of the pairs of wedge holes (excluding the transverse timber holes) in rail 360 averaged at 500mm from centre to centre.

Transverse timber holes

The four transverse timbers that crossed the bottom of the boat passed through these roughly rectangular holes in rail 360 (380, 382, 384, 386; Tables 5.11; 5.12; *see* Fig 5.6). The spacing of the wedge holes (W) and the transverse timber holes (T) from centre to centre is presented in Table 5.13.

West plank edge

The central edge of the plank where it abuts plank 300 is approximately squared off between 27mm and 59mm west of the central rail 360. The upper surface of the plank slopes down to the vertical face of the edge, presumably owing to compression of the wood grain. This means that the present height of the edge is probably not a true reflection of its original height. The plank thickness on the west side of the central rail was thicker than the plank on the east side to strengthen the central seam of the vessel.

East side of plank inboard

Seam rail (370)

This rail, along the eastern side of plank 303, forms part of the seating for the bottom of ile plank 304. The stitching to join planks 303 and 304 passes through holes under the side rail to emerge in the outer edge of the plank. The rail is approximately rectangular in cross section, standing proud of the inboard surface of plank 303, but appears to be somewhat pushed over towards the eastern edge of the plank. The rail is 32–40mm wide at the top, and a little thicker (up to 50mm) at its base; it stands about 52–61mm above the main inboard plank face. Its junction with the plank face is slightly rounded.

Table 5.10 Dimensions of wedge holes in the central rail of plank 303 (in mm)

wedge hole	*size (length × height)*
393	76 × 35
394	73 × 26
395	85 × 31
396	76 × 19
397	73 × 20
398	68 × 29
399	67 × 18
400	65 × –
401	71 × 17
402	78 × 24
403	destroyed
404	– × 14

Table 5.11 Dimensions of transverse timber holes in the central rail of plank 303 (in mm)

transverse timber hole	*size (length × height)*
380	–
382	–
384	135 × 20
386	–

Table 5.12 Spacing between transverse timber holes in the central rail of plank 303 (centre to centre; in mm)

transverse timber holes	*distance*
380–382	[1730]
382–384	[1750]
384–386	[1660]
average	1713

Stitch holes

Eighteen stitch holes are cut into the top of plank 303 immediately west of side rail 370, with the hole passing under the rail to emerge from the east edge of the plank (452, 454, 456, 458, 460, 462, 464, 466, 468, 470, 472, 474, 476, 478, 480, 482, 484, 486; Tables 5.14; 5.15; *see* Fig 5.30). It is remarkable that the holes did not break through the outboard surface of the plank and so expose the stitch to wear from the boat grounding. Each stitch hole is smaller than the actual opening, as it is shaped to allow the stitch to curve round into the hole – hence the D-shape of the opening.

Table 5.13 Spacing between wedge holes and transverse timber holes in the central rail of plank 303 (centre to centre; in mm) T = transverse timber hole; W = wedge hole

	holes	*distance*
W–W	393–394	[525]
W–T	394–380	315
T–W	380–395	380
W–W	395–396	523
W–W	396–397	465
W–T	397–382	[350]
T–W	382–398	[390]
W–W	398–399	480
W–W	399–400	500
W–T	400–384	340
T–W	384–401	340
W–W	401–402	[510]
W–W	402–403	–
W–T	403–386	–
T–W	386–404	–
average		426

Table 5.14 Dimensions of stitch holes on plank 303 (in mm) breadth = fore-and-aft measurement on the plank face; length = across the boat

stitch hole	*breadth*	*length*
452	57	26
454	56	25
456	57	33
458	60	30
460	47	28
462	52	40
464	62	40
466	65	40
468	50	50
470	65	40
472	?70	50
474	?57	40
476	60	40
478	–	–
480	unclear	–
482	58	–
484	60	30
486	missing	–
average	58	36

It was difficult to examine and measure the interior of the stitch holes without breaking the plank or removing the surviving stitches. Stitch hole 470, however, is 20mm in vertical dimension under the rail 370; stitch hole 452 – under rail 370 at the extreme south end of the plank, where constructional features are more massive than in the main part of the boat – is 60mm broad and 12mm high. Its neighbouring stitch hole 454 is, under the rail, 55mm broad and 10mm high.

Table 5.15 Spacing between stitch holes on plank 303 (centre to centre; in mm)

stitch holes	*distance*
452–454	350
454–456	[360]
456–458	363
458–460	365
460–462	[370]
462–464	367
464–466	388
466–468	[430]
468–470	395
470–472	[380]
472–474	390
474–476	376
476–478	[390]
478–480	412
482–484	380
484–486	[390]
average	381

Table 5.16 Dimensions of wedge holes in the yoke rail of plank 303 (in mm)

wedge holes	*size (length × breadth)*
390	85 × 25 +
391	87 × 43
392	93 × 63

Table 5.17 Spacing between wedge holes in the yoke rail of plank 303 (centre to centre; in mm)

wedge holes	*distance*
390–391	214
391–392	210

East plank edge

The outer edge of the plank lies between 27mm and 78mm beyond side rail 370. The edge is roughly squared off and the plank is about twice as thick as it is immediately west of the side rail, to form a solid seating for the bottom of the ile plank. For example, at stitch 543 the east edge of the plank is 38mm thick, whereas just west of the side rail the plank is 23mm thick. The edge at stitch 544 is 40mm thick, whereas the plank west of the side rail is only 20mm thick. This extra thickness is also seen by stitch 540 where the edge of the plank is 30mm thick, but west of rail 370 it is 18mm thick.

South end of plank inboard

The south end of the plank was fashioned with a flat shelf ending with a diagonal edge, and next to it is a diagonal end rail pierced with holes for three wedges, the whole construction forming part of a yoke-shaped scarf.

Yoke rail (361)

This rail formed the east side of the scarf joint with the missing end board (306). It dog-legged from the south end of the central rail (360), and is about 55mm higher than rail 360. Its top is 85–120mm above the inboard surface of plank 303. The rail narrows southward from 92mm to 75mm wide, and then terminates with a diagonal-cut end. The side of the rail next to the missing end board (306) has an upper ledge to support the lath (810) that originally overlay the top of the east side of the missing end board 306. Below that, plank 303 has a broad flat lower ledge to support board 306.

Rail wedge holes (390–392)

Three rectangular holes have been cut through the yoke rail and contain wedges, the purpose of which was to secure the lower end of the now missing end board (*see* Tables 5.16; 5.17).

Ile plank west (301)

Shape and size

This incomplete plank survives to 6.70m long, and runs along the entire surviving length of the west side of the boat, and its south end tapers to a point (*see* Fig 5.20). The plank in transverse section is curved and forms the junction between the flat bottom and the vertical side of the boat. The plank is fashioned from a split section of a large oak log, and its inboard features carved from the same log include cleats on its inboard face, and primary stitch holes beside its lower and upper edges. Secondary stitch holes near the centre of the plank repaired a split. The curve of the ile plank follows the curve of the annual rings of the tree, with the pith originally above the inboard face. The grain is fairly straight, with few knots. Its thickness varies, but, in general, it is thickest in its upper half, thinning down in its lower half.

There are a few traces of cut tool marks, all suggesting the use of an axe. Vertical cuts exist in stitch hole 662, and also a curved cut 48mm long in cleat 820. There are also possible cut marks at the south end of plank 301 where it butts against the missing end board 306.

Outboard face

The outboard face is curved and flat, though pierced by stitch holes at the top and bottom, and, for repairs, near the middle (*see* Fig 5.24).

The cleats

Cleat 820 is a semicircular projection of the inboard face of the plank, 350mm long on its lower face and 325mm long on its upper face (Fig 5.35). It stands 143mm above the plank, and is 48mm wide in the middle, widening to 85mm at its north end and 88mm at its south end. Passing through the centre is an eye-shaped hole, 90mm long and 38mm broad. The narrowest part of the opening is in the centre of the cleat, suggesting that the hole had been fashioned from both top and bottom sides. Just below the hole is a slight hollow with a broken surface on the inboard face of the plank, probably caused by a timber that once existed in the hole.

Cleat 822 is a similar semicircular projection on the inboard face of the plank. It is 470mm long, 82mm high and 48mm wide at its apex, with ends that are wider than the apex (*see* Fig 5.36). It too has an eye-shaped opening, 82mm long and 27mm broad in its centre. The plank face immediately under the cleat is slightly damaged, owing to wear from a vertical timber that once lay in the cleat. The cleat has sharp corners with no wear on its exterior faces, and there are also sharp unworn corners inside the opening.

Lower edge of plank

The lower edge of plank 301 is much narrower than the mid-point of the plank, and is either squared off at an oblique angle or is rather rounded, particularly on its upper corner. It is 38mm thick at stitch 563, 34mm at stitch 557, 35mm at stitch 560 and 23mm at stitch 561. The edge has been shaped to fit neatly into the corner of the rail at the edge of plank 300, leaving enough room for wadding.

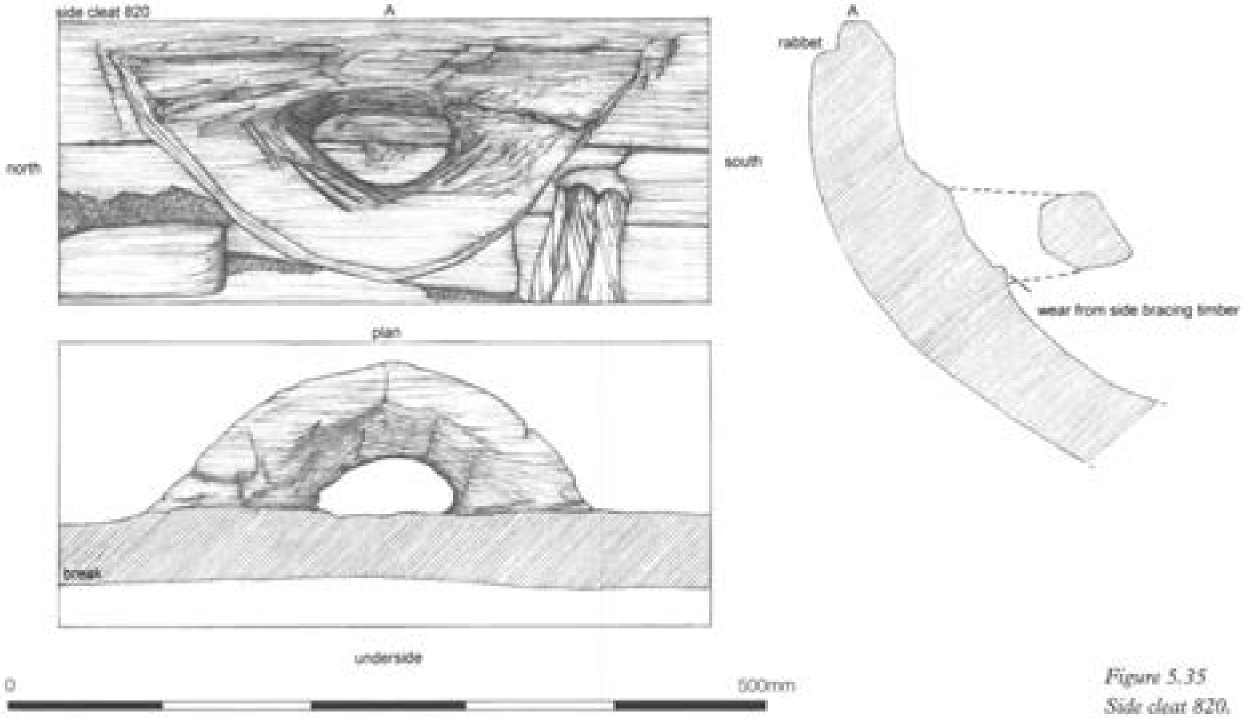


Figure 5.35
Side cleat 820.

Lower stitch holes
Eighteen stitch holes exist on the inboard face and pass through the thickness of the plank to exit at the plank edge beside plank 301 (Tables 5.18; 5.19; *see* Fig 5.30). They contain the stitches that attach plank 301 to plank 300. They are D-shaped in plan, the straight side being closest to the lower plank edge. The holes narrow inside so their internal size is often slightly less than the opening.

Table 5.18 Dimensions of stitch holes on plank 301 (in mm) breadth = fore-and-aft measurement on the plank face; length = across the boat

stitch hole	*breadth*	*length*
490	–	–
492	66	23
494	50	25
496	55	25
498	61	20
500	55	30
502	52	28
504	52	–
506	50	26
508	–	–
510	45	–
512	42	36
514	55	50
516	50	35
518	50	37
520	50	–
522	50	30
524	missing	–
average	52	30

Table 5.19 Spacing between stitch holes on plank 301 (centre to centre; in mm)

stitch holes	*distance*
490–492	[325]
492–494	[540]
494–496	[330]
496–498	[375]
498–500	335
500–502	375
502–504	[330]
504–506	355
506–508	375
508–510	[360]
510–512	364
512–514	[350]
514–516	[385]
516–518	415
518–520	410
520–522	370
522–524	?
average	375

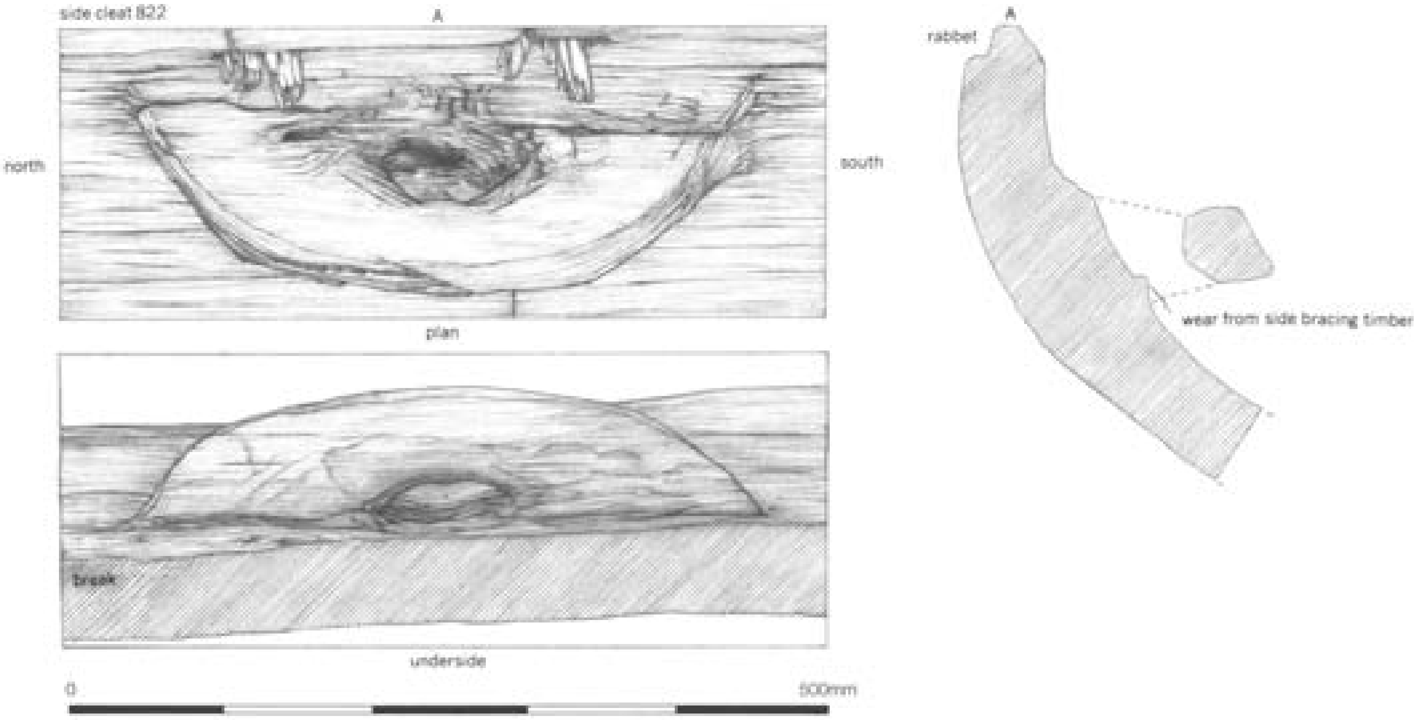


Figure 5.36
Side cleat 822.

Upper edge of plank

The upper edge of plank 301 is 52–5mm thick, is neatly shaped with a bevel 20–5mm wide on the inboard edge, and has a right-angled rebate cut into the outboard corner. The rebate slightly varies in size, but the horizontal face was clearly intended to be smaller than the vertical face. This is significant when reconstructing how the rebate was used, as it formed one side of a seam with plank 302.

Upper stitch holes

The upper stitch holes pass through the plank roughly at a right angle to the inboard plank face, about 35mm below the upper edge of the plank (*see* Tables 5.20; 5.21; Fig 5.37). Inboard, the holes are mostly D-shaped or rectangular with rounded ends. The measurements in Table 5.20 are of the hole openings on the inboard face, although the holes become smaller within the plank. For example, hole 662 measures 32mm long on the plank face, but internally is 23mm. Hole 670 is 50mm × 18mm on the face, and 32mm × 10mm internally. Hole 694 has an internal width of 16mm, and hole 678 is 50mm × 20mm on the face, and 33mm × 11mm internally.

Excluding the spacing of 694–698, it is clear that the regularity of the spacing of the remaining stitch holes (at intervals of between 320mm and 360mm) indicates that some form of measuring device would have been used – for example, the measurement might simply have been the length of the lower arm from elbow to wrist. The spacing is broken by stitch hole 696, which appears to have been added, as the distance between stitch holes 694 and 698 is 337mm and fits neatly into the general spacing pattern.

Ile plank east (304)

Shape and size

This oak plank ran along the east side of the boat and was no doubt fashioned from one timber, as was ile plank 301 (*see* Fig 5.20). Unfortunately, part of the plank near the northern extremity of the excavated vessel was recently destroyed, and it is just possible that a scarf was situated there. Tree rings and rays show that the plank was fashioned with a curved profile that roughly followed the shape of the tree rings, and show that the pith originally lay above its inboard face. Its shaping includes cleats left standing proud of the inboard face (*see* Fig 5.38), and it has stitch holes along its upper and lower plank edges. The plank has split longitudinally near its middle, and has been repaired with stitches for which two rows of secondary holes have been made. The timber is fairly straight-grained, with few knots, and, although the plank varies in thickness, it is at its thickest mostly in its upper half.

Table 5.20 Dimensions of upper stitch holes on plank 301 (in mm)

stitch hole	*breadth*	*length*
660	55	34
662	62	32
664	64	25
666	61	20
668	52	17
670	50	18
672	48	15
674	45	20
676	44	18
678	50	20
680	*c* 50	*c* 20
682	60	24
684	57	24
686	49	27
688	47	21
690	49	22
692	49	22
694	40	20
696	50	18
698	? 50	18
average	51	22

Table 5.21 Spacing between upper stitch holes on plank 301 (centre to centre; in mm)

stitch holes	*distance*
660–662	343
662–664	340
664–666	335
666–668	340
668–670	?
670–672	335
672–674	335
674–676	[330]
676–678	320
678–680	330
680–682	[325]
682–684	343
684–686	340
686–688	[360]
688–690	330
690–692	330
692–694	[340]
694–696	180
696–698	157
average (excluding stitch hole 696)	336

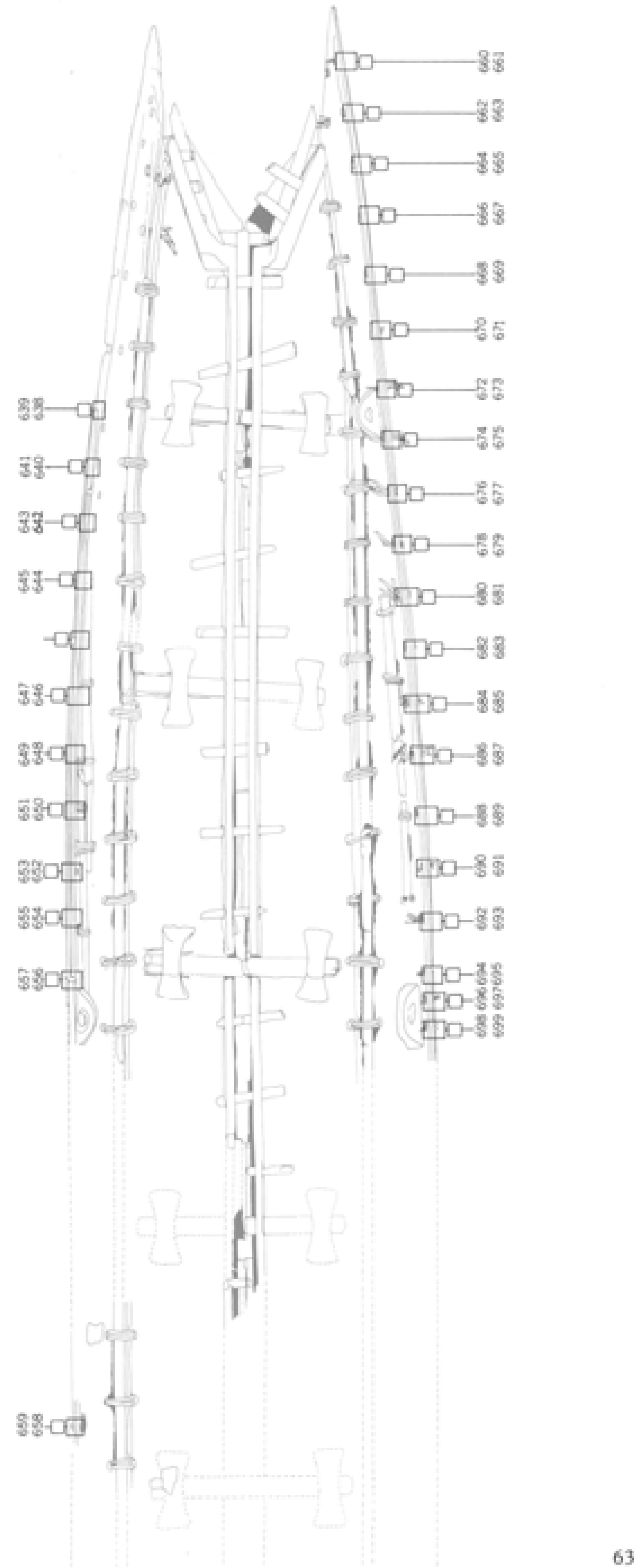


Figure 5.37
Key showing the position and numbering of the upper stitch holes described in the text.

Figure 5.38
An example of one of the side cleats (823).

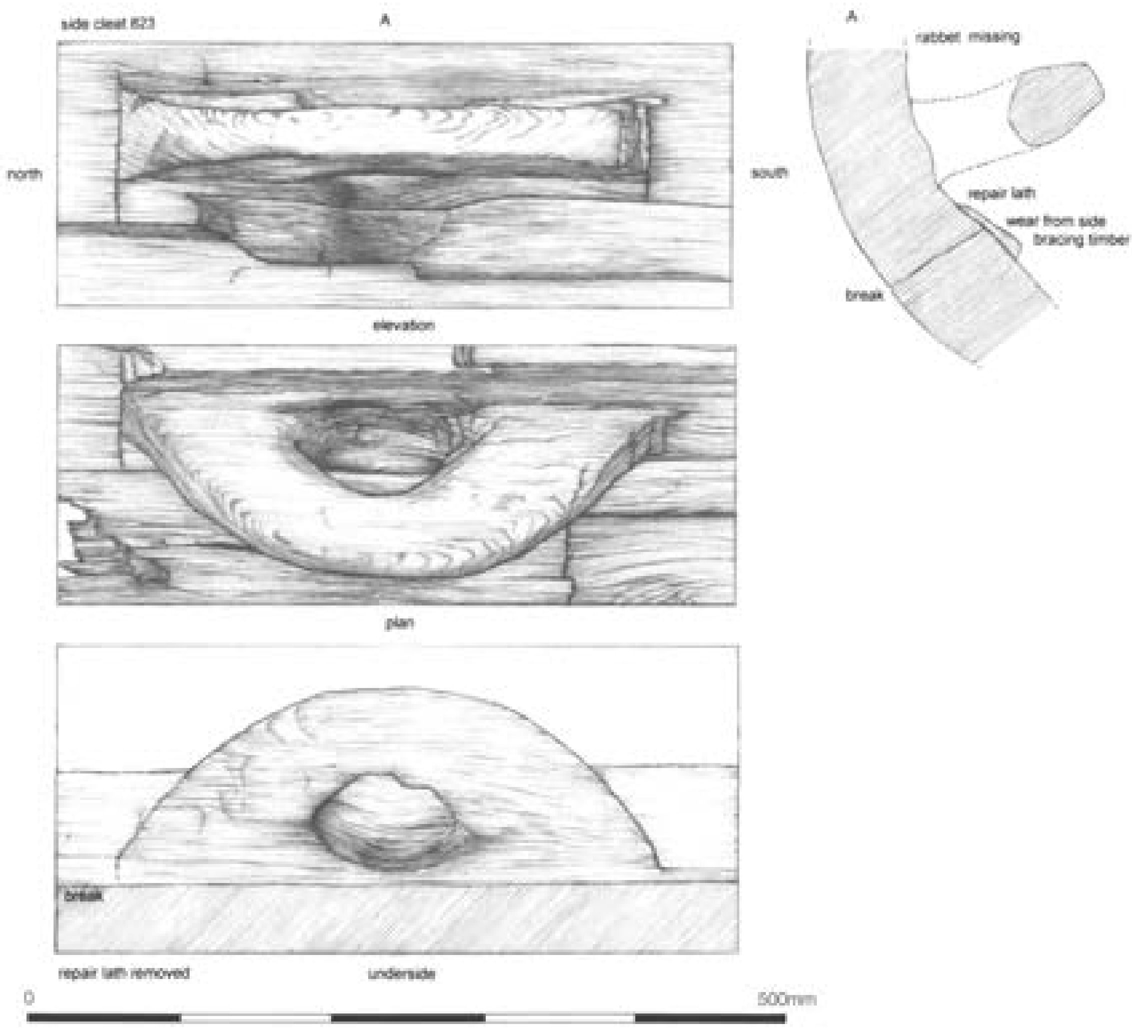


Figure 5.39
Side cleat 823.

Outboard face
The outboard face is curved and smooth, though pierced with stitch holes at the top and bottom, and with repair stitch holes in the middle (*see* Fig 5.24). It also has wear marks.

The cleat
Cleat 823 is the only surviving cleat on this plank (Fig 5.39). It is a semicircular projection running fore and aft, and is 340mm long, 116mm high and about 60mm wide at its ends, with the top of the narrow centre being only 28mm wide. There is an eye-shaped hole, 57mm broad and 90mm long, through the cleat. As the narrowest part of the hole is in the centre, it is clear that the hole was shaped from above and below. There is a worn hollow, 85mm fore and aft, by 60mm in the plank face just below the hole, suggesting that a vertical timber had once filled the hole. This cleat is noticeably more slender than cleats 820 and 822 in the ile plank west (301), and axe marks 16–20mm long indicate that the cleat has been trimmed on its lower side to make room for the repair lath (793). It would seem, therefore, that the cleat had been larger before the repair was made.

Lower edge of plank
The lower plank edge varies from being rounded to appearing to have a diagonal face, its thickness varying from 33mm to 43mm close to the edge.

Lower stitch holes
The stitch holes pass vertically through the plank close to its lower edge, and contain the stitches that attach plank 304 to the bottom plank 303 (Tables 5.22; 5.23; *see* Fig 5.30). The openings on the inboard face of plank 304 are mostly D-shaped in plan, the straight edge lying fore and aft, close to the lower edge of the plank.

Richard Darrah has pointed out that there are two groups of spacing, stitches 450–463, which are 355–375mm apart, and stitches 463–485, which are almost all above 385mm apart – possibly suggesting that two men worked on making the stitch holes.

Upper edge of plank
The upper edge varies from 49mm to 62mm in thickness, and the top is slightly rounded, with a bevel on the inboard face. The outboard top corner has a rabbet recessed between 8mm and 23mm into the thickness of the plank, and has a vertical depth of 20–5mm.

Table 5.22 Dimensions of lower stitch holes on plank 303 (in mm) breadth = fore-and-aft measurement on the plank face; length = across the boat

stitch hole	*breadth*	*length*
450	65	25
451	62	19
453	62	19
455	58	25
457	59	34
459	49	30
461	60	33
463	60	35
465	58	32
467	–	–
469	49	30
471	57	30
473	56	34
475	58	35
477	70	32
479	50	25
481	damaged	–
483	50	30
485	58	35
average	57	29

Table 5.23 Spacing between lower stitch holes on plank 303 (centre to centre; in mm)

stitch holes	*distance*
450–451	375
451–453	370
453–455	[370]
455–457	355
457–459	363
459–461	[370]
461–463	365
463–465	400
465–467	[?420]
467–469	367
469–471	[400]
471–473	392
473–475	385
475–477	[380]
477–479	405
481–483	394
483–485	400
average	383

Upper stitch holes
These generally have D-shaped openings on the inboard face of the plank, and the holes pass through the plank and contain stitches that attached the plank to the lower side of the missing plank 305 (Tables 5.24; 5.25; *see* Fig 5.37). The interior of hole 658 is 20mm high, and it is cut slightly oblique to the plank faces. The interior of stitch hole 658 is 18mm wide.

Missing planks

Upper side plank west (302)
This longitudinal timber is missing and is presumed to have been a plank, though it could have been a rail along the upper edge of the side of the boat. There are a few clues to its length and minimum width. The plank lay above the ile plank 301, and presumably slotted into the rebate at the top of the ile. It was attached to the ile by stitches; stitch holes and stitches survive all along the upper edge of the ile (Fig 5.40). The remains of stitches were found in stitch holes in ile plank 301 (672, 674, 676, 680, 684, 686, 692), and reflect the spacing of stitch holes in the missing plank 302. The length of the stitches indicates the former position of the stitch hole in the missing plank 302, one stitch (727) having survived in hole 674, being 142mm long on the inboard face of the ile plank. As hole 674 is 45mm below the top of the ile plank, the opening for the stitch in the missing plank 302 must have been about 100mm above the top of the ile plank. By adding 20mm for the thickness of the stitch as it passed through the missing plank, and a further 10mm of timber thickness above that, we can conclude that the top of plank 302 must have been at the very least 100mm above the top of ile plank 301.

Figure 5.40
Here the severed stitches along the upper side of the ile plank can be seen, evidence for the existence of an upper side plank. The stitches had been deliberately cut through at the time of the boat's abandonment.

Upper side plank east (305)
This is the missing plank above ile plank 304. It was originally attached to the top of ile plank 304 by stitches.

End board south (306)
Although this southern end board is missing, its former shape and thickness at its lower end is reflected by the shaping of the surviving timbers and in the moss caulking. The lower end of the plank slotted under laths against the bottom planks 300 and

Table 5.24 Dimensions of upper stitch holes on plank 303 (in mm) length = across the boat; breadth = fore-and-aft measurement on the plank face

stitch hole	*breadth*	*length*
636	–	32
638	60	32
640	55	23
642	damaged	–
644	48	23
646	52	24
648	49	12
650	49	18
652	50	16
654	50	25
656	–	–
658	55	28
average	52	23

Table 5.25 Spacing between upper stitch holes on plank 303 (centre to centre; in mm)

stitch holes	*distance*
636–638	360
638–640	352
640–642	?355
642–644	?
644–646	350
646–648	[360]
648–650	348
650–652	342
652–654	?
average	352

303, and was about 0.40m wide. It widened out southwards for a distance of 1.30m, at which point it became 1.15m wide, but how much wider it became above that is unknown as it depends upon the original shape of the missing upper part of the boat.

The thickness of the lower edges of board 306, impressed in the caulking of the yoke-shaped scarf, was 20–30mm. At this point, it was held in position by wooden wedges, but presumably it thickened at a higher point where it was stitched to the end of the ile planks 301 and 304.

The sharp edge of the shelf in the bottom planks 300 and 303 suggest that the lower end of the end board (306) was stepped to protect it from wear on running aground. The wedges passing through the yoke rails of planks 300 and 303 indicate strongly that the lower end of the end board also had rails into which the wedges slotted. Perhaps the edges of the board higher up had seam rails to hold the stitches, and the ends of the ile and upper side planks slotted into rabbets at the edges of the end board.

Jointing and waterproofing

Plank edge fastenings

The planks of the boat are fastened together entirely by edge fastenings of two types, *wedges* and *stitches*. The wedges fastened the two bottom planks together side by side through raised inboard rails of timber along the vessel's centre line, and the stitches fastened side planks together and attached them to the outer edges of the bottom planks. A reason for the difference is no doubt that the wedges could not be worn by the boat running aground. The lowest stitches were carefully protected from wear, whereas the upper stitches were not protected, as there was little chance of wear.

Waterproofing

Making the boat watertight was particularly difficult because (by the standards of today) the methods employed were rather primitive. To one who is used to seeing the caulking material of more recent boats (Roman or later) jammed into the seams between planks, it is curious to see that the Bronze Age boatbuilder lay the wadding mostly on the inboard face of the seam, in some cases overlying a waterproof stopping. Instead of letting the pressure of two adjacent planks help make the seam watertight, particularly when the wood is swollen by the water, the Bronze Age boatbuilder relied on thin laths laid inboard under the stitches to hold the wadding in place. The laths themselves were held in position both by the wedges and by the stitches. The seams were not the only potential leaking points, for the stitch holes passing through the outboard plank face also would allow in water. This was overcome by placing a stopping material into each stitch hole after the stitch had been completed.

The wadding material over the plank seams is moss, sometimes overlying a stopping, held by laths of wood that are, in turn, held by stitches. Moss (or bryophyte) samples were taken from many locations for analysis. Five taxa were identified (Fairbairn 1993; Hather and Wales 1993):

- *Plagiothecium cf denticulatum*. Often medium-sized, erect and robust plants found in damp places adjacent to streams, marshes, etc, with a worldwide distribution.
- *Isopterygium cf elegans*. Small to medium-sized, slender and erect calcicole plant of damp habitats with a north-west to central European distribution.
- *Thamnobryium sp*. Robust, erect and densely branched plant of moist woodland and stream edges with a worldwide distribution.
- *Hypnum sp*. Only a few fragments of this very varied and widely distributed genus were identified. Plants may be creeping or erect, slender or robust.
- *Eurhnchium sp*. A very varied genus of largely creeping plants, slender or robust. Only a few fragments from one sample were identified.

The main species of bryophytes used as packing material on the boat fall into two types: a wiry and robust moss and a lighter and slender moss. As such, the robust taxa are *Plagiothecium cf. denticulatum* and *Thamnobryium sp.*, and the slender taxon *Isopterygium cf elegans*. It seems possible – as the taxa were found in different samples – that the different growth habits of the different taxa were used for different purposes, as the slender moss was found to be below the more robust moss in some locations. There seems, however, to be no relationship between location within the boat as a whole and taxon used; nor does there seem to be any relationship between bryophyte taxon and type of constructional feature being packed.

All the Bryophytes present are taxa that favour damp conditions such as rocks and

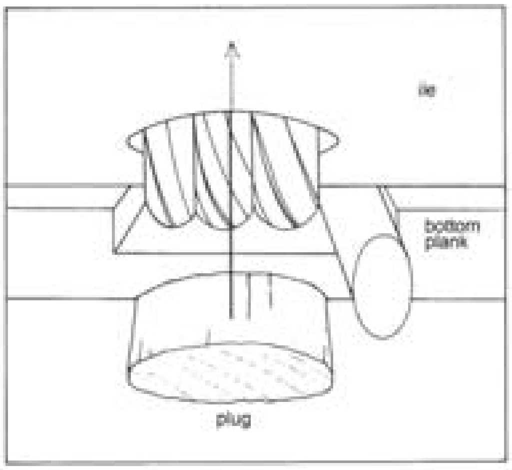


Figure 5.41
The stitch holes were made watertight with a stopping of wax, resin and animal fat; this was sometimes accompanied by a small wooden plug, pushed into the hole from the outboard side of the boat.

boulders adjacent to flowing water. Past distributions of Bryophyte taxa are difficult to determine, especially so for taxa that, at present, have limited distribution. The taxa identified here, however, are currently of wide distribution, including, in all cases, North West Europe. On the present data, therefore, it cannot be said with any certainty that the mosses were collected at any specific location within north-west Europe. It is as likely that the taxa were collected from a location near Dover as from a location near Calais (Hather and Wales 1993, 9–10).

A stopping appears to have been used in each of the stitch holes between the bottom planks and the ile planks 300–301, and perhaps at the junction with planks 303–304. This was sometimes accompanied outboard by a small wooden plug pushed into the outboard end of the stitch at the lower edge of the two ile planks (Fig 5.41). The stopping is hard and a light colour, and inboard has a flat surface slightly below that of the plank. At stitch 558, the stopping was found to extend along the seam between the adjacent planks.

Thin wooden laths held the wadding material in place against the inboard face of the planks. These laths vary from 0.95m to possibly 3.45m in length.

Central seam

The following features fastened the bottom planks 300 and 303 together and made the joint watertight (Figs 5.42; 5.43):

Figure 5.42 (opposite)
Key showing the position and numbering of the wedges and transverse timbers described in the text.

Wedges

Oak wedges – each roughly rectangular in section – were driven through holes in the rails that run along the edge of each plank next to the central seam.

436 Under rail 360, this is 72mm wide and 16mm thick. Just east of the rail, it is 67mm wide and 26mm thick. It is 475mm long and has squared ends, the west end being 72mm wide and the east end 65mm wide. It was probably driven from west to east.

437 This is recorded as being 640mm long when found, with a squared west end 95mm wide and a narrow east end 54mm wide. In its incomplete state (445mm long) near its east end, it is 58mm wide and 15mm thick. It was cut from timber with vertical rays. It was driven from west to east.

438 This is incomplete and, although recorded at 400mm long, was originally probably about 450mm long. It is 70mm wide and 23mm thick at its east end and 35mm wide at its rounded west end. Under rail 362, it is 68mm wide and 14mm thick. It had been cut from timber with horizontal rays. It was driven from east to west.

439 This is 500mm long, 65mm wide at its east end and 40mm wide at its west end. Just east of rail 362, it is 57mm wide and 20mm thick, and over the central seam it is 60mm wide and 13mm thick. It was cut from timber with horizontal rays. It has a rounded west end, and had been driven from east to west.

440 This was 580mm long, 63mm wide at its east end and 68mm wide at its west end. Both ends appear to be broken. At rail 362, it is 62mm wide and 10mm thick, and is cut from timber with horizontal rays. The driven direction is not clear.

441 This is 425mm long, 75mm wide at its west end and 60mm wide at its east, suggesting that it had been driven from west to east.

442 This is 520mm long with a squared east end 60mm wide and a reconstructed west end 40mm wide. Under rail 362, it is 60mm wide and 17mm thick. It was probably driven from east to west.

443 This is 420mm long, with a pointed west end. At the central rail 362, it is 46mm wide and 18mm thick. It was driven from east to west.

444 This is 420mm long with a squared west end 55mm wide. Over plank 303, it is 56mm wide, and over the central seam it is 15mm thick. The driven direction is not known.

445 This is 440mm long, with a squared west end 65mm wide, and possibly a broken east end, also 65mm wide. Over the central seam it is 65mm wide. Where it is protected from compression in slot 402 it is 6mm thick, but outside it is 2–5mm thick. The driven direction is not known.

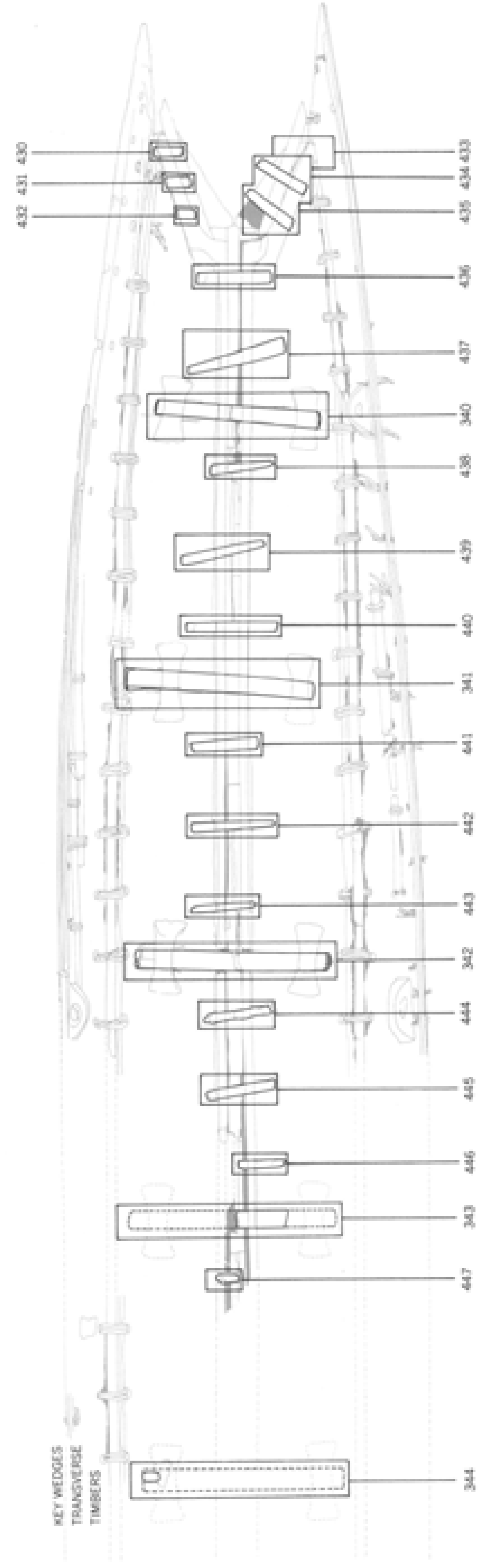
446 This is 290mm long, but only its western half survives, the eastern half from the central seam having been lost by the modern cut. The west end is 50mm wide, and it is 55mm wide and 16mm thick over the central seam. It thins towards its west end. The driven direction is uncertain, but the widths and thickness hint at its having been driven from east to west.

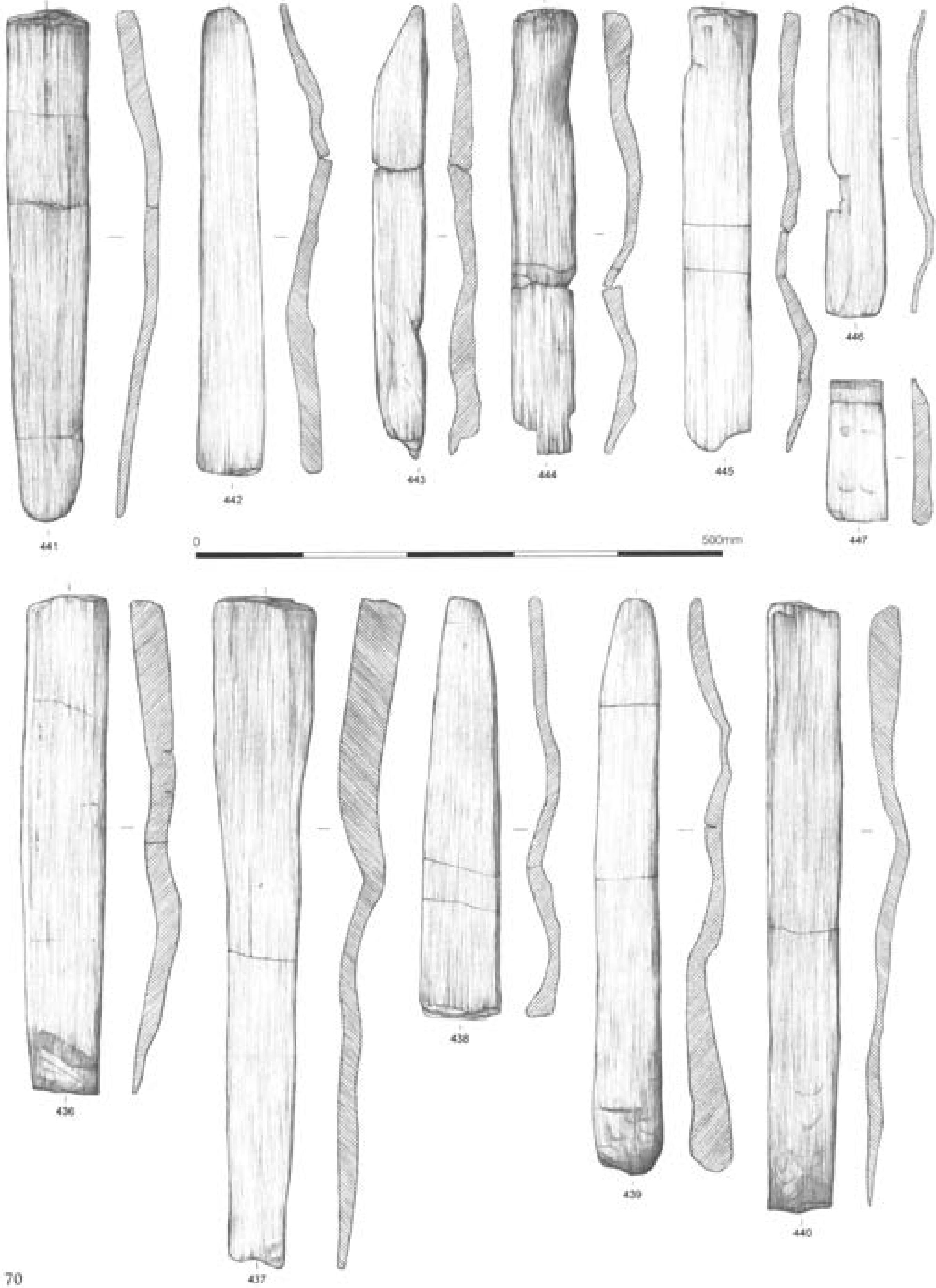
447 This wedge is incomplete, having survived only over the central seam area, where it is 140mm long. Its east end is 57mm wide and the west end 49mm wide, suggesting that it might have been driven from east to west.

Wadding 843 at the central seam

There is a clear layering of moss over the central seam inboard, reflecting the laying of patches of wadding. However, the method of wadding the seam was quite complex. The interpretation partly depends upon defining the original width of the seam between the bottom planks 300 and 303. At wedge 445, for example, had the bottom planks been laid against each other, with no gap between, the distance between the rails would have been 80mm. At this point, the lath over the moss caulking is 79mm wide. At wedge 442, the distance between the rails would have been 75mm, and the lath was 70mm wide. At wedge 440, the gap between the rails would have been 80mm wide, with the lath 76mm wide. This means that, generally, the gap over the central seam and between the rails was only slightly greater than the width of the lath. It appears, however, that the seam had opened up slightly during the use of the boat, as, when excavated, the seam was found to be 25mm open at wedge 441, but otherwise was obscured by the wadding and laths. Nevertheless, the fact that the laths had been compressed downwards in the centre shows that the seam was open before the boat was buried. Also, when excavated, the rails were apart, exposing some of the moss wadding.

It was difficult to examine the wadding of the seam without taking it apart, although it was possible to examine the seam where the boat was cut into pieces to remove it




441
442
443
444
445
446
447
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500mm
436
437
438
439
440

from the site. At wedge 447 in plank 303, the wadding seems to have followed this sequence: first, a layer of moss was laid on the top of the adjacent planks; second, lath 742 may have been laid over the moss; third, as the lath is narrower than the distance between the rails a separate line of moss 20mm wide was laid between the edges of rail 360 and lath 742 (how this was held in place is unclear); and fourth, wedge 447 was driven across between the rails and over the lath to hold the planks together.

There is inconsistency in this overall pattern, which might suggest repairs and patching to keep the boat watertight. These descriptions, therefore, are of individual features where they could be examined.

In some places there is another material, here called a stopping. It appears at wedge 441 where, on plank 330, in the corner between the rail and the moss covering the central seam, there is a triangle of fibrous material. Perhaps the seam had opened up during the use of the boat and the stopping was pushed into place to help waterproof the seam. It was possible to examine the wadding sequence around wedge 440, which proved to be particularly enlightening, as it showed which feature overlaid the others. It seems that, first, moss was laid over the bottom planks and the central seam between the rails of planks 300 and 303 (the moss lay under the wedge, stopping and lath); second, the wedge appears to have been driven into place through the two rails (the wedge lies over the moss and lath); third, a stopping was placed along the edge of the rail of plank 303, but only up to the edge of wedge 440, as if the wedge were already in position (the stopping lies over the moss, but stops either side of the wedge); fourth, lath 741 was positioned (the lath under the wedge, and over the stopping and moss). Although the wedges overlaid the moss wadding, it is not necessarily axiomatic that the wedges were driven into position after the moss had been laid, as a narrow gap existed between the bottom of the wedge and the top of the planks to allow for the wadding and lath. However, wedge 438 did show that the moss was already in position before it was driven into wedge hole 410, for there is moss in the wedge hole above and below the wedge as if it had been carried through when the wedge was driven into position. This also confirms that wedge 438 was driven from east to west. Traces of moss in other wedge holes, but not so clearly seen, also suggest that the moss was in position before the wedges were driven in. What this sequence does not take into account is the possibility that this, or any other sequence found, was a repair. Consequently, it may be that this sequence is not representative of the original waterproofing process in the entire boat. Beneath wedge 437 moss was found both under and over the lath below, suggesting that sometimes the construction was tightened with the addition of moss.

Figure 5.43 (opposite) Plans and cross sections of the wedges driven through the two central rails along the centre line of the boat.

Laths between the central planks 300 and 303

At least three laths were found along the centre of the boat: the south lath (740), the central lath (741) and the northern lath (742; *see* Figs 5.44; 5.46).

As the laths were obscured by the wedges and silt during the excavation, and were damaged in recovering the boat, it is difficult to be sure exactly how many there were. It is possible that there were more, but the overlapping joints between them were not clear. Therefore, although this section is written on the assumption that there were only three laths, it is important to bear this caution in mind. Note that, in Figs 5.44 and 5.46, five possible laths have been identified, numbered 740, 741a, 741b, 742a and 742b.

Judging from the blunt north end of lath 740, and the fact that the central lath 741 underlay both laths 740 and 742, it seems that lath 742 was positioned first, and then laths 740 and 742 were positioned subsequently, the latter (742) having been driven beneath the wedges and transverse timber 340 from north to south.

The southern lath 740

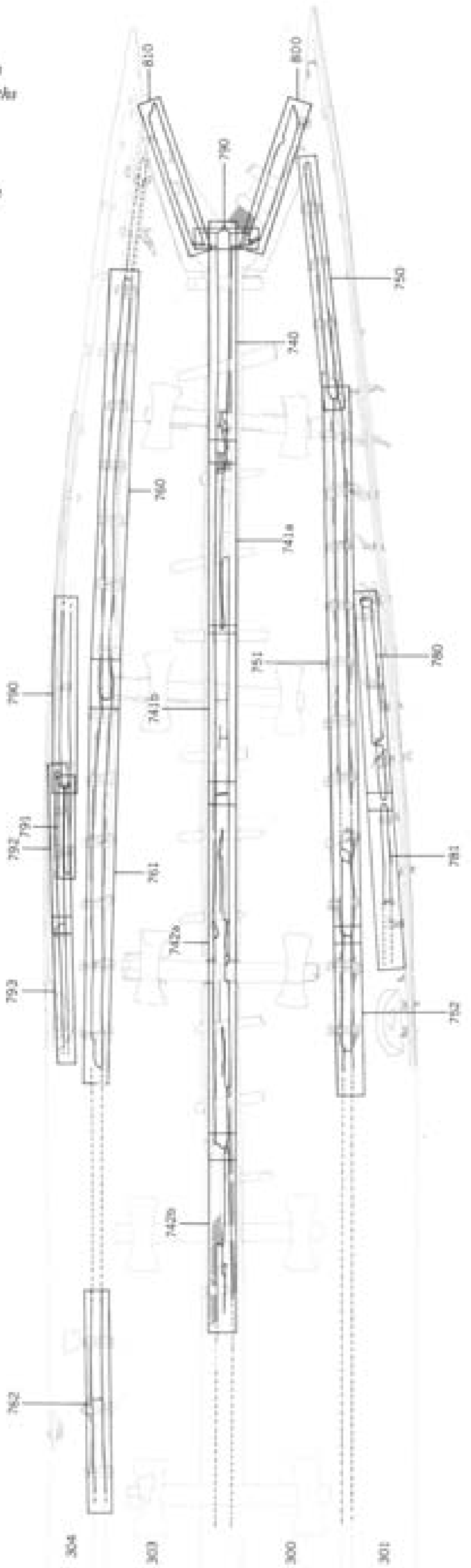
This lath is 1.39m long, and has a blunt north end, indicating that it was driven under the wedges from north to south. It is of oak and commences at the south end of the central seam at the yoke-shaped scarf, and ends between transverse timber 340 and wedge 438, where it overlaps the south end of lath 741 by 120mm. Between wedges 436 and 437, the lath is 70mm wide and has a slightly rounded upper surface. It is thin near the edges but thickens to 8mm in the centre, its shape evidently being due to unequal pressure over the bottom planks and the gap between them at the central seam.

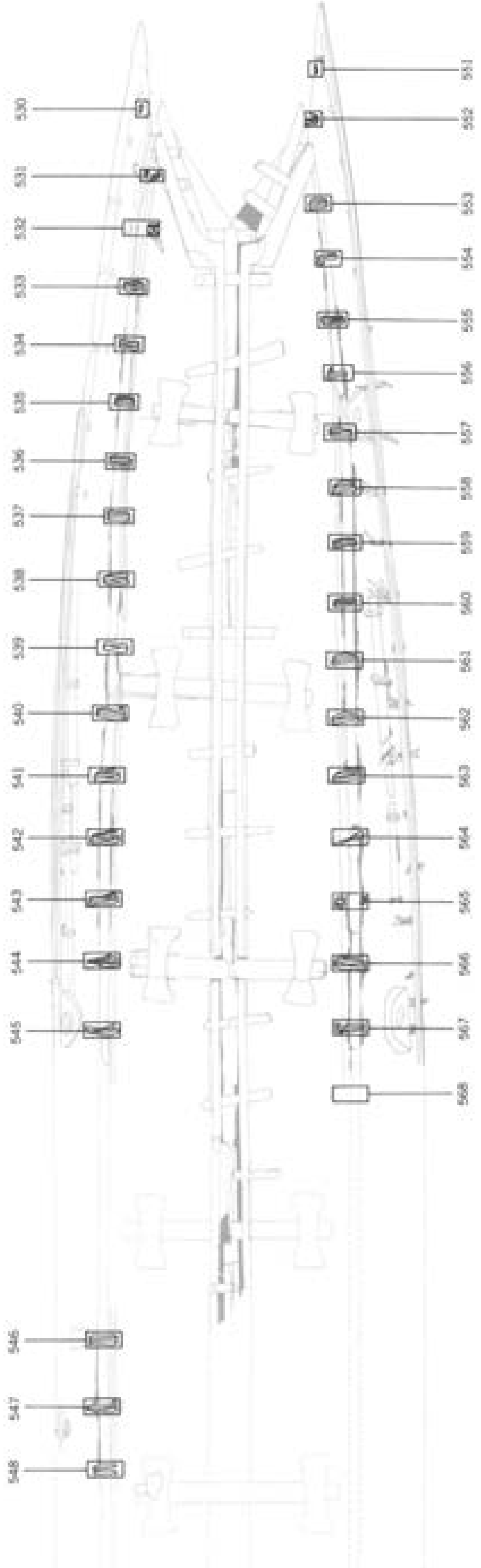
The central lath 741

This damaged oak lath appears to have been 2.43m long extending from between wedge 438 and transverse timber 340 at its

Figure 5.44 (right)
Key showing the position and numbering of the laths described in the text.

Figure 5.45 (far right)
Key showing the position and numbering of the lower stitches described in the text.





south end, to between wedges 441 and 442 at its north end. Its south end runs beneath the northern 120mm of lath 740, and its north end runs 180mm under lath 742 and terminates in a transverse feather edge. The form of its south end is not known. At wedge 440, the lath is 76mm wide and up to 19mm thick along its centre. The sides thin down to sharp edges, and the top is slightly dished. Its shape is evidently caused by variations in compression over the bottom planks and the gap between them. Elsewhere nearby the lath is up to 72mm wide and 17mm thick in its centre line. The width matches that of the distance between the rails of planks 300 and 303, indicating that, when first built, the central planks were intended to lie exactly side-by-side. Near its north end, between wedge 443 and transverse timber 342, the lath is about 70mm wide, although the distance between the rails would be 65mm if they had originally been laid immediately next to each other. This shows that when the boat was first built the seam below must have been at least 5mm wide at this point.

The northern lath 742

Although damaged and of indeterminate timber, this lath extended beyond the north end of the excavation and is at least 3.28m long. Its south end commences between wedges 441 and 442, and overlies 180mm of the north end of lath 741. At wedge 445, the lath is 78mm wide and 4–5mm thick, with its centre line slightly depressed where it overlies the gap between the bottom planks. The distance between the rails, had the bottom planks been placed against each other, is 80mm, indicating that the lath was intended to fill the gap. The fact that the centre line of the lath was depressed over the central plank seam shows that when the boat was abandoned the central seam had opened up. There may have been variations in the thickness of the lath originally, as just north of transverse timber 342 it is 10mm thick in its centre – although this could have been due to variations in pressure.

Western ile seam

Stitches between bottom plank 300 and ile plank 301

Each stitch commenced outboard immediately below the lower edge of the ile plank, and was led through plank 300 to surface inboard near to the rail (Fig 5.45). The stitches were then looped over the rail to pass through holes by the lower edge of the ile plank 301, and then down outboard and back into the hole in plank 300 again (Figs 5.47; 5.48). Each was looped round about three or four times, and the point was often tucked down into the stitch hole in the ile plank (*see* Fig 5.49). It is intended that the record of each stitch should be as it was found *in situ*, rather than as it was when

Figure 5.47
An example of one of the yew stitches (inboard view).

Figure 5.48
An example of one of the yew stitches (outboard view).

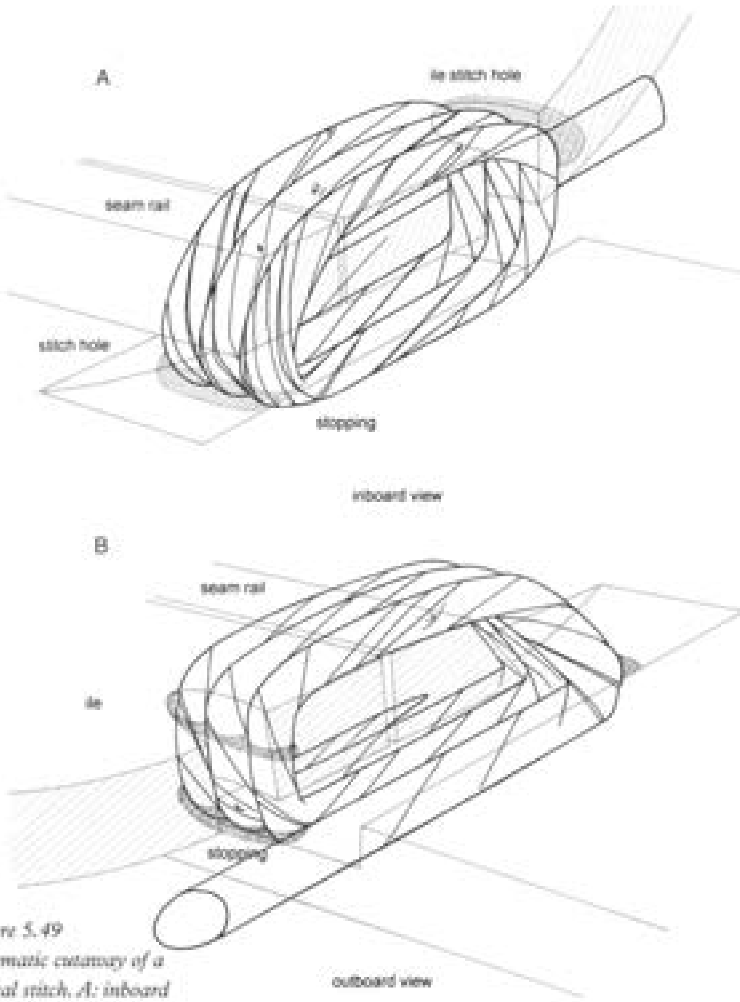


Figure 5.49
Schematic cutaway of a typical stitch. A: inboard view. B: outboard view.

recorded after the boat was removed from the site. It was difficult to remove the pieces of the boat without damaging some stitches. The stitches were all recorded on their inboard face, as this is what could be seen. Of the seventeen stitches, ten had three loops (Fig 5.50), most with the thick end of the withy to the north. One (558) had an untwisted section lying over the lath inboard, and its narrow end was tucked down into the hole in ile plank 301. Three other stitches had four loops (553, 555, 559; Fig 5.51), with one example (554) having five loops. These also had the thick end of the withy lying to the north. The remaining three stitches could not be recorded accurately.

Wadding 844 between planks 300 and 301

Where the lower edge of the ile plank 301 fitted into the rebate at the outer edge of the bottom plank 300 it was necessary to place wadding over the seam. In some places, as at stitches 563 and 564, it appears that the two planks fitted together tightly and the seam was covered inboard only by layers of moss held down by a lath. Elsewhere the seam was not a close fit and extra waterproofing in the form of stopping was necessary. The extent of such extra waterproofing is not known because the seam is still covered by its lath. One place where the extra waterproofing was investigated is around stitches 558 and 559.

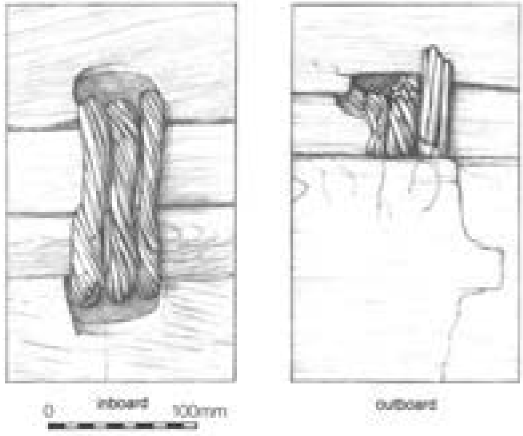


Figure 5.50
An example of a three-loop stitch (537).

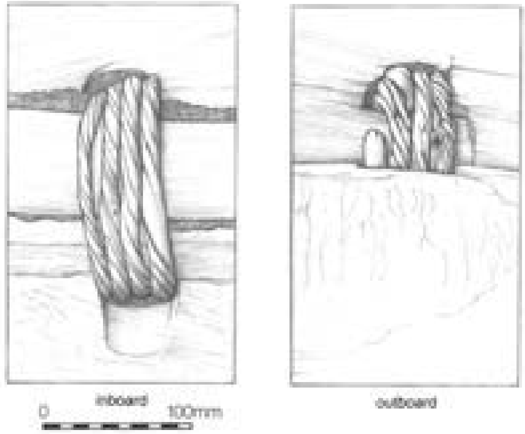


Figure 5.51
An example of a four-loop stitch (559).

The lower edge of plank 301 was not squared to fit the rebate at the outer edge of plank 300, but instead was rounded on its inboard corner. Stitches 558 and 559 must have been in place holding the planks together, and the planks must have been in their final position, presumably as part of the completed boat, for the extra stopping to function as a caulking. The rounded top corner of the edge of plank 301, next to and along the rail of plank 300, was found to be filled with a stopping of a hard substance. A sample was removed measuring about 17mm on each of its flat sides that were not in contact with plank 301. In effect, this acted like a modern wood filler, closing up the junction between the two planks (*see* Fig 5.13). Chemical analysis of the stopping proved inconclusive, though it did appear to contain neither wax nor resin, in contrast to the material used in the stitch holes (Evans 1999).

This stopping between stitches was found to be in two layers tapering upwards along the seam, and to have a maximum thickness of 20mm. The angle of the interface between the two layers of stopping shows that this section was being caulked from north to south, as was the primary stitching in the boat as a whole. The stopping extended into stitch hole 503 and around its stitch 558. This shows that the stitch was in place before the stopping was introduced. Above the stopping is a layer of moss wadding lying flat on top of the inboard surface of the ile plank 301 and along the top of the side rail 371. The moss is about 80mm wide and up to 10mm thick, tapering towards the edges. This must have been placed in position after the stitches had been completed to hold the planks together, and, as the stopping was traced at least as far as stitch 558, the moss must have been placed in position after the stitches at least that far. Whether or not the moss was put in position in the entire boat before the stitches were made is not known, and can only be tested by taking the boat apart. Above the moss is a lath of wood generally 61–8mm wide, which was passed under the stitches and held the moss in place.

Laths between planks 300 and ile 301

Three laths were found, the southern lath (750), the central lath (751) and the northern lath (752; *see* Figs 5.44; 5.46). Although the north ends of laths 750 and 751 overlap the south ends of the laths to the north, the sequence of their positioning is not known, as their thin ends could have been driven below the lath to the south (*see* Fig 5.52). What is clear, however, is that each lath was driven from north to south.

The southern lath 750

This lath, of indeterminate timber, was found to be 1.75m long, its north end being between stitches 556 and 557 and its south end, possibly broken, being at stitch 552. It is 65mm wide at stitch 556 and 48mm wide at stitch 555. It was in a broken condition and little detail about it is recorded. Its north end overlies the extreme south end of lath 751.

The central lath 751

This oak lath is 3.45m long, with its north end overlying the south end of lath 752 and its south end below lath 750. It is 61–8mm wide, and, although its extreme sides were very thin (1–2mm thick), presumably due to compression, its centre line was considerably thicker (7–12mm) over the seam between planks 300 and 301. At stitch 558, it was noted that its tree rings were almost

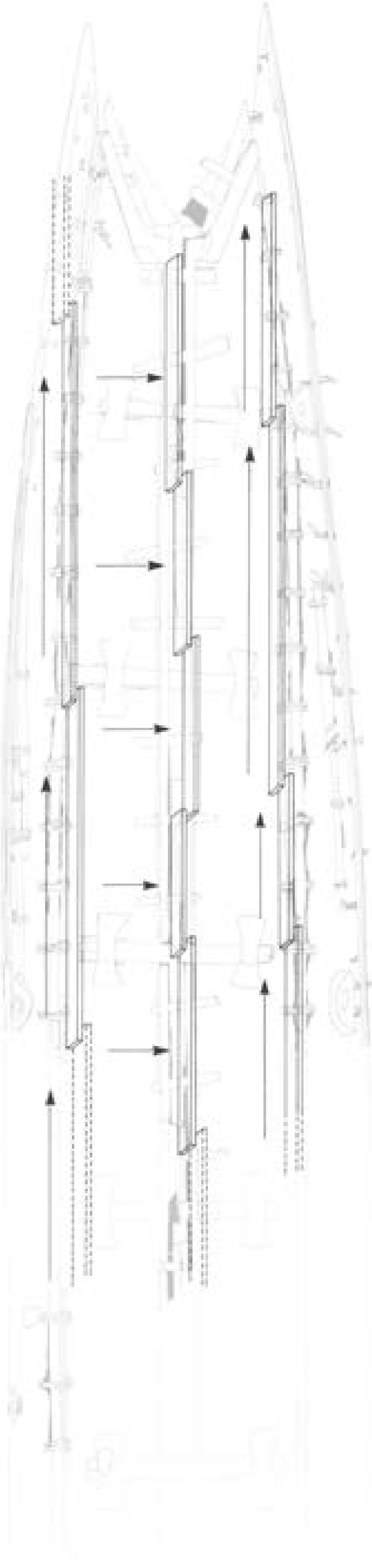


Figure 5.52
Schematic diagram showing the physical relationship of the laths. The overlapping ends may suggest a sequence of insertion, though underlying laths may have been driven into position under the end of a lath already in position.

vertical, showing that it did not follow the outer shape of a tree but instead had been cut tangentially from the tree. Its north end is 67mm broad, and its south end narrows to 30mm wide.

The northern lath 752
This lath of hazel was traced for a distance of 0.95m, but its north end lay beyond the excavation. Its south end lies below lath 751. The lath is 56–8mm wide.

Eastern ile seam

Stitches between bottom plank 303 and ile plank 304
These stitches are also all recorded on their inboard face, but they had been threaded from the outboard face (*see* Fig 5.45). They are identical to those between planks 300 and 301. Of the 19 stitches, 12 had three loops; five had the tips of the withy visible inboard (533, 534, 535, 543 and 544). Two stitches had four loops (531 and 540), the latter with the withy tip visible inboard. All had the thick end of the withy to the north. Four stitches could not be recorded accurately.

Wadding 845 between bottom plank 303 and ile plank 304
The moss wadding at the junction of planks 303 and 304 is spread over the inboard face of the lower edge of plank 304 and over the top of side rail 370 of plank 303. It varies in thickness, but in general is about 5mm thick. It is mostly not in the seam, but was used to fill the gap left by the rounded shape of the edge of plank 304. At stitch 533 there is an indication of layering within the moss, for it has two colours, suggesting that the moss between the planks was inserted in a separate operation from the placing of the moss packing beneath the lath. It seems from all this that the wadding and the overlying laths must have been placed in position after the stitches had fastened the planks together.

Laths between bottom plank 303 and ile plank 304
Two laths were found (760, 761) in the main southern part of the boat, with part of what is presumed to be a third (762) on the north side of a modern damage hole in the boat (*see* Figs 5.44; 5.46).

The southern lath 760
This oak lath was traced for a distance of 2.65m south of its north end beside

stitch 540. Its south end appears to be broken beyond stitch 533, the seam between planks 303 and 304 having opened up and the stitches broken south of that point. It is irregular in width, varying from 54mm to 67mm. At one point, by stitch 539, it has trimming facets on its surface.

The central lath 761

This lath, of unidentified timber, was traced for a distance of 2.52m, its south end lying below the north end of lath 760, and its north end presumably having been destroyed by a modern excavation. The overlap of this with lath 760 is 220mm. It varies in width from 60mm to 70mm, and is thickest along its centre where it overlies the seam, the thickness ranging from 6mm to 12mm. The top tends to be curved and the underside flat, except along the centre line, where it thickens over the seam below in contrast to the sides of the lath, which have been compressed against the plank surfaces.

The northern lath 762

This oak lath lies north of a gap of 1.5m, caused by a modern excavation, north of the surviving end of lath 761. Since lath 761 is already 2.50m long it is most unlikely that lath 762 is part of it, otherwise it would mean that lath 761/762 would be more than 5.20m long – nearly 2m longer than any other lath found in the boat. A length of only 1.15m was found. It is 67–9mm wide and up to 12mm thick in the centre, but had suffered from compression.

End board fastenings

Wedges in the yoke scarf between bottom planks 300/303 and end board 306

The wedges are all rectangular in section, and project out from the rails towards the centre line of the boat and over the former position of the end board (*see* Figs 5.42; 5.53; 5.54):

430 This is 65mm wide and 25mm thick. Its west end had been cut, the axe blade having left clear impressions of two curved cuts, one 33mm long cut by the second 45mm long. Both of the cuts had been cut with downward strokes.

431 This is 65mm wide and 31mm thick, and its west end has axe cuts, one being curved and 45mm long.

432 This is 46mm wide and 19mm thick. The wedges in the west yoke rail (363) are also rectangular and, with the exception of wedge 435, projected from the east face of the rail only, where they were measured.

433 Wedge missing in antiquity.

434 This is 66mm wide and 22mm thick at the east face of the rail, and at the west face of the rail it is 65mm wide and 35mm thick. It fits very tightly, indicating that it was driven from west to east.

435 East of the rail this is 60mm wide by 26mm thick, but in the west face of the rail it is 65mm wide and 35mm thick, showing that it was driven from west to east. The west end of this wedge projected slightly from the west side of the rail.

Figure 5.53
Plans and cross sections of the wedges driven through the yoke rails at the southern end of the boat, intended to help hold the missing end board in position. Note the tool marks at the ends of wedges 431 and 430, suggesting they had been deliberately cut through with an axe.

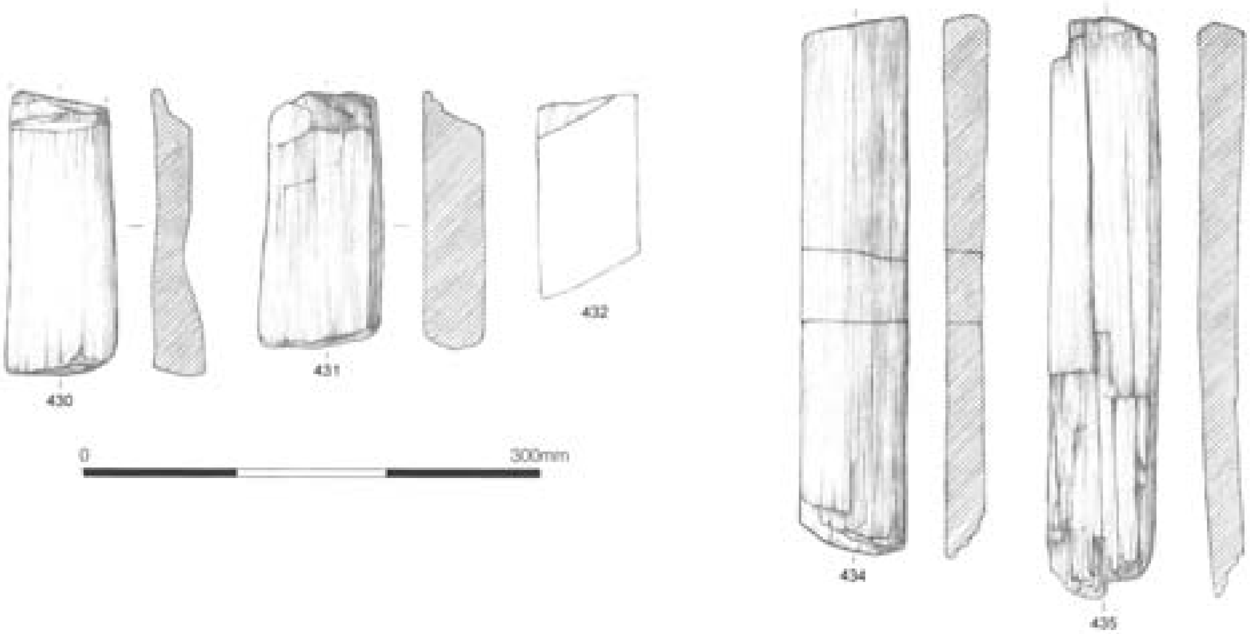
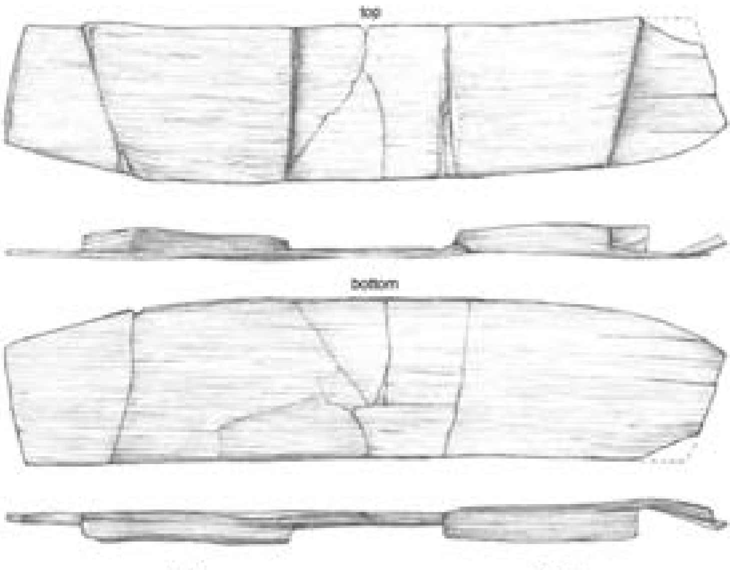


Figure 5.54
Southern end showing wedges and laths. Note that the western wedges have not been cut through, unlike those on the eastern side.

Figure 5.55 (below)
Lath 790, which fitted between the end rails of the bottom planks and the postulated rails of the missing end board. This small timber encapsulates the complexity and craftsmanship of the Dover boat. Cut to fit perfectly in the narrow gap between three large and complex timbers, it also had shallow recesses cut into its upper surface to accommodate the side and central laths. This was the only lath found on the boat that was not held in place by stitches or wedges.

Caulking 840 between planks 300/303 and 306

An extensive bed of moss caulking was placed over the flat shelf formed at the south end of planks 300 and 303 before the end board 306 was placed into position, helping to make a watertight junction. Although the end board 306 is missing, its impression remains at its former edges under the laths 790, 800 and 810. Judging from its impression in the wadding under the surrounding laths, especially on its east side, it appears that the edge of the end board was about 25–30mm thick. Under lath 810 on its east side is a thin layer of moss showing that, originally, moss lay above and below the edge of the plank. In addition, on the east side, at the junction with the base of the rail 361, is a corner filled with a brown substance, possibly vegetable matter. This seems to fill an ill-fitting joint between the edge of the end board 306 and the bottom plank 303.



Laths

Lath 790 between planks 300/303 and end board 306

This oak lath is 85mm wide and about 0.37m long (*see* Figs 5.46; 5.55). It is rectangular in cross section and generally 15mm thick. In the centre, however, is a recess 11mm deep, cut into its top face to accommodate the north end of lath 740 covering the central seam, and at each of its two ends is a further recess, about 10mm deep, cut in the top to take the ends of laths 800 and 810. This lath is particularly important, for it may have helped to hold in place the bottom end of the missing end board 306.

Lath 800 between planks 300 and 306

This lath, of unidentified timber, is about 0.78m long and is 75–80mm wide (*see* Fig

5.46). It is rectangular in cross section and 5mm thick. Its north end was shaped to fit against plank 300, and its south end cut at an angle.

Lath 810 between planks 303 and 306
This lath, of unidentified timber, is about 0.95m long and 63–76mm wide (*see* Fig 5.46). It is rectangular in cross section and 8mm thick. The north end was shaped to fit against plank 303, and its south end cut at an angle.

Between western side planks 301–302

Stitches between ile plank 301 and the missing upper side plank 302
These stitches are broken and very incomplete, mostly having survived within the stitch holes at the top of the ile plank (Fig 5.56). Where possible, the thick end was recorded to reconstruct the direction of the stitching process. No traces of laths or wadding were found. Of the fourteen surviving stitches, ten had three loops, three had four loops (728, 730, 736) and one (737) had only two loops surviving; all had the thick end of the withy to the north.

Between eastern side planks 304–305

Stitches between ile plank 304 and the missing upper side plank 305
Few traces of the stitches remained on this side, though there is enough to show that the stitching was originally like that between planks 301 and 302 (Fig 5.56). Only three possible stitches survived; one (706) was incomplete, one had three or four loops (710) and one had four loops, (708).

Bracing

The Dover boat depended upon a system of embryonic frames with which to brace the hull and so keep its shape. These comprise transverse timbers in the bottom, while at the sides were slender side timbers whose function seems to have been connected with bracing the boat in some form, but the actual mechanism is unclear. These 'frames' were all threaded through cleats on the inboard faces of the planks.

Bottom transverse timbers

Five transverse timbers were found joining the two bottom planks 300 and 303 (*see* Figs 5.42; 5.57).

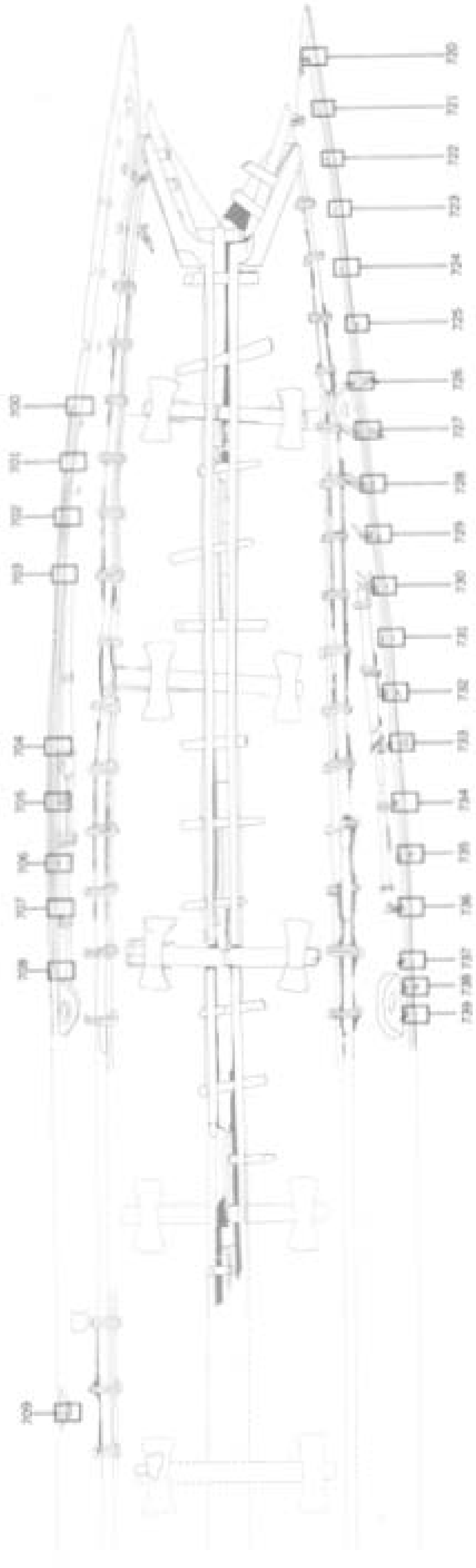


Figure 5.56
Key showing the position and numbering of the upper stitches described in the text.

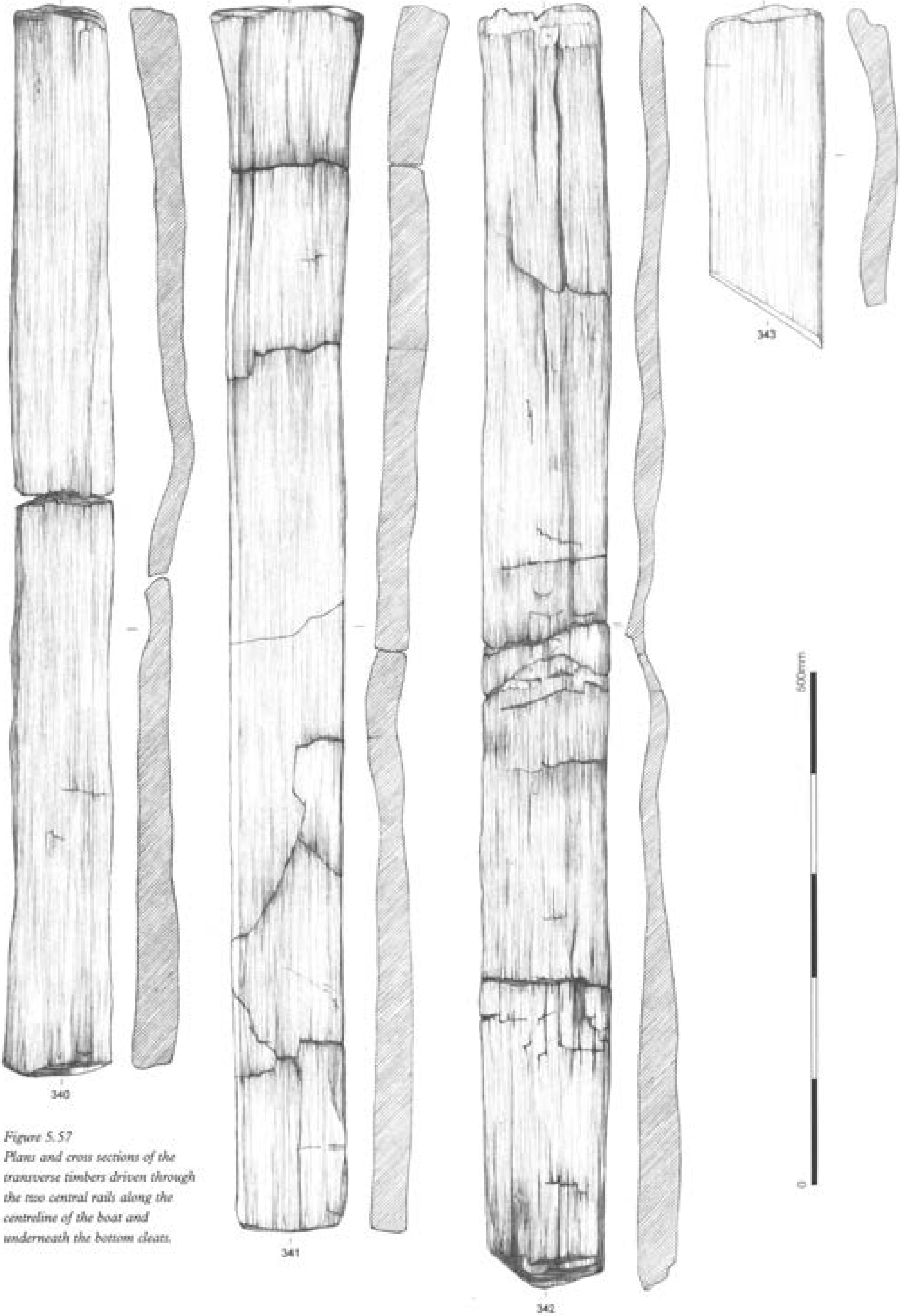


Figure 5.57
Plans and cross sections of the transverse timbers driven through the two central rails along the centreline of the boat and underneath the bottom cleats.

340 This oak timber, rectangular in cross section and with squared ends, is [1.08]m long, and passes through cleats 310 and 311. Its width varies from 85mm in the centre to 90mm at cleats 310 and 311. However, it is 35mm thick at cleat 310, 30mm thick in the centre and 26mm thick at cleat 311, showing that it is slightly thinner at its west end.

341 This oak timber is [1.22]m long, and passes through cleats 312 and 313. Under cleat 312 it is 110mm wide and 38mm thick, and west of cleat 313 it is [105]mm wide, showing that it has nearly parallel sides. It was badly damaged by the cofferdam and detailed accurate measurements are not possible. It is rectangular in section, with squared ends.

342 This oak timber is [1.25]m long, and passes through cleats 314 and 315. It is rectangular in section with squared ends, and is 127mm wide and 26mm thick at cleat 314 and 108mm wide and 31mm thick at cleat 315. However, just west of cleat 315, it is 125mm wide. In the centre of the boat, it is 135mm wide.

343 A length of only [0.32]m survived of this oak timber, in the centre of the boat where it is rectangular in cross section, 106mm wide and 35mm thick. Originally, it passed through the now missing cleats 316 and 317.

344 This oak timber was not found, though the side of the hollow cut into the top of plank 303 to accommodate it was found at the incomplete cleat 318.

Side timbers

The side timbers were vertical elements, now missing, that appear to have passed through the side cleats on the inboard face of the ile planks, where they left wear marks. It is presumed that the missing upper planks of each side of the boat also had cleats that carried the side timbers upwards. The only clue to the size and shape of the side timbers is the size of the hole in each side cleat.

830 The position of this side timber on the east side of the boat is conjectured as it is presumed that a side cleat existed on ile plank 304 opposite the discovered cleat on ile plank 301.

831 On the west side of the boat is side cleat 820, through which there is a lens-shaped hole measuring 90mm fore and aft, by 38mm. There is no obvious wear on the inside of the cleat hole, but immediately below the cleat is a worn hollow 40mm long fore and aft, and 17mm high in the face of the ile plank 301. This missing side timber, therefore, must have been a modest element unlike the bottom transverse timbers.

832 Cleat 823 on the east side of the boat has a lens-shaped hole 90mm fore and aft, by 57mm to accommodate an upright side timber. There is no wear from the timber on the inside of the cleat, though there is a small worn hollow in the face of plank 304 immediately below the cleat, suggesting that the vertical timber was about 50–60mm wide.

833 Side cleat 822 on the west side of the boat lies opposite cleat 823, and has a lens-shaped hole 82mm long fore and aft, by 27mm. The plank face inside the hole is damaged as if by a vertical side timber that had been repeatedly rammed down from above. The damage suggests that the vertical timber measured about 60mm by not more than 25mm in cross section.

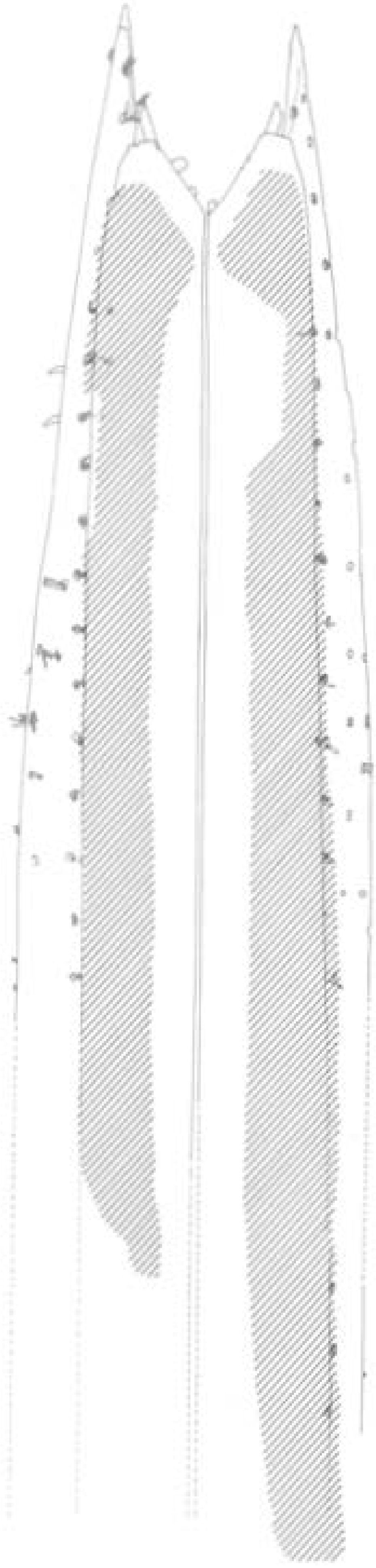
Wear, damage and repair

The Dover boat has extensive evidence of wear, damage and repair during its use, particularly on its outboard face (*see* Figs 5.9; 5.58). As the inboard face was exposed during the excavation, it was slightly damaged, in spite of the greatest care having been taken by the excavators. Consequently, it is difficult to know which marks are ancient and which are modern, although all have been recorded. The outboard face, in contrast, was protected during excavation and was cleaned only under controlled post-excavation conditions. Damage and wear marks there are therefore significant.

Wear and damage outboard

As the outboard face of the two bottom planks was originally under water, the wear marks and damage must relate to grounding. The lower part of the ile planks also may have suffered from grounding, but damage and wear to their upper parts must have been owing to other causes during the Bronze Age.

Figure 5.58
Schematic plan showing the areas of wear on the outboard surface of the boat, suggesting that it had been regularly beached or grounded. The lack of wear along the centreline suggests the boat hull was slightly concave from side to side.



Bottom plank west (300)
The main evidence of wear on this plank exists on the half of its face furthest from the centre line of the boat (*see* Fig 5.24). Here the plank surface is smooth, but with localised depressions caused by the plank having been pressed down on stones on the layer upon which the boat lay. The fore-and-aft tooling from the shaping of the plank remained only on the half of the bottom nearer the centre line. At one point, a crack follows the grain and a long fragment of plank was found to be split off and missing. There are no obvious signs of impact.

Bottom plank east (303)
The tooled outboard face of this plank also exists only near the centre line of the boat, but is similarly worn away in the half of the plank farther from the centre line (*see* Fig 5.24). At the outer edge of the plank, where it joins the ile plank, the wood outboard is extremely thin (between 3mm and 8mm) where it covers stitches at holes 536–538. Roughly below cleat 312 there is an area of major ancient damage. It is an irregular dent about 240mm by 90mm that appears to have been caused by an impact.

Ile plank west (301)
The upper half of this plank has a horizontal zone of score marks that appear to have been made during the use of the boat (Fig 5.59). They were found while cleaning the boat after the vessel had been removed from the site, and so cannot have been caused during the excavation. As they lie where the plank face is more vertical, it is curious that they generally lie at an angle of roughly 45 degrees to the waterline, though a few are at right angles. As no study of the wear marks on the outboard face of a recent boat has been carried out, it is very difficult to suggest how these ancient marks were caused. A possible theoretical explanation for their oblique angle is that they were caused by the boat's rocking fore and aft against a waterfront, whether natural or man-made. At one point near the south end of the plank, the lower part of the outboard face is damaged by deep pitting. This is in marked contrast to the face of the adjacent bottom plank 300 and raises the question whether or not the bottom plank was a replacement, or perhaps suggests that the ile plank 301 was an old plank. The wear seems to relate to grounding, as it ceases on plank 301 in a line about 11cm from the

stitch holes linking the ile to the bottom plank. This plank has been split and repaired with stitches. A possible point of impact that caused this fracture exists between repair stitches 603 and 605. A damaged area about 140mm by 40mm, on a north-south orientation, suggests grounding on a ledge or rock.

Ile plank east (304)

The pattern of scoring on the outboard face of the east ile is somewhat different from that on the west ile (Fig 5.59). Instead of there being a zone of marks, there are far fewer scores in the zone just below the top of the plank. The few marks are mostly diagonal. Instead, most of the marks exist in the lower half of this plank at the south end where the plank was almost horizontal, and they are presumably a result of the vessel having run aground. The pattern is interesting as the marks do not run fore and aft, as would be expected, but instead sideways. Perhaps this reflects a sideways and fore-and-aft motion to the boat while aground. The scores vary in length, some being only about 40mm long, but others are longer. In particular, two run intermittently for a vertical distance of 180mm, and other score marks are up to 260mm long. In the area of stitch hole 572 there is a locally depressed area that suggests impact. This lies on the underside of the ile plank at its extreme south end and, together with the score marks, suggests that the boat grounded at this end. What is puzzling, however, is that there are no comparable score marks in a similar position on the bottom of the ile on the other side of the boat. Just above repair stitch 620, there is a major oblique depression about 400mm long, running downward towards the south end of the boat. This suggests an impact, and may have caused the fracture that was repaired.

Discussion

About 100 score marks have been recorded on the outboard faces of the ile planks; the marks, together with the repairs, all show that the boat was well used. Assuming that the marks were caused as a result of the vessel lying beside a rocky waterfront, the greater number of score marks on the upper part of the west ile suggests that the west side of the boat more commonly lay against the waterfront than did the east. The score marks on the bottom of the south end suggest that the boat was beached at that end, although the absence of marks at the

Figure 5.59
The outboard faces of ile planks showing score marks. Perhaps these had been created by the boat's rocking fore-and-aft against a natural or man-made waterfront.

bottom of the western ile plank is difficult to explain. Damage from impact is to be expected in any boat, and the Dover boat is no exception. Possible impact points have been noted on the bottom plank 303, and on both ile planks. In addition, a piece of timber has been split from the bottom plank 300. One of the most interesting features is the wear on the outer parts of the bottom planks, leaving the tooled surface to survive in the half nearest the centre line. This can only mean that the force of buoyancy had slightly arched the two bottom planks upwards along the centre line, so that only the outer edges of both planks ran aground.

Damage and repair inboard

Repair to the bottom

It has been noted that extra stopping appears to have been added to the central seam between the bottom planks. This was presumably in response to the central seam opening a little and admitting water, perhaps caused by the centre of the boat's bottom being forced upwards by the buoyancy force, which resulted in an uneven wear pattern on the outboard face of the two bottom planks. As the function of the transverse timbers was to keep the bottom of the boat flat by passing through holes in the central rails and the cleats, the need for a tight fit in the holes was essential to minimise leaking. Two attempts to tighten the transverse timbers have been identified, the first being the addition of some moss caulking in some wedge holes in the rails. The other is a flint flake that was under transverse timber 342 between cleat 314 and the hole in rail 360 on the eastern bottom plank 303. The flake, about 41mm × 50mm, and 18mm thick, was no doubt deliberately pushed into that position, as it lay under the transverse timber in the centre of the bottom plank and in a transverse timber slot. Its effect, small as it might have been, was to help jam the transverse timber against the top of the hole in the cleat and therefore slightly depress the timber across the central seam and so help close that seam. Its insertion could be made only when the boat was out of the water when there was no buoyancy force jamming the bottom plank against the transverse timber.

Splits and repairs to the sides

Western ile plank 301

There are two repairs to this ile plank (Fig 5.60).

Extra stitch

An extra stitch (696) has been added to the row of stitches along the top of the ile

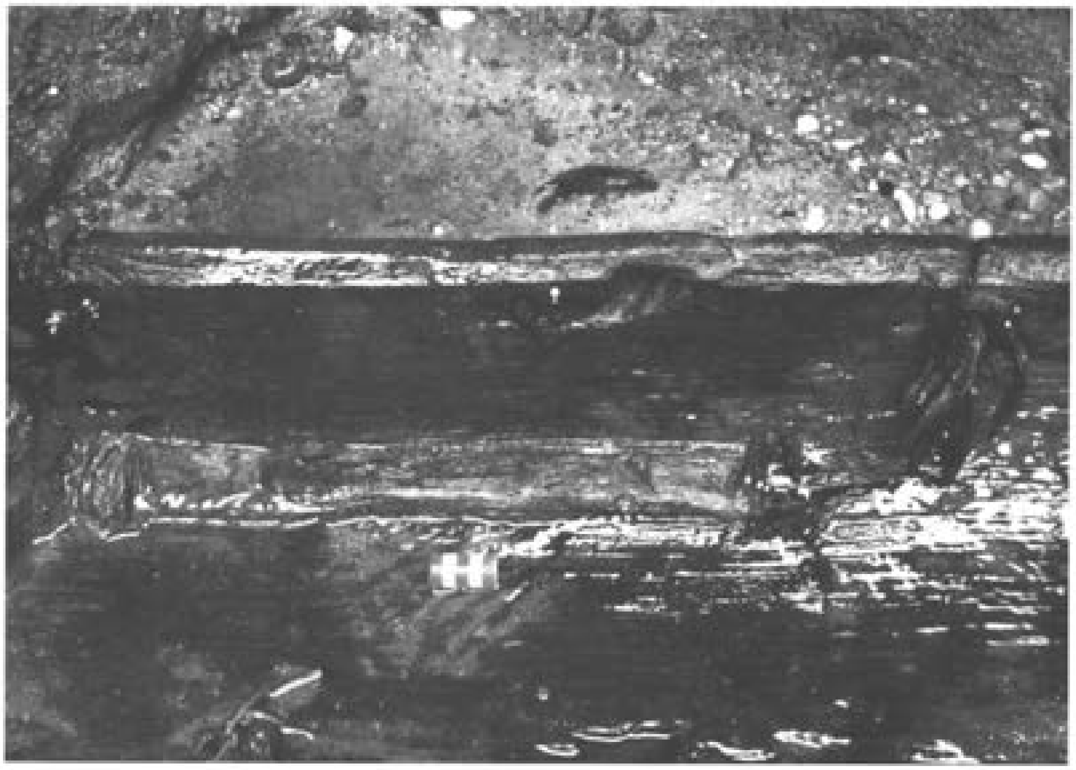


Figure 5.60
Repairs to the western side of the boat (Piece H).

plank, to fasten it to the plank above (302). This extra stitch lies between stitches 694 and 698. It is assumed to be additional as all other stitches along this seam are spaced at an average of 336mm between centres, but stitch 696 is only 180mm and 157mm from its neighbours. It may be relevant that it is situated immediately above cleat 822.

The repaired split

The ile plank had split in antiquity and been repaired. The split follows the rays passing through the plank at a right angle to the plank faces, and, judging from the length of the repair, was about two metres long. The split in this plank may have been caused by the impact described above. The sequence of making the repair was to cut stitch holes through the plank on either side of the split. The inboard face of the split was covered with a wadding of moss, and the stitches were fastened from outboard. The thick ends of most stitches (stitches 630–634) lie at the south end of the stitch holes, showing that the boat-builder worked those stitches from south to north. The outboard part of each stitch was not protected but instead simply lay against the face of the plank (Fig 5.61). Finally, the lath, about 2m long, was apparently driven into position from south to north. The stitch holes are generally D-shaped.

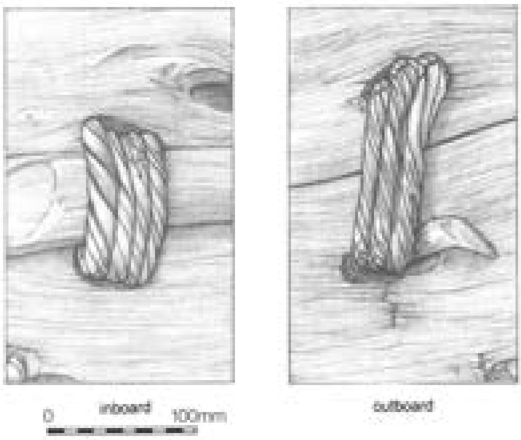


Figure 5.61
An example of a repair stitch (630).

Eastern ile plank 304

There are two stitched repairs to splits in this plank, each with their respective laths (792/793 and 790/791; Fig 5.62). Where the two laths lie side-by-side, there are two stitches that pass over both (619 and 621), but there is also a third stitch (620), which overlies only the upper lath. This indicates that the upper repair is the earlier.

Upper repaired split

A split in this plank follows the rays at a right angle to the plank faces. It was found extending for a distance of about 1.8m, but its north end lay in the recently destroyed area north of cleat 823. The split had passed immediately below cleat 823 and, in

Figure 5.62
Repairs to the eastern side of the boat; a total of four oak laths of differing sizes had been stitched over cracks in the ile plank, compressing pads of moss to make the repairs watertight.

order to accommodate the repair, it was found necessary to trim off the lower part of the cleat. The result is that side cleat 823 is noticeably slender in section, its base being 50–5mm wide. Axe cuts 16–20mm long show where the cleat has been trimmed on its lower side to make room for the repair lath. Fragments of the wadding used for the repair adhere to the lower angle of the cleat. Two stitches (620, 622) and their pairs of stitch holes (590–591, 594–595) belong to the repair of this split. The distance of the stitches apart, 780mm between centres, with a further one, now destroyed, north of the cleat, suggests that this was not considered to be a major damage. Moss originally covered the split inboard before the lath was placed in position. Only stitch 620 could be examined and its thick end lay to the north, showing that the boatbuilder on that stitch at least had worked from north to south. The lath may have been placed in position after the stitches were made, though its sloping south end indicates that it could not have been driven from south to north, unless it was trimmed off after being positioned. The presence of stitches 620 and 622 and the laths 792/793 and 790/791 made it impossible to record the size and shape of stitch holes 590–591 and 594–595. Stitch 620 was made of Yew (*Taxus baccata*) and had three loops, with the thick end to the north. Stitch 622 was not preserved.

The lath (792/793), whose wood is unidentified, although somewhat distorted and flattened, has clear traces of rays which, at stitch 622, cross it diagonally, showing that its shape has been man-made rather than formed from the side of a branch. It seems that it was originally D-shaped in section, with a flat face against the moss and a semi-circular top side. It was 46–63mm wide and originally about 20mm high in its middle. The south end of the lath is flat and appears bruised from having been driven from south to north under the stitches. The lath was traced for a distance of 1.55m from its south end to a point under cleat 823 where it had been broken off, probably recently. The split that it covered extended north of the cleat, and there must originally have been a stitch to hold the north end of the lath beyond the cleat in the area recently destroyed. The south end of the lath is sloping, and may have been trimmed to accommodate the later lath 790/791.

Lower repaired split

A second split, only a few centimetres below the first, also follows the rays at a right angle to the faces of the ile plank. This was a major damage, extending from just south of cleat 823 to the south end of the plank, for a length of about 5.2m, and was repaired by stitches, laths and moss caulking. Stitches and the lath survived only in the northern part of the repair. Oval-shaped stitch holes were cut through the plank on either side of the split, and the stitches were inserted. The split was covered by moss wadding and then by a lath or laths. There is no evidence to show if the surviving lath (790/791) had been driven beneath the stitches or had been in position before the stitches were made. Lath 790/791 apparently survived for a distance of 1.62m at its north end, but stitch holes in the ile plank south of this show that it originally extended beyond this. The word 'apparently' is used here because what appears to be the extreme 540mm of the north end of the lath under stitch 621 is narrower than the lath to the south. Those who initially recorded it, however (it subsequently collapsed before it could be studied in detail), seem to believe that it was part of the same lath rather than parts of two laths, even though it was drawn as if it were two laths and photographs suggest that there were two laths. Stitch 621 is loose, as if the north end of lath 790/791 was much wider and filled the stitch and overlapped lath 792/793. The narrow north end of lath 790/791 lies next to lath 792/793 already in position, and is held by stitch 621, which passes over laths 780 and 781. It is only where lath 780 ends that lath 781 widens and thickens to become a normal width of about 75mm and is there held by stitch 619. Only two stitches preserve the direction of stitching, stitch 621 having been worked from south to north, and stitch 619 having been stitched from north to south. They therefore show none of the regularity of the original stitching of the boat. The stitch holes either side of the split are oval-ended in shape to accommodate the stitches. Throughout much of the length of the split, the stitches repairing it were destroyed in antiquity, as were some of the upper stitch holes. Nevertheless, sufficient remains to enable the construction to be reconstructed.

If the measurements directly made between the stitch holes only are taken into account, and the measurements taken from the plan of the boat are omitted because of the difficulty in recording them, the average spacing between the stitch holes is 365mm. However, the distances between the stitches show considerable variation, which suggests that the repair was not such a skilled job as was the original construction. Lath 790/791 is recorded only in photographs and in the initial drawing because it collapsed before it could be recorded in detail. It was about 75mm wide immediately south of stitch 619. It appears to have been of oak (*Quercus sp.*).

Dismantlement and decay of the boat

The boat had suffered damage – most notably the splits in its ile planks, which had been repaired – and it is clear from the wear marks and repairs that the vessel was fairly old and leaking when abandoned. It is certain that the boat was dismantled, though it is difficult to know just how many of the missing stitches and portions of the vessel were lost as a result of subsequent erosion and decay. One thing seems clear, however. The survival of the ragged ends of the fragile stitches indicates that the boat was quickly buried and, therefore, that the effects of erosion and decay were minimal. In general, it is possible to quantify some missing constructional elements, as well as to quantify the damaged features. But how much of all of this belongs to one phase of dismantlement is uncertain for the only certain evidence of deliberate dismantlement is the removal of the southern end board using an axe. With these cautions, then, the evidence for the dismantlement of the boat appear to be as follows:

- Removal of the southern end board: At the south end of the boat are axe cuts through wedges 430–432 on the east side of the boat, which show how the end board 306 was released from its scarf and removed. Two axe cuts exist on the west end of wedge 430. Both are from above and curved, though incomplete, one being 33mm long and the other 45mm long. The curved incomplete cut, 45mm long on the end of wedge 431, is from above the south side as if the man wielding the axe was standing north of the wedge. In contrast, wedges 434 and 435 on the west side of the scarf remained long and have no traces of axe cuts. Wedge 433 is missing and was presumably removed when the end board was dismantled.
- Removal of the western upper side plank: Along the west side of the boat are stitches along the top edge of the ile (301) that have been broken open and remain ragged, suggesting that they were deliberately broken, perhaps by axe, to release the upper side plank west (302). The fragile state and great length of the stitches indicates that this part of the boat was quite quickly buried to ensure their preservation.
- Removal of the eastern upper side plank: There are some stitches along the top of the east ile plank (304) that, although not so well preserved, are broken to release the upper side plank (305).
- Removal of side timbers 831–833: Side timbers 831–833 are missing, although they left their worn impressions in the ile planks below the side cleats. To be removed they needed to be lifted out of the cleats.

Other damage to the boat

Other evidence of ancient damage exists, although none of it seems to relate to a planned dismantlement of the vessel. It is possible that some damage is owing to the natural decay of the boat. The central rails (360, 362) of the bottom planks at transverse timber 342 were found to be badly damaged, as if someone had tried to break up this part of the boat. Almost all of the bottom stitches joining the lower edges of the ile planks to the bottom planks are intact, except stitches 564 and 565 on the west side of the boat, and stitches 531 and 532 on the east side of the vessel at the south end. In the latter place, the east ile plank (304) had begun to spring away from bottom plank 303. The upper half of the east ile plank (304) at the south end, above the repaired split, had broken away before the boat was buried and is missing.

Interpretation

Sequence of constructing the boat

The choice and fashioning of the timbers is considered elsewhere (Chapter 9), but it is necessary to draw attention to the tool marks that are recorded here. The tool marks found in the boat are all related to the final trimming of the planks, so none represents the initial fashioning of the timber. The plank faces, both inboard and outboard, have roughly parallel channels of tooling to leave a fair finish; the cleats having been rough-cut from the log appear to have been smoothed on their upper faces, though deep axe cuts still exist on their fishtails. Axe cuts exist both inside the cleats and in the wedge holes in the rails showing working from both sides. Axe cuts exist in the sides of the recesses in the bottom planks to carry the transverse timbers. The stitch holes have been very carefully prepared, particularly to protect the stitches outboard, but no clear tool marks exist to show how they were made. It is important to note that the stitch holes are about the width of an axe blade so presumably this tool was used to fashion them. The axe cuts show that the boat-builders had to have access to all sides of each plank, so it is clear that the planks themselves could not be fashioned in their final positions relative to each other. Moreover, access was needed to the edges, indicating that the planks were raised above the ground. As stitch and wedge holes had to correspond reasonably well when the vessel was assembled it is clear that some method of rough measurement and marking off was used. (The word 'rough' is used deliberately because there are many signs that features did not match up as is shown below.)

The probable stages in the construction of the boat – after the planks and fastenings had been fashioned, for which there is evidence – are as follows (Fig 5.63):

1 The bottom planks were brought together and the transverse timbers were inserted into the cleats of the bottom planks.
2 The bottom planks were fastened together with the bottom wedges, their angles diagonal to both the central rails and the transverse timbers, presumably so as to 'lock' the bottom planks together.
3 The south end board was fastened with wedges.
4 The lower side of the ile planks was sewn to the bottom planks and to the end board.
5 The upper side planks were sewn to the top of the ile planks and to the end board.
6 The side timbers were slotted through the side cleats.

What this does not include is (a) any thwarts or cross-timbers at gunwale level to help support the shape of the sides, and (b) how the unexcavated north end was completed. These points are discussed below, with each stage being considered in detail.

Stage 1: inserting the transverse timbers

The insertion of the transverse timbers into the holes in the central rails of the bottom planks and through the nearby cleat holes might have been from the centre of the boat. This is because most of the transverse timbers were roughly parallel sided, and because the presence of the side rails may have made access difficult. The transverse timbers are all of fairly small dimensions, so their purpose in establishing a flat bottom to the boat might have been limited. Transverse timber 340 is about 90mm wide and 26–35mm thick, and is slightly thinner at its west end than at its east end, which might suggest that it could have been driven through the bottom cleats from east to west. Transverse timber 341, however, has parallel sides and is about 105mm wide and 38mm thick, but its east end is wider suggesting it was driven through cleat 312 from east to west. Transverse timber 342, although of varying width, does not have a thinner or narrower end. The conclusion is, therefore, that the shape of these timbers supports the view that some were probably pushed into the cleats from the centre line as the two bottom planks were brought together. The spacing between the transverse timbers is about 1.70m, roughly the height of a man today.

Stage 2: inserting the central wadding and wedges

Before the bottom planks were brought together, the wedge holes had to be cut through the centre rails. As these holes were cut by tools from both sides they could not have been fashioned after the planks were laid next to each other. This possibly explains why the wedge holes in the two rails are mostly not in line, resulting in the wedges being at various angles to the rails. Alternatively, the angles may have been deliberate to form a kind of locking mechanism to hold the two bottom planks together. The wadding and wedge fastening of the bottom planks need not have occurred at this stage, but probably did, as this would help to make the bottom rigid. The sequence of attaching the fastenings and applying the wadding is not completely clear, but there is evidence that two schemes may have been followed. Either, the moss was laid over the seam, and the lath above that, and then the wedges were

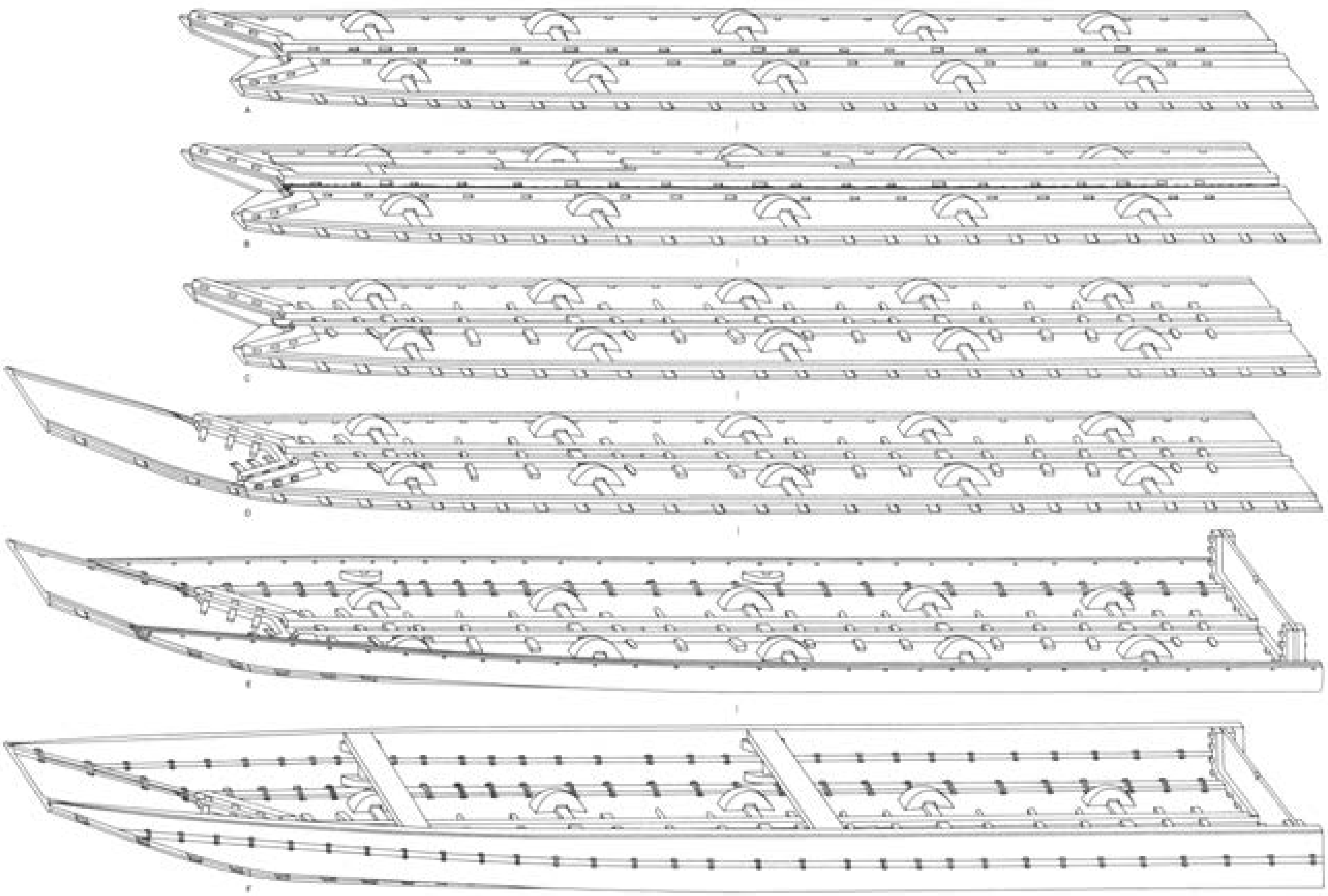


Figure 5.63
A conjectural sequence of constructing the Dover boat. A: bottom planks brought together. B: moss wadding and central laths inserted along centreline. C: transverse timbers and wedges hammered through cleats and centre rails. D: insertion of end board and associated moss wadding, laths and wedges. E: attachment of the ile planks and end transom board with associated stitches, stopping, laths and wedges. F: attachment of the upper side planks, stitches, wadding and laths, together with the side timbers and thwarts. The end board, transom and upper side planks are, of course, hypothetical.

driven into position, or, after the moss was laid, the wedges may have been driven into position, then a stopping added and, finally, the laths were driven under the wedges. The first of these two alternatives may relate to the original construction of the boat, and the second to a repair. That a repair was needed is evident, as it is clear that when first built the two bottom planks were intended to lie tight against each other to create a watertight joint. This is shown by the distance between the two rails, when the planks lay against each other, being exactly the width of the central lath. The stopping, however, seems to be a subsequent attempt to make the central seam watertight after the two bottom planks had pulled apart a little during the use of the boat. The purpose of the wedges was evidently to help lock the bottom planks together, as they are too short to brace the vessel. There is a pattern to how they were driven into position, which suggests that the boatbuilder was trying to lock the planks from both sides. There are three wedges between each of the transverse timbers, and they are spaced 480–520mm apart from centre to centre (about the length of the lower arm). In addition, the wedges are spaced 340–400mm on either side of the transverse timber's centres (about the length of the lower arm to a fist).

The pattern of driving the wedges in pairs from opposite sides of the boat is clear from the shape of the wedges, and, on this basis, it can be concluded that wedges 440, 444 and 445 were all driven from west to east. There is also a pattern to suggest how the laths were laid along the central seam. Assuming that where one lath overlies another the one above was positioned later, it seems that lath 741 was placed in position first, and that laths 740 and 742 were placed subsequently.

Stage 3: the southern end board

The lower end of the plank (306), at the south end of the boat, had to be fixed into position at an early stage with its caulking, and is held by six wedges (430–435; Fig 5.64). It was presumably in position before the central lath 740 was laid over it. The end board was laid on the shelf formed by planks 300 and 303, and was initially covered by lath 790, a carefully shaped timber recessed in the top to take laths 740, 800 and 810, which were subsequently laid over it to hold it in position. Wedges 430–435 were driven into position over the side laths 800 and 810, thereby creating a strong scarfed construction, made watertight by the bed of moss caulking.

Stage 4: sewing the ile planks in position

Up to this point, the bottom and end boards of the boat had been fixed to each other by wedges, but these could be pulled apart for they had not been fully locked together. The locking mechanism was mainly provided by the ile planks that were sewn to the outer edges of the bottom planks as well as to the sides of the end board at the south end of the boat. It was essential that the locking mechanism should also extend around the north end of the boat, and that is considered below. The preparation of the stitch holes in the outer edges of both bottom planks and in the lower edges of the two ile planks must have been a time-consuming task. More than twenty-two stitch holes were made along the edge of each plank, giving a total of eighty-eight that were either found – or can be conjectured with certainty – at these two lower seams. More existed northwards, depending on how long the boat was. The stitch holes between the bottom plank 300 and the ile plank 301 averaged at 365mm apart from centre to centre, and those between bottom plank 303 and ile plank 304 averaged at 378mm apart from centre to centre. These distances are similar to those between the transverse timbers and the wedges in the bottom planks, and are about the length of the lower arm to a fist. The thin end of the stitches must have been threaded into the stitch holes, leaving the thick, usually untwisted, end of the wood protruding from the outboard face of the stitch. A careful record of each stitch between the bottom planks and the ile planks shows that, of the thirty-six stitches represented, twenty-seven had the thick end of the stitch at the north end of the stitch hole. In the remaining eight stitches, it was not possible to ascertain the direction of the stitch. This means that, at each stitch, the boatbuilder definitely started at the north end of each hole, and possibly suggests that the boatbuilder was stitching the entire boat from north to south.

Although modern experiments have been carried out to try to discover how the stitches were made, the boat itself provides a few clues. It is clear that the boatbuilder had some difficulty in lining up stitch holes in the edges of adjacent planks, for, in the most extreme cases – at stitch hole 515 in plank

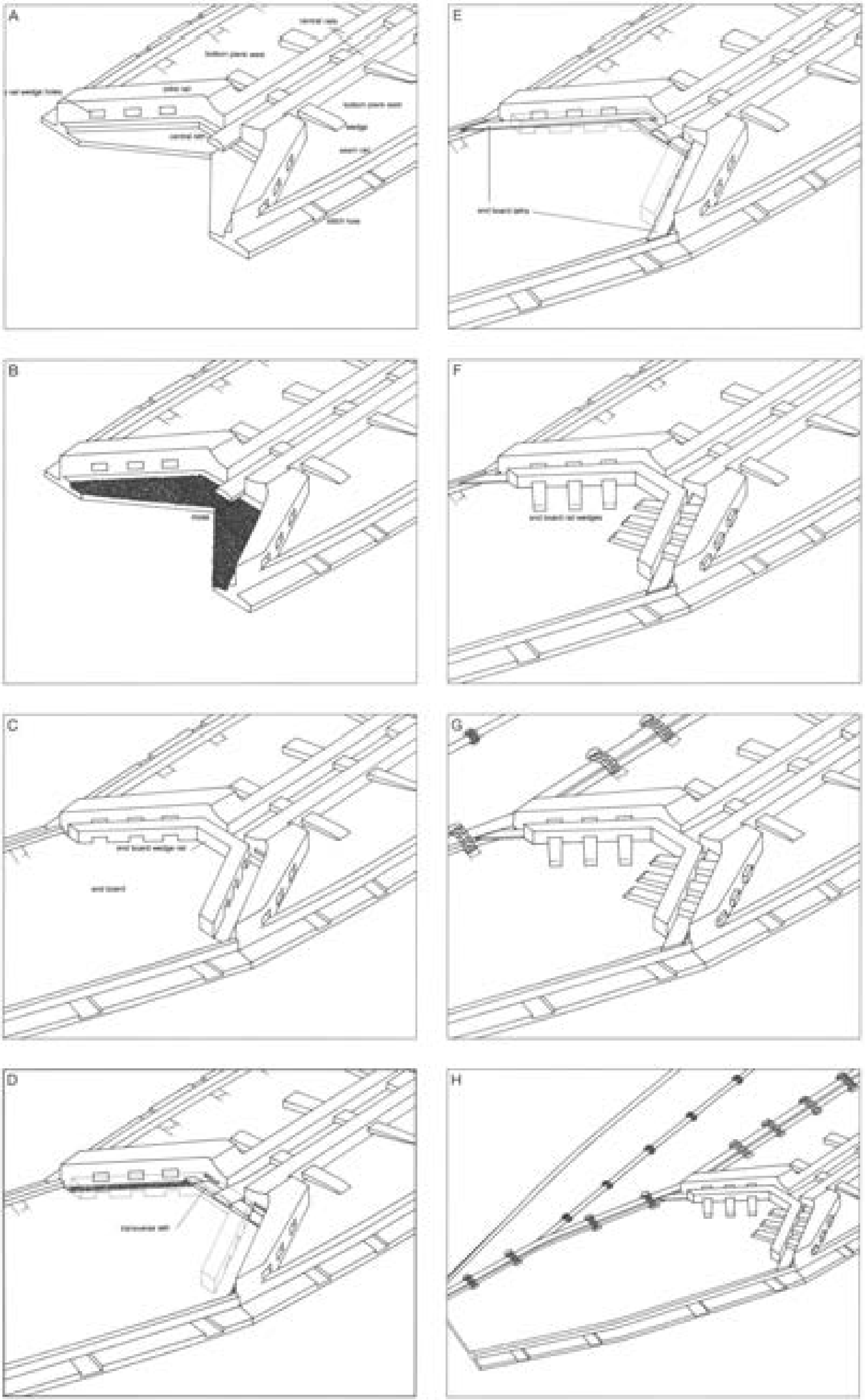


Figure 5.64
A conjectural sequence for inserting the end board.
A: the southern end of the bottom planks brought together, showing the central lath inserted under the wedges.
B: moss wadding lid on the thin shelf formed by the ends of the bottom planks.
C: the end board inserted against the two bottom planks, the wedge holes in the end board wedge rail matching those in the yoke rails.
D: the small transverse lath inserted over the moss wadding in the gap between the end board wedge rail and the yoke rails (the central lath may have been hammered into its final position after the insertion of lath 790).
E: the two endboard laths inserted; these, together with the southern end of the central lath, fitted into recesses cut into the top of transverse lath 790.
F: wedges hammered into position through endboard and yoke rails, attaching the end board and holding the end-board laths in place, compressing the moss wadding.
G: attaching the ile plank; the ile was stitched to the endboard, continuing the system of moss, stopping and lath waterproofing similar to that used along the seam with the bottom plank.
H: schematic cutaway illustrating how the bottom planks, end board, ile and upper side plank articulated to close the end of the boat and provide it with rigidity.

300 and stitch hole 516 in ile plank 301 – the centres are 45mm out of accord. Each stitch was made from a withy of yew wood, partly twisted to give longitudinal splitting to make it pliant while being threaded through the stitch holes. Not only was the thick end of the stitch often not split but, in stitch 558 – between planks 300 and 301 – the inboard part of each of the three loops overlying the seam lath had not been split. The splitting to make it pliable had occurred only where it curved through the planks.

The wadding of moss had been laid over the inboard face of the seams and, at least in the area of stitches 558–559, before the moss was put down, a layer of stopping had filled a gap in the seam. This stopping may have been a repair, although, as it also extended into the stitch holes to seal the stitches, it may have been part of the original construction; all the stitch holes containing stitches appear to have been filled with stopping at the primary stage of building the boat. The moss wadding on the seams between the bottom planks and the ile planks was held in position inboard by laths of wood. Once again, a pattern has emerged in that the ends of the lengths of lath overlap each other. If it is assumed that where a lath overlies another it was inserted later, then it is possible to reconstruct the direction from which the boatbuilder worked. On the east side of the boat, lath 761 is overlaid by lath 760 indicating that the boatbuilder was working from north to south; on the west side of the boat lath 752 is overlaid by lath 751 which is, in turn, overlaid by lath 750 – again showing that the boatbuilder was working from north to south. It is not really clear how these laths were positioned, whether laid over the wadding before stitching, or driven under the stitches.

Stage 5: Fastening the upper side planks

The missing upper side plank on each side of the boat was stitched to the top of the ile. The stitch holes were fashioned first in each plank, and, judging from those existing on the top of the east ile plank, it is possible to conjecture that there were 25 holes in the discovered length of the boat. The same number must have existed at the lower edge of the upper side plank, giving a known total of 50 along the east side. The west side would have the same number, giving an overall total of at least 50 stitches in 100 stitch holes in these two upper seams. It is fortunate that 12 broken stitches (726–729, 731–732, 734–739) had survived on the west side of the boat and were sufficiently complete to show which was the thick end of the stitch. On the basis that the boatbuilder had first threaded the thin end of the stitch it is clear that he had worked from north to south, as he had with the lower stitches and with the laths. No trace of wadding was found, and it is not known if there were laths under the stitches.

Stage 6: inserting the side timbers

Once the upper side planks were in position they could be reinforced by the vertical side timbers slotted into the side cleats. These bracing timbers were rather thin – probably not more than 60mm × 25mm in cross section – so they could not have added much to the strength of the hull. Their purpose was more likely to be connected with providing thwarts across the boat at gunwale level to support the shape of the top of the sides, and perhaps to provide seats for the crew. This will explain why the side cleats 822 and 823 are directly opposite each other. No doubt there was a cleat (821) opposite the discovered cleat 820. The distance of 3.75m between the cleat centres, and therefore between the side timbers, is more than is needed if the presumed thwarts are present only to provide a seating for paddlers – unless, of course, the boat had a small crew.

The completed boat: minimum reconstruction

The discovered remains of the boat are 9.35m long and 2.32m wide, and are incomplete both as to length and height. It is necessary to consider at this stage that what the foregoing description of the vessel suggests is the minimum reconstruction possible. The reality may well have been substantially greater than the minimum and is considered elsewhere in this publication (Chapter 10). It is important to remember that the boatbuilders were constructing their craft to give a shape that was not only well suited to the environment in which the vessel was to be used, but also strong enough for the uses to which it would be put – within the limits of their knowledge, technology and traditions. So, although the method of construction is most important, the picture that the boatbuilder had in his mind was primarily the shape of the vessel. The construction is simply a means of achieving that shape and, as later developments demonstrate, a great range of materials and construction methods have been used in boat construction in England. The relatively primitive technology of the Bronze Age restricted the construction methods, and some of the construction methods used were dead ends. The shape achieved is that of a flat-bottomed, punt-like vessel, with roughly vertical sides and a sloping south end. The possible form of the unexcavated north end is discussed below, but was most likely to be either another sloping end, or a flat vertical transom. The flat bottom at the south end is 1.2m wide, and it widens northwards to 1.5m. Each side curves up from this edge and it is known that a plank existed above this, although its height is unknown.

The missing north end

The construction of the bottom and south end of the boat comprises two bottom planks and the south end board, all of which are held together by wooden wedges. Although the wedges held the planks in position relative to each other, it is unlikely that they stopped the planks from pulling apart while afloat, even allowing for the fact that the wedges would swell when wet. For the safety of the crew, the boatbuilder had to provide a locking mechanism that would hold the bottom and end boards together, particularly in rough water, when stresses would flex the boat. This was part of the function of the ile planks, which were firmly attached by being sewn both to the outer edges of the bottom planks and to the sides of the south end board. The fact that the ile planks were curved in cross section – somewhat like modern girders – increased their strength and, therefore, the rigidity of the locking. The sides of the boat and the south end were therefore secure.

But, for the locking to be fully secure it was essential that the north end of the boat also was locked together. Two possibilities exist: firstly, that the ile planks encircled the north end too and were sewn to another sloping end board like that at the south end. And alternatively, that the south end had a flat transom or board somehow attached to the ends of the bottom, ile and upper side planks. Defining how such a transom could have been fixed to all the planks is a problem. Comparison might be made with the Hasholme boat of Iron Age date (322–277 Cal BC; Millett and McGrail 1987), although as that vessel is a dugout canoe, the function of its transom is not to hold the stern in shape in the same way, so it is not particularly relevant to this matter. Moreover, as not a single treenail exists in the Dover boat – or in the Ferriby and Brigg boats – there is no reason to suggest that treenails were used to hold a conjectured transom. So, not only is a transom solution completely conjectural, but so is its method of construction. Nevertheless, the importance that the boatbuilder gave to the method of closing the ends of the Dover boat is reflected by the highly elaborate method of his constructing the south end. The north end of the boat can be expected to be equally well made and secure, and the balance of probability favours a north end similar to the south end. It should be added that the Brigg boat apparently had straight ends, although the nature of those ends is unknown. Its flat bottom might suggest that some form of transom was used. In any case, the Brigg boat is later in date than the Dover and Ferriby vessels and might be expected to include structural developments.

The question of rocker

Although the excavation drawings of the Dover boat *in situ* show that the vessel was slightly twisted, the drawings help to establish the original shape of the boat. The vessel was found with a fairly flat bottom, but it is important to investigate whether or not it had a rounded transverse shape. Also, it is important to see whether, longitudinally, the bottom was either originally flat or was rounded with 'rocker' – a form that helps a beached vessel to 'unstick' itself from the seabed or riverbed and also helps it to turn when afloat.

With these possibilities in mind, three inboard transverse profiles were drawn, as well as two long profiles – one along the eastern central rail adjacent to the centre line of the boat, and the other along the top of the west ile plank.

It is clear from the curving ile planks that the bottom planks must have been fastened to form a flat transverse bottom, for, had they been curved originally to form a U-shaped hull bottom, the vertical upper parts of the iles would have sloped inwards and given a less than boat-like transverse shape.

The two long profiles – one along the west side of the boat and the other along a rail at the centre line – were curved when found, as if to suggest a slight rocker originally. However, as the longitudinal curves were unequal, it is just as possible that the boat was flat-bottomed and has settled into a slight hollow. The top edge of the west ile plank is almost at a level height above the bottom plank, and does not have any shape to suggest that the bottom had a rocker. So, although this question of rocker is not fully answered, the conclusion from this evidence is that there is no reason to believe that the boat originally had any rocker. Instead, the changes in the hull shape are best explained by the boat having taken up the shape of the land on which it was found to be lying, and that it was originally built with flat transverse and longitudinal profiles. It was a flat-bottomed boat.

Methods of propulsion and steering

There is no evidence for the boat's methods of propulsion and steering, though it is clear that there is an absence of structural features associated with sailing (eg a mast-step) or rowing.

The use dilemma

The environment in which the Dover boat was used is not easily defined. It was found in a context of fresh water, and, with its flat bottom, it is particularly well suited to calm inland waters (as is shown by the Roman and medieval river craft found in the Rhine, and vessels such as punts and swim-headed Thames barges of the 17th century, that have been used in English rivers in more recent times). In the lumpy open sea, its low sides and flexing flat bottom could have resulted in the bottom seam opening up, and, in a strong side-wind, the vessel would be blown sideways (leeway). Together, these factors do not favour the use of the Dover boat in anything but the calmest sea.

The least speculative reconstruction described in this chapter takes into account only the evidence of the boat itself, and leads to one preferred conclusion – that this flat-bottomed, punt-like vessel was used on the inland waters of a river or lake, and might have been used at sea only in coastal waters in calm weather. But the evidence for the Bronze Age environment in the Dover region indicates that there appears to have been no such river or lake of any consequence that could justify the use of this boat then. There is, therefore, a conflict of evidence between the suggested minimum reconstruction of the Dover boat and its perceived environment.

This dilemma can be resolved by considering two possible alternative solutions that, although they embrace levels of speculation that cannot be supported by any further evidence, seem to be entirely reasonable. The first is to accept the minimum evidence – that the boat was indeed built for a riverine environment – and to consider that the location of that environment was elsewhere along the coast. In this suggestion, the boat would have had to have been brought to Dover, where it was broken up and the removed parts perhaps reused. There are numerous documented examples of this having occurred to boats in more recent times, showing that this suggestion is reasonable. The second alternative is to suggest that the boat had originally been built for use at sea, and that the reconstruction of its missing structure must include necessary strengthening elements. Although this will incorporate constructional features that are unknown in Bronze Age plank-boat building – such as a transom stern to keep the vessel's length to a minimum – it is important to remember that very few plank-built boats of the Bronze Age have been found upon which to base a reconstruction. Moreover, although it is possible to suggest solutions that are based on the evidence of the more numerous finds of prehistoric dugout canoes, it is important to remember that they were non-flexible craft – unlike the Dover boat – and that some, like the Hasholme boat, belong to a much later age, with an iron technology, and therefore that we are not comparing like with like. Caution is therefore most important. Nevertheless, the discovered parts of the boat can be incorporated fully into a hypothetical seagoing reconstruction showing that this suggestion could be equally valid. But, until further information is found, this central question of interpretation cannot be resolved.

Answers have been given to some of the research objectives, although only minimum solutions are suggested in this chapter because of the limited evidence. A more hypothetical discussion is given by Owain Roberts (Chapter 10) that seeks to create a practical view of what the vessel might have been like and how such a reconstruction would work. As regards its punt-like shape, the original vessel was more than 9.2m long – perhaps as much as 15m – and was about 2.30m wide. Unfortunately, there is no direct evidence to show how high the sides were originally, but estimating the height is essential if we are to determine the original volume and density of the timber used in the complete boat, and, therefore, suggest the original distribution of the boat's weight, and its stability and loading. Consequently, much depends upon estimating the size and shape of the missing timbers. These all have a bearing on the central question of whether or not this was a seagoing craft or an inland waters vessel. Sadly, this must remain unresolved, as it is hedged around by conflicting evidence. The only possible solution would be to excavate the site of the north end of the boat in the hope that it has survived.

The study of the construction of the boat in intimate detail has been a fascinating experience, for it has been possible to recognise and understand the work of a master boatbuilder working more than 3000 years ago. Detailed measurements have been taken throughout, partly to explore the possibility that the boatbuilder used some form of measuring rule and, if so, what might it be. This has led to the following conclusions:

- there are variations in the spacing of the stitches and other features, showing that no kind of precise form of measuring system was used;
- the average spacing of the primary stitches (361mm) and repair stitches (418mm) roughly equate with the length of the lower arm, so perhaps one might imagine the boatbuilder laying out the position of each stitch by laying his lower arm on the plank with his elbow on the last hole and his hand on the site of the next;
- the wedges – spaced at an average of 501mm – might have been roughly laid out by the boatbuilder kneeling on the plank, as the spacing is roughly the length of the lower leg from the knee to the foot;
- the transverse timbers – spaced at an average of 1.68m – were laid out to correspond with the height of a man.

The boatbuilder found solutions to many constructional problems, such as how to maintain a rigid hull, how to make it watertight, how to be stable, how to propel and steer and how to climb on board. Those solutions included the use of wedges and stitches, but, in spite of the considerable ingenuity shown, these were to become a dead-end route in shipbuilding history. In some ways the Dover boat equates with Neanderthal man in that part of its method of shipbuilding had no future. However, the use of planks to build a boat that is larger than a tree, and to incorporate transverse timbers to give a lateral bracing, shows the beginning of a need for frames. Moreover, in the longitudinal rails we are seeing an embryonic form of keel, keelson and stringers. During the next thousand years in northern Europe, someone would invent and use nails in boatbuilding – nails either of wood or of metal. And they would find that, by nailing planks to the frames, it would be possible to build even bigger large seagoing vessels. By the time of the next post-Bronze Age plank-built vessel discovery in Britain – the Romano-Celtic Blackfriars 1 ship, built after AD 89, probably in the 2nd century AD – the constructional way forward had been found in Britain. But that was 1,500 years after the Dover boat had been built. Sometime in the intervening thousand years somebody found answers, and one day their work may be discovered.

Meanwhile, the Dover boat remains a remarkable monument to its builder and users, and to the inventiveness of men who had a deep practical knowledge of technology and hydrodynamics, even if their understanding of the scientific processes involved was limited. It is also a tribute to their courage that allowed them to put their safety in the hands of their creation, working in an alien environment – the water.

6
Illuminating the original shape of the Dover boat timbers

by Richard Darrah

The Dover boat had been buried for approximately 3,500 years under an increasing thickness of overburden. By the time the boat was discovered, this overburden was around 6m thick, exerting a considerable pressure on the structure. The wooden planks recovered from beneath Bench Street were therefore a puzzle. Was this their original shape? Had they been compressed over time and, if so, what was their original shape? Understanding this would be the key to understanding the overall shape of the finished boat, how it was built and how it functioned in water.

To illuminate the original shapes and sizes of the bottom and slide planks used to build the Dover boat, it was important to use information provided by the pieces of the boat in their current state, combined with knowledge of the growth characteristics of modern oak. The discovery progressed through five stages:

- describing the characteristics of the timber used to build the boat;
- quantifying the characteristics of modern oak timber;
- comparing these characteristics and determining whether and how the wood had been compressed;
- correcting for any compression to provide an estimate of the original dimensions of the boat planks; and finally,
- defining which changes in plank shape, size and weight might affect our understanding of the construction and functioning of the boat.

(A paper giving fuller details of this process and the results is available online at http://www.canterburytrust.co.uk).

The quality and character of the Dover boat timbers

The timbers were carefully examined by the author, in conjunction with the drawings made by Alison Gale and Caroline Caldwell. Distinct features present in the oak timbers provided clues about the growth of the original trees and the conditions in which the trees had lived.

The most prominent feature is the series of annual rings. These occur when, each year, large spring vessels form a fresh cylinder of vertical tubes up to 1mm in diameter. These tubes are then covered with dense summer wood giving the tree its ring porous cross section.

Medullary rays are another important feature. They radiate from the centre of the tree in planes. Each vertical plane is made up of a series of horizontal vessels, again of a large diameter. Experience in working with oak timber indicates that each medullary ray can grow perfectly straight across the rings for a number of years (although there are trees with curved rays) and where straight, medullary rays converge roughly on the centre of the tree.

High-quality timber is regular in its growth pattern, so that, in cross section, the annual rings will form a circle, and the medullary rays will cross these rings at right angles. Where there has been some extra stress in the tree, or where a knot has grown over, the area is marked by a distortion in the regular pattern of growth. Trees correct this distortion so that within a few years the regular pattern of growth is restored.

No large knots were seen in the Dover boat timber, and only a few small knots. One of these had been overgrown in the trunk, the steep angle of this small branch indicating that it had been forced up by dense shade. The angle of the knots also told us which way up the tree grew – the crown (top) of the tree was at the south end of the boat, so that the tree was still at least 1m in diameter at a place at least 10m up the tree. As the annual rings were evenly spaced at about 2mm per year, the tree was over 250 years old when felled. The medullary rays were very tall, running about 10mm up the trunk, again indicating clean, even growth. All the evidence from the bottom planks and lowest side planks suggests clean, even, steady growth of the trees, with few side branches. Evidence from the wedges indicates that they are made from a similar quality of timber (but this is harder to verify, owing to their small size).

This habit of growth is associated with trees grown in high forest. The straight grain, evenness of growth, lack of knots and large size of the trees makes this very high-quality timber – in modern timber the whole length of the trees used would be of 'veneer butt' quality (Chapter 7, pp 113–7).

The next stage was to look for irregularities in the medullary rays that might suggest that compression had occurred. But, before this, the characteristics of medullary rays had to be defined; in clean and evenly grown timber, could we rely on the medullary rays to show any distortions, or might distortions in the medullary rays occur without compression having occurred? To check this, a modern piece of large timber was studied, augmenting a general knowledge of the properties of oak acquired over years of working and splitting it.

The modern oak that was used was straight grained and knot free, 180 years old, 1.2m in diameter and had grown at 3.3mm per year – faster than the Dover boat timber.

The first stage was to assess whether the convergence of medullary rays in a transverse section (a horizontal cut straight through the trunk of a tree) could be used to provide a realistic indication of the centre of the tree. If this were possible, it would allow diagnosis of areas in the Dover boat timbers where the medullary rays were not all 'pointing' to the same centre, and so must be distorted or compressed. This was done by drawing medullary rays from the modern oak into the outline of a Dover boat bottom plank and then extrapolating these rays blind to assess whether convergence occurred (Fig 6.1). This did provide a rough convergence point, or geometric centre, the medullary rays closest to the centre of the section giving the best indication of that centre point (not the exact growth centre of the tree, as there is often uneven growth during the first few years of growth, but the centre of the mature tree growing cylindrically). This suggests that it is possible to use the medullary rays to indicate a tree's geometric centre, and is

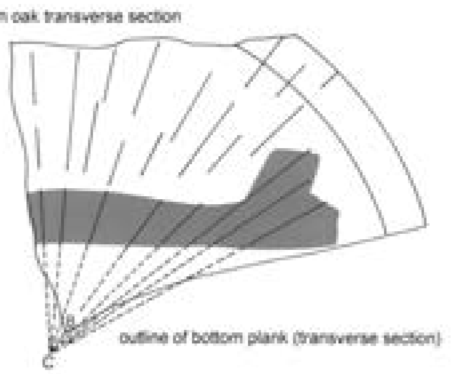


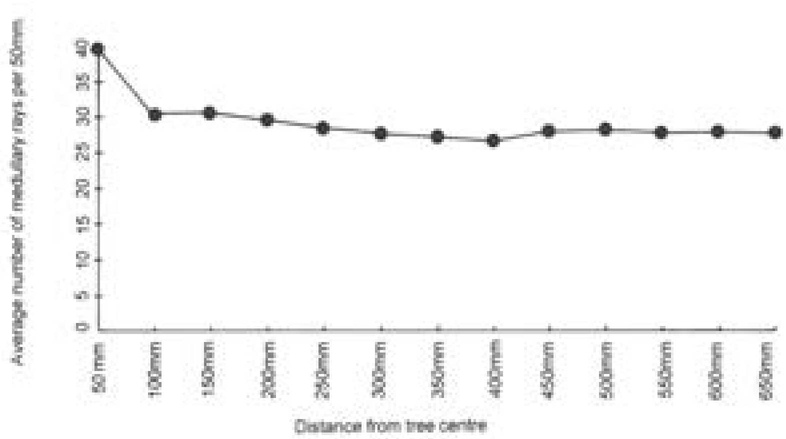
Figure 6.1
Using medullary rays to suggest a geometrical tree centre. Fifteen medullary rays from the modern tree were chosen and drawn onto the outline of a bottom plank (shaded area). The medullary rays were then extrapolated with a ruler to a convergence point indicating the centre of the tree. This provided a rough approximation at a convergence point, or geometric centre (C), the medullary rays closest to the centre giving the best indication of that centre point. The geometrical convergence point (C) was not the exact growth centre of the tree (B), as there is often uneven growth during the first few years of growth, but the centre of the mature tree growing cylindrically.

supported by practical evidence that splitting an oak tree can provide almost perfect, straight-sided quarters.

To assess just how straight medullary rays are (again in transverse section) a series of medullary rays was traced from their start to their ends. The medullary rays are not completely straight (even in very straight-grained timber) but vary from a straight line by only 1mm or 2mm over a 250mm ray length. While the medullary rays tend to converge on the geometric centre of the tree, they do not all start at the centre but run up to about 250mm, starting at any distance out from the centre of the tree. They end in a variety of ways: most commonly, they taper away to nothing, or they might converge with another ray, or stop for a millimetre then start again on the same course.

Counting the number of medullary rays per 50mm along annual rings at varying distances out from the tree centre allowed assessment of their frequency and regularity. The number of medullary rays per 50mm decreases slightly with increasing distance from the tree centre (Fig 6.2), but, after 100mm from the centre, this decrease is small.

Figure 6.2 (below)
Assessing the frequency and regularity of medullary rays counted per 50mm along annual rings at varying distances out from the tree centre. The number of medullary rays per 50mm drops slightly with increasing distance from the tree centre, but after 100mm from the centre this trend is small.



This suggests that in any uncompressed timber within the Dover boat, the medullary rays should converge on a theoretical geometric centre, run straight along their course, cross annual rings at right angles and, counted along annual rings, be of a similar frequency. Deviations from this pattern indicate that the timber structure has been distorted.

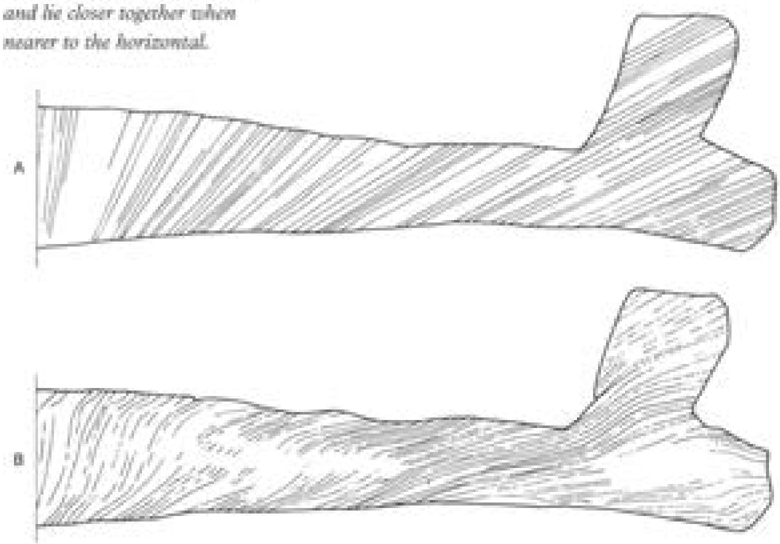


Figure 6.3
Comparison of modern, undamaged medullary rays and those found in the Dover boat. A: undamaged medullary rays from modern timber traced onto a cross section of a bottom plank. B: original tracing of the medullary rays on the cross section of a bottom plank; note the rays are bent over towards their ends and lie closer together when nearer to the horizontal.

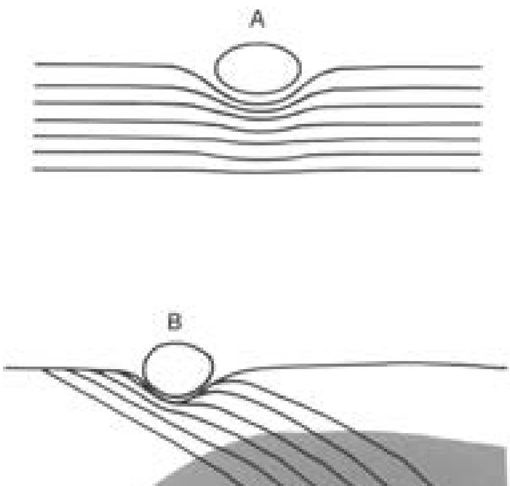


Figure 6.4
Local compression.
A: the effect on the annual rings in a longitudinal radial section. B: the effect on the medullary rays in transverse section (the shaded area is an area of undamaged wood).

Were the Dover boat timbers compressed?

So how does this compare with the pattern of medullary rays seen in the timber remains of the Dover boat? While the timber is straight grained and even, there is within it a regular distortion of medullary rays, providing strong evidence of compression in the Dover boat timbers. In these timbers a large number of medullary rays do not seem to converge on a centre; the distance between them varies enormously between different parts of the same timber, they run much less straight, and the angle between the annual ring and medullary ray can be very different from 90 degrees. A sensible explanation of this is that the timbers started out with the same characteristics as our modern timber, but have been compressed over time.

A general pattern of compression is seen such that wherever medullary rays run vertically, the ends of these rays are broken and distorted and wherever they run horizontally, they become more closely spaced. This pattern occurs clearly across all the (transverse) sections of both the bottom planks and ile timbers. (*See* Fig 6.3, comparing the medullary rays in a cross section of the modern timber with the medullary rays seen in a similar cross section of the Dover boat.)

The compression seen is of two types: local compression, where a solid object bears down on a portion of the structure (Fig 6.4), resulting in a local squeezing together of the medullary rays and spring vessels; and general overall compression, due to overburden of earth on the structure (Fig 6.5), which might result in distortion of the ends of vertical medullary rays, compression of medullary rays (so that they lie more closely together) and/or a distortion of the overall shape of the object so that the medullary rays might lie at new angles to each other. Other distortions that might have occurred include: bridging effects, where a large object protects part of the structure from compression; distortion due to decay; seasoning effects (Fig 6.6); and hydraulic compression (Fig 6.7).

In each of the bottom plank cross sections there are three areas of minimal compression and distortion (Fig 6.8). Two of these areas occur under the rails, where the rails might perhaps provide protection by increasing the amount of timber around

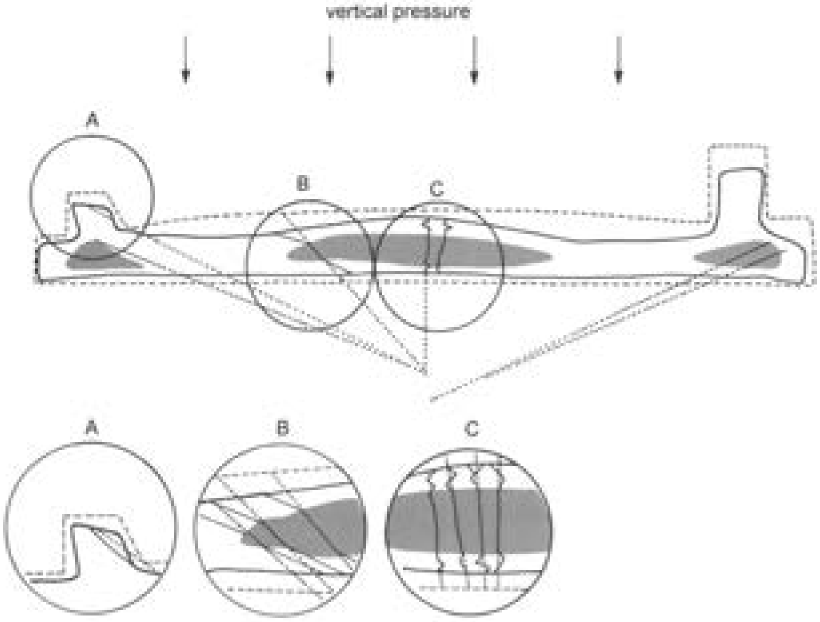


Figure 6.5
General overall compression. Shaded areas are uncompressed wood; unbroken lines show the compressed outline and compressed rays; dotted lines extrapolate the uncompressed medullary rays; dashed lines show the proposed pre-compression outline. A: correction for medullary rays both bent over and moved sideways as the rail slipped. B: correction for medullary rays bent over and compressed close together. C: correction for vertical medullary rays that have zigzagged at the ends, split or become S-shaped.

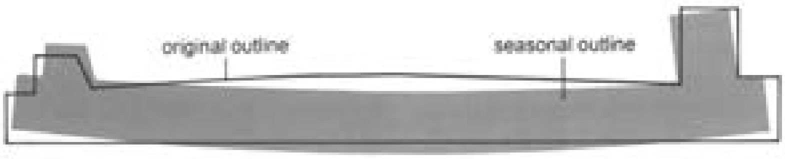


Figure 6.6
The effect of seasoning on a tangential plank, causing slight shrinkage over the width of the plank, and a bowing. It is not clear whether this occurred in the Dover boat.

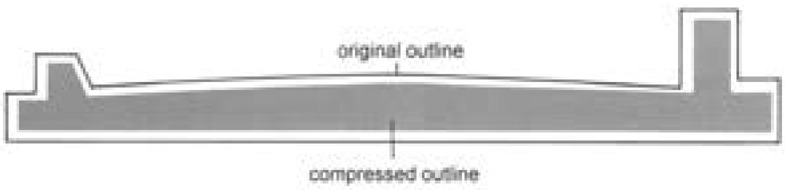


Figure 6.7
The effect of hydraulic pressure, where the original timber shape would have been compressed equally from all sides. This does not occur in the Dover boat.

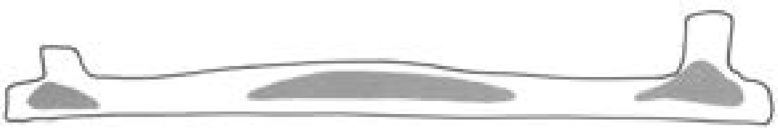


Figure 6.8
The bottom planks each show three areas of undecayed timber, identified by their harder consistency and the presence of annual rings still at right angles to the medullary rays.

those areas, and perhaps by a bridging effect. The other area is in the centre of the plank, where the medullary rays are nearly vertical. The medullary rays seem to provide a structural element, so that even where decay occurs compression is less likely. Medullary rays running through the least distorted areas of wood do converge on a geometric centre, with notable exceptions.

This structural effect of the vertical medullary rays is also seen in the ile timbers; where the rays lie horizontally the compression is very marked (the rays lying very close together), but where the medullary rays begin to lie out of the horizontal plane

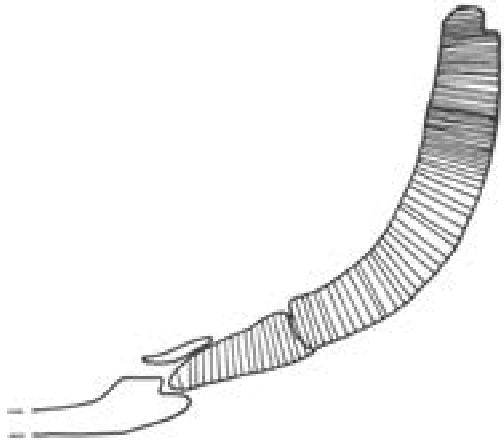


Figure 6.9
Medullary-ray compression in an ile timber. The structural effect of the vertical medullary rays is seen in the lowest side planks. Where the rays lie horizontally (as at the tip), the compression is very marked (the rays lying very close together); where the medullary rays begin to lie out of the horizontal plane, compression levels drop rapidly – as indicated by the wide spacing of the medullary rays lying vertically.

compression levels drop rapidly (Fig 6.9). The ile timber which is least compressed is the one found lying at an angle so that its uppermost medullary rays are not lying horizontally. The more vertical the position of the medullary rays, the less compression occurs, and the more horizontal they are the more compression is seen.

The deflection of the medullary rays is consistent throughout the boat, so that each plank exhibits the same type of ray deflection in the same areas of the cross section. As two trees were used in the bottom of the boat (Chapter 7, pp 116–17), this indicates that the ray deflections are caused by compression and not unusual growth patterns.

This was promising; it was clear that compression of the timbers of the Dover boat had taken place, and a pattern was emerging in how this compression had occurred. The next stage was to try to take account of the effects of compression and estimate the original size and shapes of the timbers.

The characteristics of waterlogged wood

Freshly felled and seasoned wood behaves elastically; when you apply a little pressure it deforms, then springs back to shape when the pressure is removed. If more pressure is applied, the wood might remain permanently deformed without any visible structural failure. More extreme pressure will result in the wood fibres tearing apart, leaving a jagged break.

Although some wood preserved in the ground for long periods might retain these elastic properties, they will eventually be altered through the loss of cell structure. After pressure, decayed wood does not spring back to shape, but remains bent. On further pressure, the wood will break straight across at right angles, indicating that it has become brittle. This alteration in the properties of ancient wet wood is caused by loss of cellulose from the cell walls. On drying, the wood becomes brittle and begins to collapse (as weakened cell walls cannot oppose the surface tension of the water as the cells dry, resulting in collapse of the cells and fragmentation of the wood).

The most obvious example of this loss of cell structure is in wet round wood lying horizontally with an overburden. This type of wood often becomes oval in cross section over time. This deforms the annual rings (which also become oval), and the vertically lying medullary rays (which can be bent or concertinaed). This is easily seen in roundwood as we can guess at its original round cross section. In an artefact of shaped wood, deformation from the weight of the overburden is not so obvious. However, the rings and rays will be bent by the compression, so that the wood structure will indicate that deformation has occurred.

Wood does not necessarily distort uniformly for the following reasons: the sapwood frequently distorts more than the heartwood (presumably because the cell structure is damaged more easily; distortion of the sapwood might occur even without pressure from an overburden); the wood around knots might be denser and less prone to cell damage, and the wood within the core of the object might be protected from decay by the wood surrounding it.

The amount of distortion that can occur because of a partial collapse of the cell structure of waterlogged wood might be determined by a number of factors in the ground conditions. These include the weight of the overburden (which might differ over the surface of the waterlogged wood); the solidity of the surface on which the wood lies; and different local chemical conditions (acidity or levels of oxygenation) which can drastically alter the rate of decay. Any one part of the structure might be subjected to a different rate of decay and compression than the rest.

Although distortion can be caused by decay alone, it becomes clear that compression is involved where the amount of distortion is reduced locally in a place where there is protection from some compression by another object lying above the first, bridging it. Compression has also clearly taken place where a dense object has been forced into the surface (point loading) leading to local distortion of rays and rings. In the case of 'bridging' one can see from the structure of the wood that the raised area is not caused by abrasion of the areas on either side, but by compression of the areas on either side, as the medullary rays and annual rings are coherent through both places. The same is true of point loading, where a depression is not caused by preferential decay, as the spring vessels in the annual rings are coherent but closer together in the depressed area than they are on either side.

In waterlogged wood, hydraulic compression might also be considered. This is compression that might occur to an object in deep water – where the pressure from all sides is the same. This compression would result in roundwood becoming compressed equally in all directions so that the medullary rays would shorten (possibly breaking or distorting) and annual rings would stay roughly circular but with a smaller radius. If hydraulic compression occurred in the Dover boat, one would expect to see distortion and compression of medullary rays lying horizontally (lateral compression). This is not seen and there is no evidence for hydraulic compression being a significant factor in the distortion of this structure.

The effect of seasoning on a tangential plank causes slight shrinkage over the width of the plank, and bowing of the plank (*see* Fig 6.6). If the plank were later straightened by the overburden the only remaining effect would be that the plank is less wide than originally. This would not be picked up by a study of the medullary rays in cross section. However, it must be assumed that some seasoning of the planks has taken place either during boatbuilding or while the boat was in use.

The evidence is that compression in wet wood underground results from weight bearing down from above, not from the sides, although the weight might not provide an even pressure on all horizontal surfaces.

In summary, compression of wet archaeological wood is where the wood has been deformed by the weight of the overburden. The structure of the Dover boat will have retained its original form, but not its exact shape. This distortion is not completely regular but does follow some patterns so that we were able to make general predictions about its original shape that helped in the reconstruction of the boat.

Correcting for compression – the true shape emerges

So how could the original sizes and shapes of the timbers be discerned? The technique used was to start with those areas that were least decayed (*see* Fig 6.8), and to extrapolate detail of these areas into the more damaged areas. Tree study tracings, of the modern cross cuts (Fig 6.10) that had made the timbers more manageable in their

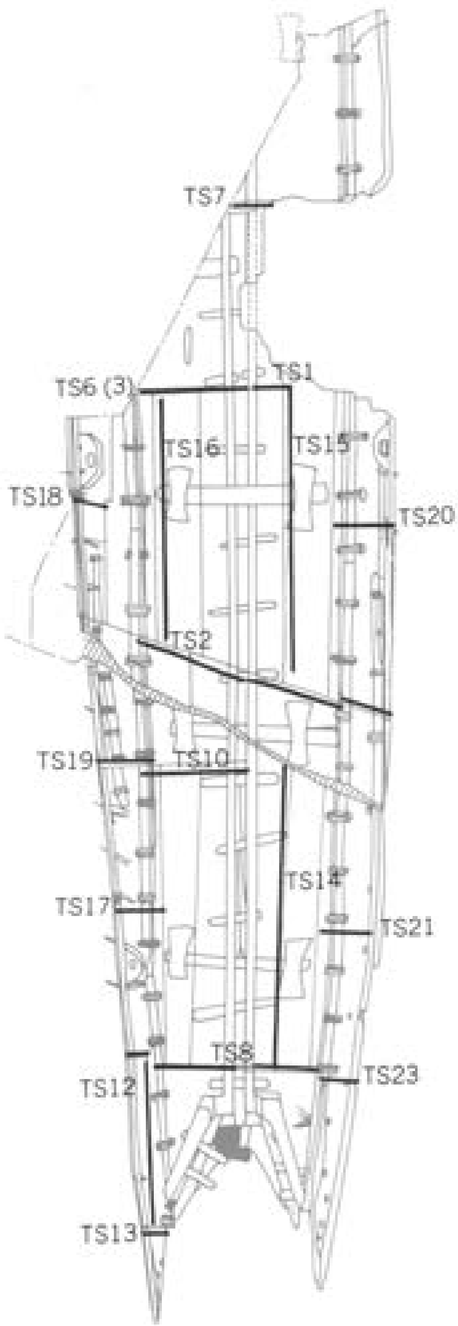


Figure 6.10
The positions of the tracings that were used in the study.

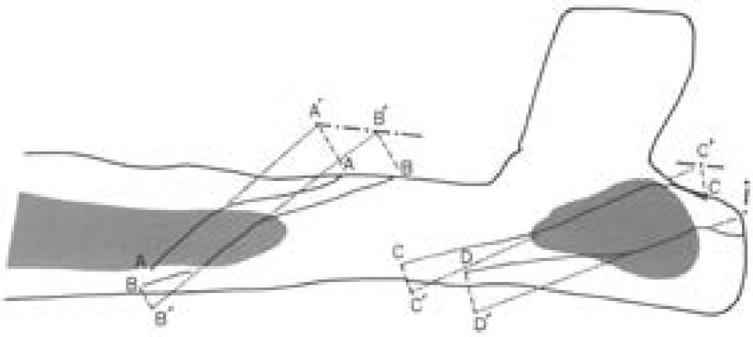


Figure 6.11
Straightening the medullary rays where they have been bent or concertinaed by local or general compression. The portions of the rays within the non-compressed (shaded) areas were used to determine the original direction of the rays, in combination with the measured lengths of the rays. The solid line is the outline of the compressed bottom plank; the fine lines are the original traced medullary rays; the dotted lines are the proposed straightened rays; the dashed-dotted line is the proposed original timber outline.

extraction, were copied and then manipulated to correct for compression.

First, where medullary rays had been bent or concertinaed, the rays that had been least distorted (in the centres of the sections) were used as guides to the original direction of the rays. The bent or distorted rays were measured and then re-aligned (Fig 6.11).

Next, the medullary rays that did not pass through the least compressed areas were aligned. The geometric centres of the trees (for the bottom planks and the ile timbers) were estimated by extrapolating the group of medullary rays in the uncompressed areas closest to that centre (Fig 6.12A). Then medullary rays in compressed areas were rotated to align them with the calculated centre (Fig 6.12B).

The average spacing of medullary rays in the uncompressed areas of each ile-plank cross section was calculated (Fig 6.13). Then, areas of compression (where medullary rays run more closely together) were redrafted by pulling the rays out to fit with the spacing of medullary rays in less compressed areas (Fig 6.14).

The average spacing of medullary rays was also calculated for the bottom planks (*see* Fig 6.15). This was used to estimate the original shape of the rails (which were especially difficult, as there are no areas of uncompressed wood and none of the medullary rays are continuous with the rays from uncompressed areas). Starting from a ray beneath the rail, which runs through an uncompressed area, the rays were straightened and stacked into their correct spacing

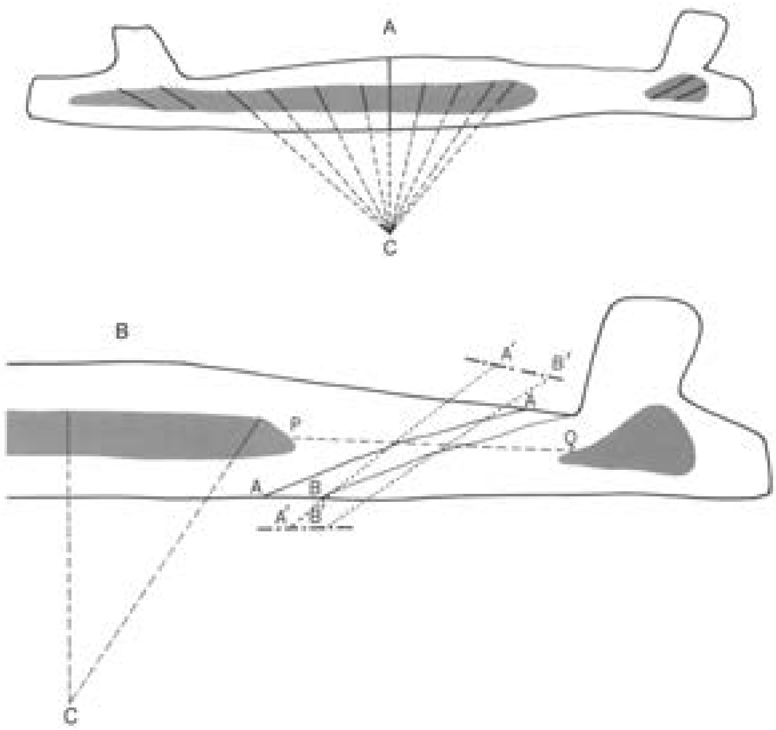


Figure 6.12
Aligning the medullary rays that do not pass through the uncompressed areas. A: the geometrical centre of the tree was determined by extrapolating the rays in the uncompressed areas (shaded) closest to that centre (C). B: next the medullary rays in the compressed areas were rotated (about the line PQ) to align them with the calculated geometrical centre.

on a theoretical annual ring (based on the geometric centre). The assumption was that rays have been compressed vertically, and so were raised vertically to this annual ring (*see* Fig 6.16).

Finally, the new overall outline of each section was drawn. Straightening of the medullary rays on the two bottom planks indicates that there has been severe compression in the bottom planks between the central cleat and the rails, resulting in up to a 50-per-cent loss of thickness; the cleat rail heights need to be increased by up to 50mm, and they were originally upright; the surface on which the central lath rests was originally horizontal; the central edges of the bottom planks were originally nearly vertical, and there has been no visible loss of wood from these edges; and the planks are symmetrical across the centre of the tree (*see* Fig 6.17).

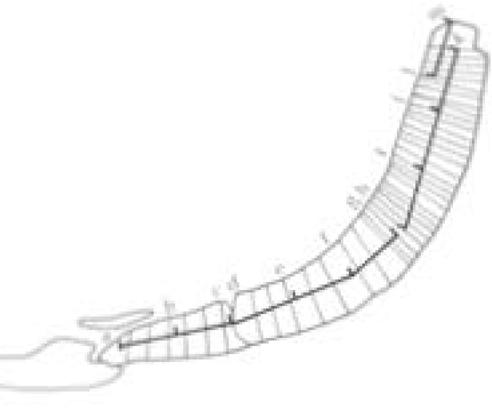


Figure 6.13
Calculation of the average medullary-ray spacing for ile timber cross sections. The medullary-ray counts at ab, bc, de, ef and fg (where the rays were vertical) were used to calculate the average original medullary-ray spacing. This enabled the counts in areas hi, ij, jk and lm to be corrected for the compression that had occurred there.

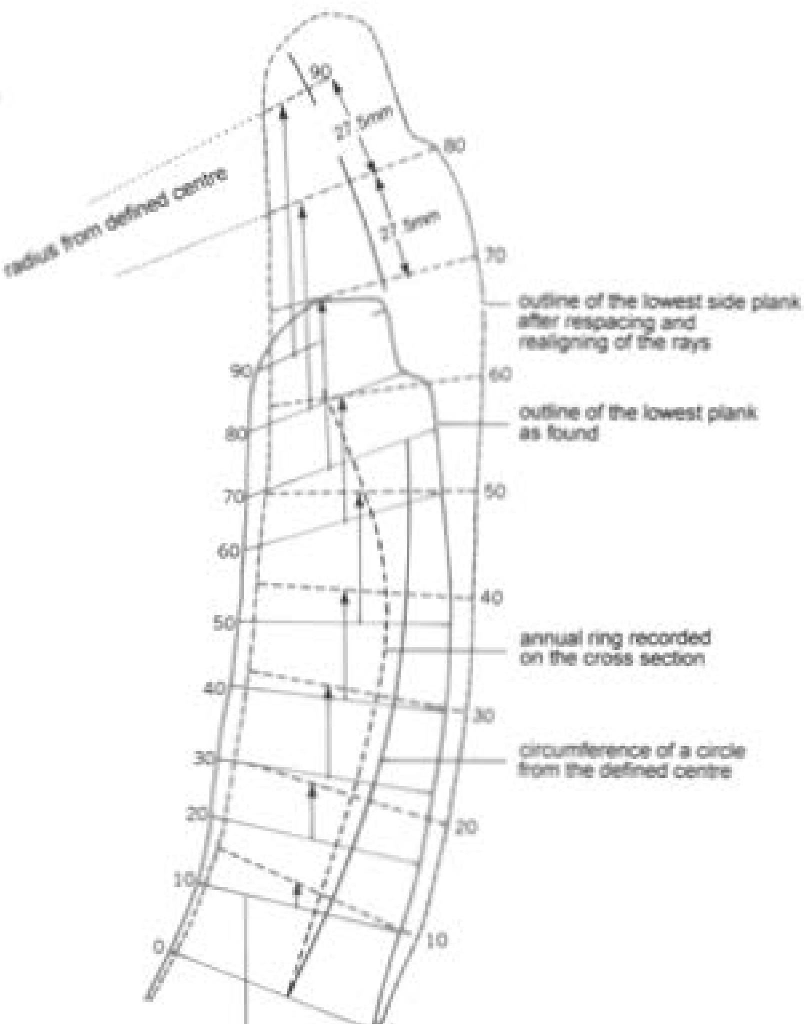


Figure 6.14
Correcting for compression and distortion of the ile timbers. Every tenth ray is re-set at 27.5mm from the last and realigned on a radial line from the geometrical (calculated) tree centre. The position of the ray on that line is defined by the position of the annual ring, redrawn to match the pattern in the least distorted area of the plank.

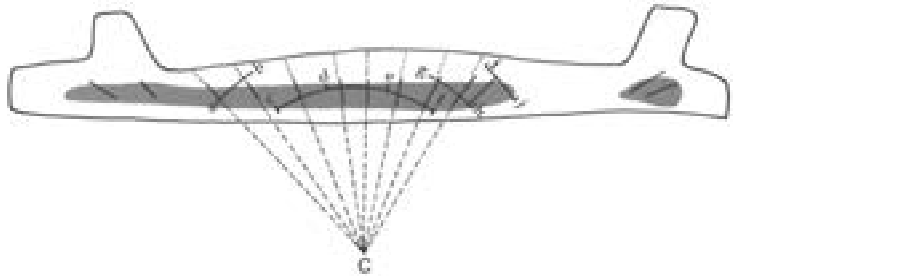


Figure 6.15
Calculation of average medullary-ray spacing for the bottom-plank cross sections. The number of medullary rays is counted across a 50mm circumference within the area of undamaged wood in each cross section. Of a circle centred on the geometric tree centre (C), the 50mm sections are labelled ab, cd, ef, fg, gh, ij. Straightened rays that fall within these 50mm sections are included. The mean ray count from all the sections is used.

Correcting for compression of medullary rays on the lowest side plank results in an increase of 70mm in height and a revised shape, although this shape is very dependant on the exact tree centre chosen so the potential for error is high (Fig 6.18).

The method gives reasonable estimates for thickness of planks, although their exact shape was harder to ascertain with any reliability. The original structure was probably more massive than it appears now, and might have been shaped slightly differently. An estimated original shape of one of the bottom planks is shown in Fig 6.19. (The exact estimated shapes of all the cross sections studied can be seen in the full paper, at www.canterburytrust.co.uk).

Implications for the design and functioning of the Dover boat

Thickening the planks will increase the weight of the bottom planks by about 25 per cent, and the increase in rail height will increase the rigidity of the bottom planks. This increased mass also gives an increased depth of wood above the wedges enabling them to be functional. Annual ring evidence suggests that, originally, the lowest side planks were less curved, and their height greater. If this were the case, then the boat would originally have been wider. Distortion of medullary rays in the lowest side cleats indicates that they have been deformed sideways; straightening

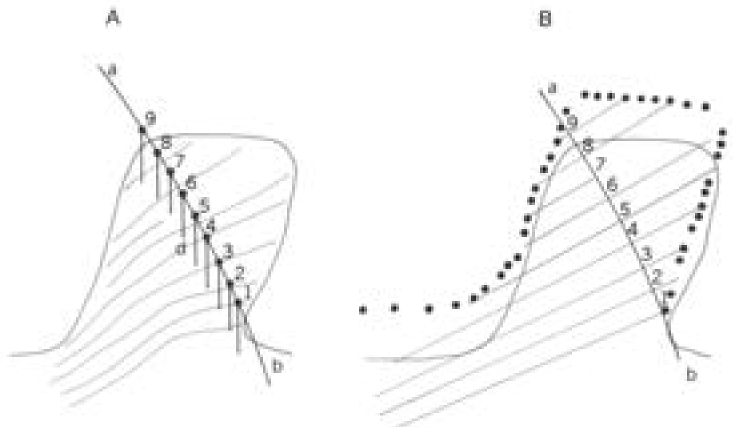


Figure 6.16
Estimating the shape of the rails on the bottom planks using the mean medullary-ray spacing calculated for the plank. A: starting from a ray beneath the rail, running through an uncompressed area, the rays were straightened and stacked into their correct spacing on a theoretical annual ring (based on the geometric centre). The assumption is that rays have been compressed vertically, and so are raised vertically to this annual ring. B: the original uncompressed cross section of the rail emerges. In detail, the arc of a circle centred on the geometric tree centre is drawn (ab, representing an invisible annual ring) and the estimated original spacings of the rays are marked (1–9). To estimate the current position of the annual ring as it would have been distorted by compression, a point is picked (7 on ab) and a vertical line dropped until it intersects the actual seventh ray (at point d). Point d is then moved to point 7, and the calculated length of the medullary ray is placed at right angles to the arc ab. This is repeated for all the medullary rays.

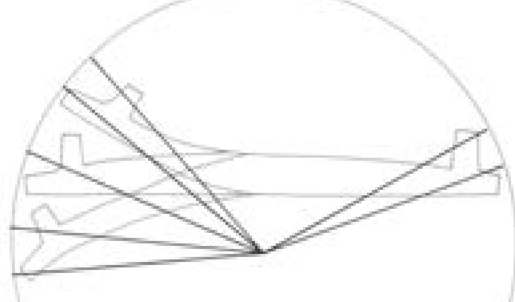


Figure 6.17
Considering the possibility that the bottom planks were not originally flat. The different shapes show that, with different cross sections, the lengths of the medullary rays alter. If the plank were not flat it would not be symmetrical across the centre, and one would see a noticeable change in the length of the medullary rays at each end of the plank. This is not seen, so the evidence is for a symmetrical, and probably flat, section.

them might allow us to understand their original function.

In the lowest side plank at the south end of the boat, the compressed horizontal medullary rays lie at the bottom of the section, indicating that the lowest side plank is cut at an angle across the timber at this point. However, lack of annual-ring evidence makes it difficult to discern the exact position in the cross section of the tree at which the ends of the lowest side planks have been cut (Fig 6.20).

The re-working of the shape and size of the timbers making up the Dover boat took us to the point at which we could begin to consider a re-construction of the structure (Chapter 9).

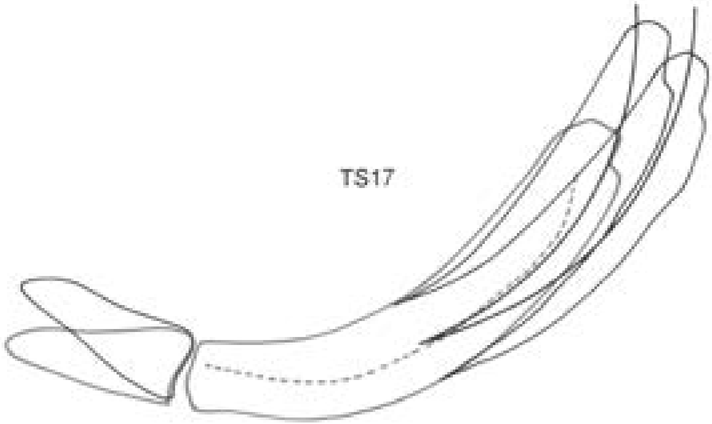


Figure 6.18 (above)
Revised shape for the ile timber. The shape is very dependant on the defined tree centre that is chosen, and two of the possible shapes are shown (in dark lines) for the corrected section.

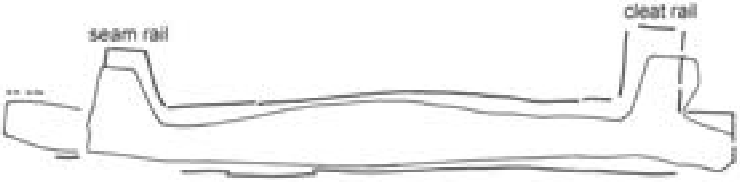


Figure 6.19 (left)
Revised shape of a bottom plank. The fine lines represent the excavated shape; the heavy lines are the estimated original shape following corrections to the medullary rays. Gaps in the heavy lines are areas where no correction could be estimated.

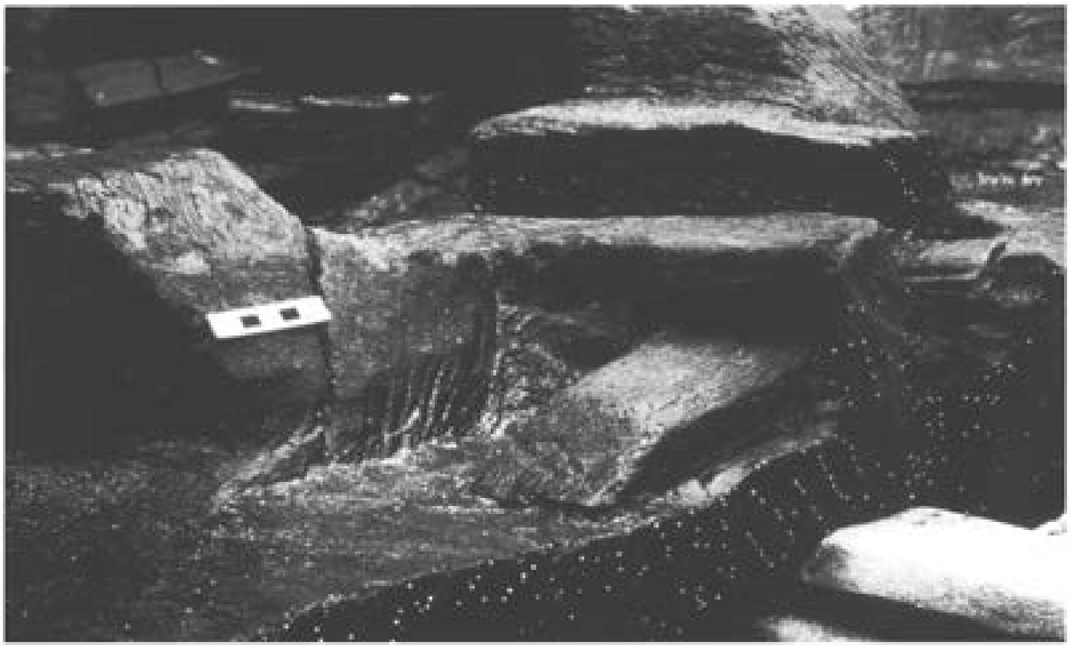


Figure 6.20
A section through the complex southern end of the boat, showing how stain-less-steel pins were used to trace the medullary rays in cross section.

7
Woodland management and timber conversion

by Richard Darrah

The position of the planks in their logs

In this section, we attempt to place cross sections of the boat planks in their correct position in a cylindrical tree trunk. The information used to do this comes from the dimensions of the planks, and the location of the annual rings and medullary rays seen in the cross sections. Understanding the position of the planks within the trunk informs our understanding of the size, straightness and utilisation of the trees originally used to create the Dover boat, and provides more information on the original shape of the planks used.

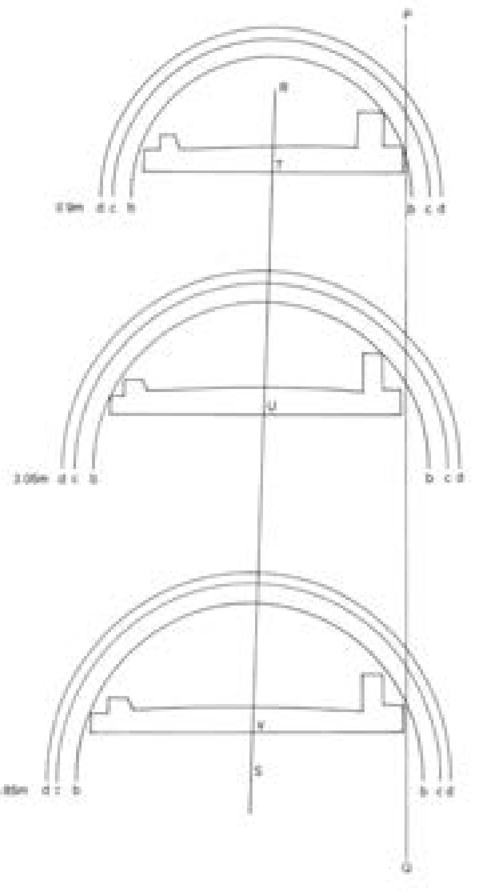


Figure 7.1
The three west bottom plank cross sections aligned along their central edges. The line PQ is spaced at the same ratios as they would be in the plank. A straight line (RS) drawn through the point where the vertical rays hit the bottom of the plank (T, V, U; the points directly above the tree centres) shows that these centres lie within 10mm of each other. This indicates that the tree is very straight over 5m of trunk length. The cross sections have been placed in a sector of tree trunk at the correct distance from the centre of the tree. By drawing on the missing sapwood and bark, the original tree diameter at the cross section can be estimated. BB: heartwood sapwood boundary; CC: sapwood bark boundary; DD: bark diameter.

Methodology and results

Confirmation of assumptions

To check the assumption that the tree is straight, the centres of the tree as calculated for each bottom-plank cross section were aligned, using the straight central edge of the west bottom plank (300), forming a straight line to within 10mm over a 5m length (Fig 7.1; Table 7.1).

Placing the bottom planks and iles in the trunks

The placing of the bottom plank in its tree was achieved using the centres defined by the compression work (Chapter 6), the vertical rays, to define the position of the plank directly over this centre, and the shape of the plank (the outline corrected for compression).

The bottom plank is drawn with the assumption that all the surfaces are flat (except the face inside the rails, which curves up to a high point of 70mm). The data from only the west plank have been analysed, as there is just one surviving cross section from the east bottom plank.

The ile was placed in the tree's cross section using the annual-ring data from the compression work, plus additional annual-ring data collected in 1997. The 1:1 data on a transparent film were placed on a set of concentric circles with radial rays, as well as the best fit found (by eye). To place the ile cross section in a sector of trunk, it was assumed that the central edge of each cross section of the ile aligns to a single radius of the log. This would be consistent with the log having been halved before the ile was carved out, and is consistent with data from the annual rings. Only the data from the west plank have been analysed, as there is insufficient annual-ring data from the east ile plank.

The diameter of the trunk

The minimum diameter of the tree at each cross section was determined geometrically by drawing a circle based on the centre of the tree that just touches the most

Table 7.1 West bottom plank cross-section data used to plot Figure 7.1

tree study number (Fig 6.10)	*distance of cross section from south end of plank (m)*	*height of plank above geometric centre of the tree (mm)*	*width of plank (m)*	*distance of vertical rays from central edge of plank (m)*
TS 11	0.9	70	0.67	0.34
TS 10	3.05	134	0.75	0.37
TS 6	5.85	125	0.81	0.385
north end*	10.0	–	0.85	–

* Measurements are taken from the reconstruction (Section 10).

Table 7.2 West bottom plank data used to work out the total diameter of tree at each cross section (in m)

tree study number (Fig 6.10)	*minimum diameter of heartwood*	*combined thickness of sapwood, assumed*	*combined thickness of bark, assumed*	*minimum diameter of tree, including heartwood, sapwood and bark*
TS 11	0.74	0.10	0.06	0.90
TS 10	0.86	0.10	0.06	1.02
TS 6	0.92	0.10	0.06	1.08
north end	0.92	0.10	0.06	1.08

Table 7.3 West ile plank cross section data used to plot Figure 7.2 and calculate minimum tree diameter at each cross section (in m)

tree study number (fig 6.10)	*distance of cut from south end of plank*	*minimum diameter of heartwood*	*combined thickness of sapwood, assumed*	*combined thickness of bark, assumed*	*minimum diametre of tree, including heartwood, sapwood and bark*
TS 13	0.6	0.58	0.10	0.06	0.74
TS 12	1.75	0.59	0.10	0.06	0.75
TS 17	2.85	0.65	0.10	0.06	0.81
TS 19	3.9	0.68	0.10	0.06	0.84
TS 18	5.85	0.77	0.10	0.06	0.93
north end*	11.05	no data	–	–	–

* Measurements are taken from the reconstruction (Section 10).

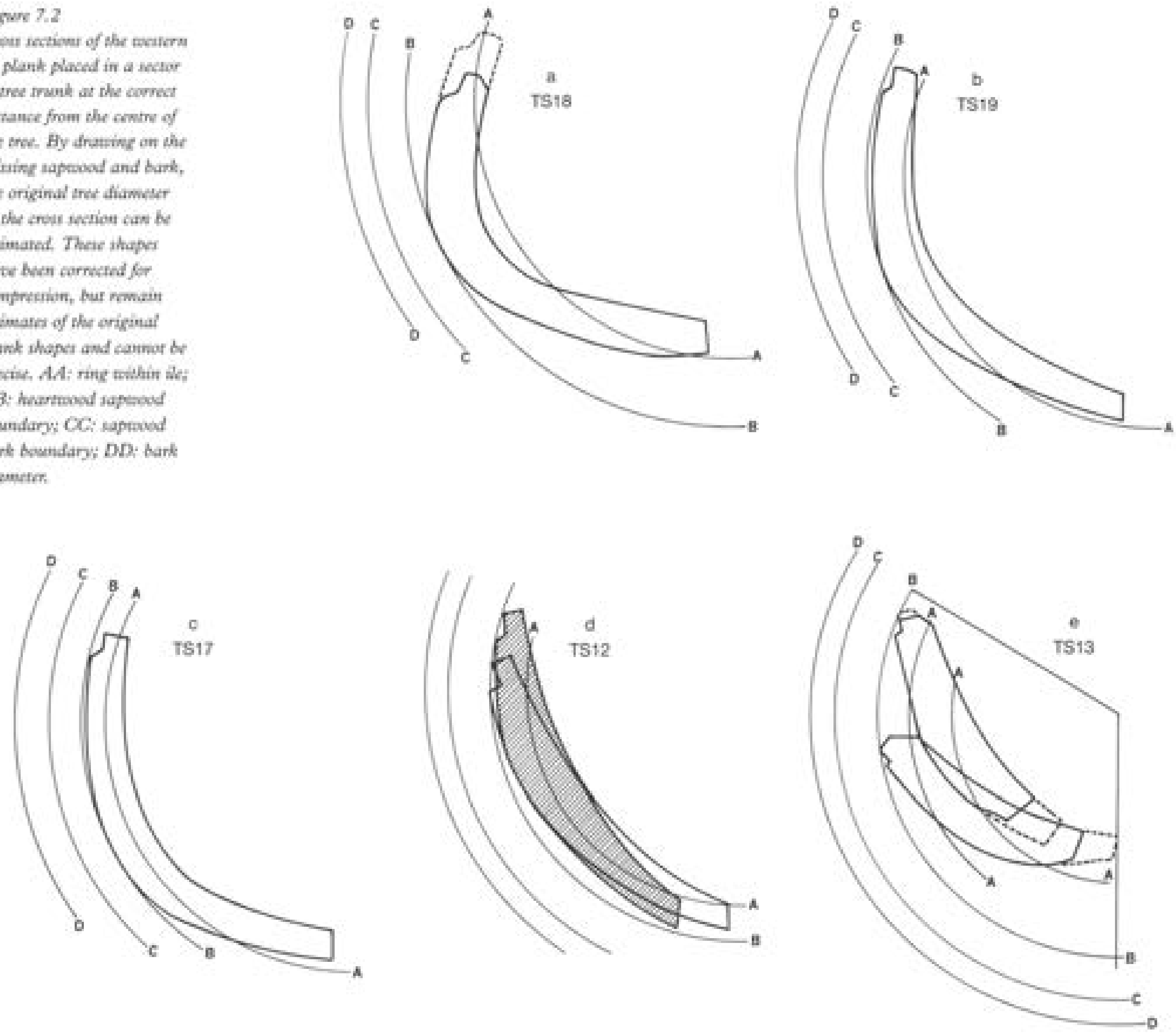
distant point of the cross section from that centre. As no sapwood was seen on the boat, this defines the minimum amount of heartwood.

To gauge the minimum size of the actual tree used, including sapwood and bark, some further estimates were made (Table 7.2). On the bottom planks, a second circle was drawn with a radius of 50mm more than the first to represent sapwood. Bark volume for a tree of this size is estimated at 9–12 per cent of the volume of the tree (Hummel and Waters 1950; Fig 7.1). For a tree of this size, the bark would add between 25mm and 30mm to the radius of the tree.

Only one complete cross section was recorded on the east bottom plank (303), so no data are recorded here. However, the cross section is very similar in size to the west bottom plank and there is no reason why it could not have been shaped from a similar-sized tree. The same process was carried out for the western ile timber (301; *see* Fig 7.2; Table 7.3).

A similar number of cross sections were recorded on the east ile plank (304), but the annual-ring data are more limited, and completely absent in the cross section closest to the southern end of the boat (TS 23; Gale 1994). This tree was probably a similar size to that used for the west ile plank (301).

Figure 7.2
Cross sections of the western ile plank placed in a sector of tree trunk at the correct distance from the centre of the tree. By drawing on the missing sapwood and bark, the original tree diameter at the cross section can be estimated. These shapes have been corrected for compression, but remain estimates of the original plank shapes and cannot be precise. AA: ring within ile; BB: heartwood sapwood boundary; CC: sapwood bark boundary; DD: bark diameter.



The original height of the trunk used
The height of the original tree trunks used to create the Dover boat can be estimated. The original height comprises the original length of each boat plank, plus the part removed in felling, plus the buttressing at the base of the tree (Fig 7.3). As the boat is incomplete, estimates of the original length of the boat have been used to make these calculations (Chapter 10; Table 7.4). It is assumed that the felling cut would be centred at 1m above ground level, thus avoiding the bottom 0.7m of oaks of this size that are heavily buttressed. Felling notches at 45 degrees in a trunk of this size would take up about 0.6m in trunk length. To reach an estimate of original tree-trunk height, 1.3m has been added to the estimated boat length.

The diameter of the tree required for the bottom planks
Having estimated the diameter of the trunk at each cross section, and the height of the trunk needed, the next stage is to define the minimum size of tree needed. For this, we need to know the taper of oak trunks and the cross section that defines the minimum trunk size (Table 7.5).

The boat tapers towards the south end, and, in both the bottom plank and the ile timber, the widest cross section is that nearest the (missing) north end of the boat. In both the bottom planks and the ile timbers, the base of the trunk lies towards this missing north end. The widest cross section suggests a tree diameter of 1.08m at that point and the indications are that this point is 5.15m above the base of the trunk.

From this, we can work out the diameter of the tree at breast height (1.3m), if we have information on the taper of the trunk. The taper of oak trunks is traditionally defined as 1 inch decrease in quarter girth every 6 feet of trunk length (James 1982). In this tree, this gives a diameter of 1.15m at breast height.

For a 12m-long trunk, with a 1.15m diameter at breast height, we should see a diameter of 0.93m at the top of the trunk. It is then necessary to confirm that each of the cross sections would fit in the defined log.

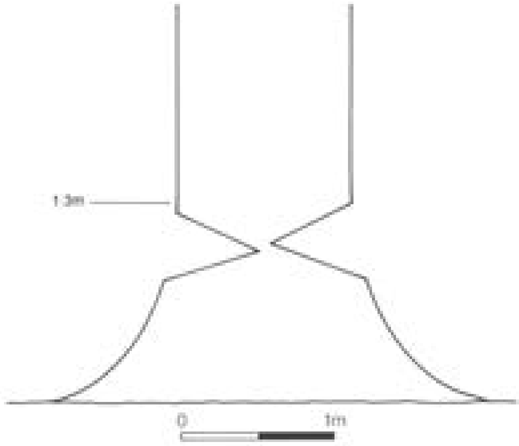


Figure 7.3
The height of the felling cut adds 1.3m to the trunk length required to make the planks. To avoid the extra effort involved in hewing away the buttressing at the base of the trunk, a felling cut centred at 1m above ground level has been postulated – a convenient height at which to use the short-handled bronze axes.

Discussion

Confirming the straightness of the trunks used and the shaping of the boat parts
Normally, the medullary rays and annual rings could be used to estimate the section of the tree from surface features, but with compressed wood this becomes difficult and, in many cases, impossible. Here, we rely on the ring and ray information from the sawn surfaces of the boat (the modern cuts forming cross sections across the body of the boat; Chapter 4, p 23).

The results in this chapter rely on the assumption that the trees are round and perfectly straight, and that the medullary rays point to the centre of the tree. Of course, in real life, trees are not quite that perfect, but, to discuss this evidence, we have to make this assumption and work from it. The assumption is shown to be realistic by Figure 7.1, which shows that the tree centres for the bottom timbers align well.

To align the centres, we have assumed that the central joint of the boat is a straight joint. If it were not a straight joint then the two halves of the boat would need to be pulled together in some way, and there is no evidence for this being achieved with fastenings or frames.

Bottom-plank data

Table 7.1 shows that the distance of the underside of the bottom plank from the tree centre varies between 134mm and 70mm over (the southernmost) 2m in length. In real trees we could expect there to be this variation in distance of the pith line from

Table 7.4 Original height of trunk used (in m)

plank	*estimated length*	*felling cut and buttress height*	*trunk height*
west bottom plank	10.0	1.3	11.3
east bottom plank	10.0	1.3	11.3
west ile plank	11.1	1.3	12.4
east ile plank	10.9	1.3	12.3
upper planks	?	1.3	?

Table 7.5 Size of tree needed to make the boat planks (in m)

plank	*length of plank*	*diameter of tree at 1.3m*	*length of trunk*	*girth of trunk at 1.3m*	*girth of trunk at top*
west bottom plank	10.0	1.15	11.3	3.61	2.90
west ile plank	11.1	1.04	12.4	3.23	2.67

the true centre of the tree, but in this case we are looking at the geometric centre, which is defined by the overall tree shape and not the pith line. What is more surprising is the evidence from Figure 7.1, which shows that the vertical rays are within 10mm of being in the vertical plane that joins the centres, if the planks are aligned along the straight central joint.

This seeming contradiction between a straight tree and a bent tree can be explained (Fig 7.4); a tree may be straight in one plane and curved in another. If one were selecting a tree that was not quite straight, one would align it so that it was straight in that plane at right angles to the plank that will be taken from it. In this way, any unevenness would not reduce the potential width of the plank. Small amounts of unevenness in the growth of the tree will be taken up by varying the distance of the plank underside from the centre of the tree, as occurs in the bottom planks.

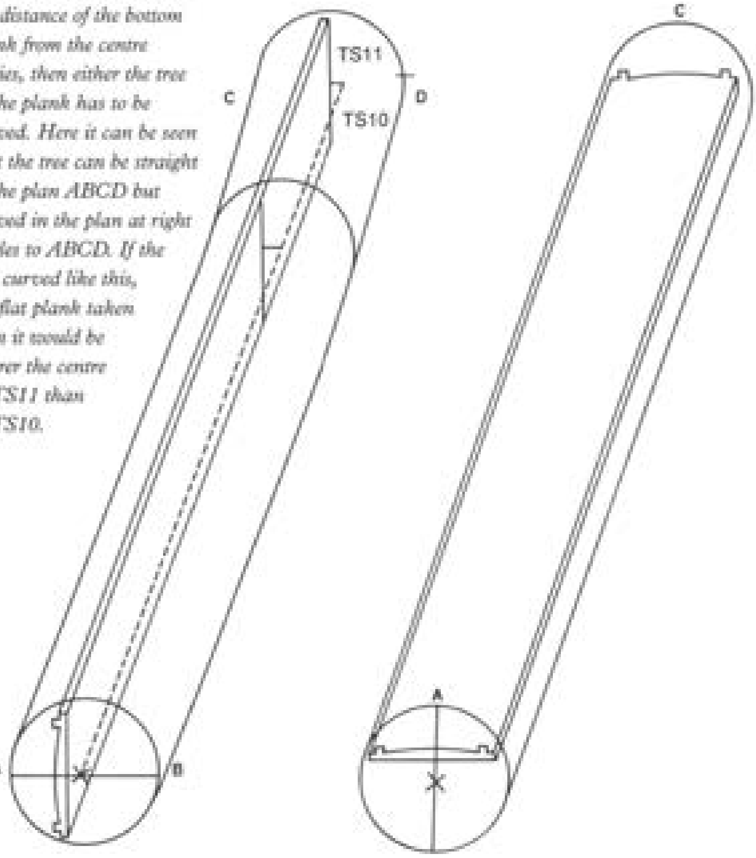


Figure 7.4
The convergence of the medullary rays in the plank cross sections indicates that the geometric centre of the tree is nearer the bottom of the plank at TS11 (70mm) than it is at TS10 (135) – suggesting the plank bottom is nearer the geometric centre (the centre created by projecting the rays back towards the centre from the established tree, ignoring the initial growth, which may be uneven). Thus, if the distance of the bottom plank from the centre varies, then either the tree or the plank has to be curved. Here it can be seen that the tree can be straight in the plan ABCD but curved in the plan at right angles to ABCD. If the tree curved like this, the flat plank taken from it would be nearer the centre at TS11 than at TS10.

Another possibility that would explain the centre of the tree lying closer to the plank bottom at the narrow end of the tree is shown in Figure 7.5. In this version, the tree is straight in all planes. As the plank nears the narrow end of the trunk, it is curved towards the centre of the tree. This gives more width for the plank at this point (where the trunk is narrowing), although the extra width might not be necessary here. As the bottom planks are joined to the ile timbers, the curved end would have to be pulled straight (and even curved a little back on itself), and this tension would provide vastly improved rigidity of the boat structure when in the water.

There is no evidence from the grain of the wood itself to support either of these possibilities, but it might be that the tensioned version produces a better boat structure.

The ile timbers

The compression report (Chapter 6) shows that the ile timbers are more likely to have distorted rays, which makes it more difficult to define the position of the tree centre without annual-ring data. These data were incomplete in the original tree-ring study, so the author collected further data in March 1997. Calculating the position of these ile timbers uses a combination of the data from the tree-ring study and the further data collected.

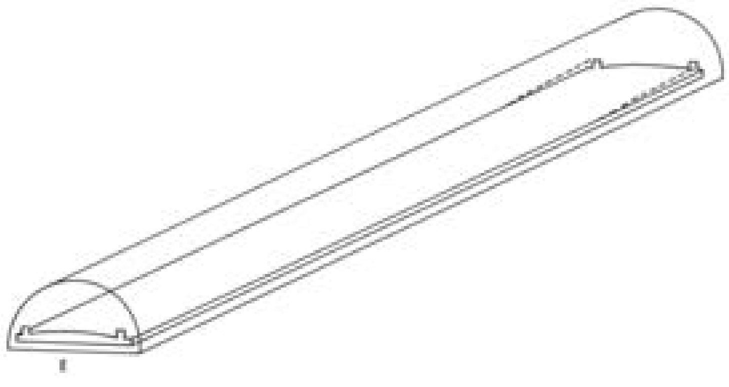


Figure 7.5
Here the tree is perfectly straight, but the plank has been carved down towards the centre at end E. In both cases, the annual-ring data and the ray data would be identical. In this case, the bottom planks would be tensioned when attached to the iles.

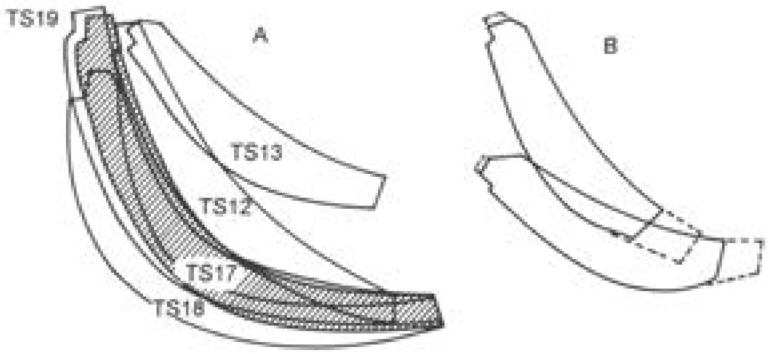


Figure 7.6
End-on view of the western ile cross sections. Note that these cross sections have been hung on their annual rings, and cross sections TS12 and TS13 can be rotated around these rings.

The ile timbers' curved cross section provides a third dimension to the boat's structure, allowing the iles to act as girders, lending rigidity to the floppy bottom planks.

There is a gentle curve in the edge of the bottom planks where they attach to the iles. The ile timbers might have been carved to accommodate this curve, or they might have been slightly bent to fit. The evidence from the annual rings and medullary rays in the cross sections of the iles show us how these timbers might have been carved from the original trunk. It is very clear that the whole ile timber in each case could have been carved from a half round timber (Fig 7.6), with the vertical face of the ile, where it butts onto the seam rail, lying at or very near the split diameter of the half round. None of the medullary rays come from a point on the other side of this suggested split diameter, so the ile cannot have been carved to fit onto the curve of the bottom plank. It must have been bent slightly or tensioned to fit. This bending of the iles means that the shape of the ile timbers was a result partly of the original carving and partly of bending near the south end of the boat.

The ile sections TS 12 and TS 13 (Gale 1994) have been placed in two positions, rotated around the annual ring, to show uncertainty as to where they were cut. There might also be subtler structural tensioning here too. If the ile timbers were not curved inwards to fit the curve of the bottom planks, it is quite possible that they ran straight, or that they curved outwards towards the southern end (*see* Fig 7.2e). If they did bend outwards, this would have allowed for more structural tensioning at the southern end of the boat

It is estimated that the bottom timbers (if carved flat) must be bent up by approximately 90mm (± 20mm) between TS 17 (Gale 1994) and the outer ends of the bottom plank. If the bottom plank was carved to curve downwards, and was then bent upwards, then this bending might be greater by as much as 50mm.

The cross section of the ile timber closest to the southern end of the boat (TS 13) shows clearly that this section originated closer to the centre of the tree than the other sections (Fig 7.6). The implication of this is that, to attach this end to the flat-bottom timbers, the end of the bottom plank will be slightly raised out of the horizontal plane. (It will be the bottom plank that 'gives' here, as the ile has extra rigidity, because of its curved shape.)

The length of the original planks

The original length of the planks used in these calculations is based on Owain Roberts' calculations on the maximum length of boat that could be built without the structure becoming too flexible and breaking up at sea (Chapter 10). It should be noted that the planks in this boat are under half the length of the trunks of tall bog oaks from the Atlantic wildwood (Rackham 1980). Plank length should not be assumed to have been a limiting factor in the construction of the boat until the supply of the tall trees, with over 1m diameter, was exhausted.

Bigger trees were used for the construction of both the Brigg and Hasholme boats (Millett and McGrail 1987). These both taper slightly over their length, but the taper seen is less than the estimate of usual taper which I have used in my calculations. This might mean that the level of taper on large, high, forest trees might be less than the average taper seen in modern oak trunks, so that the breast-height calculations might be slightly incorrect and the trees might be slimmer than estimated.

Shaping the bottom planks from what to us seems an oversized tree makes sense, as the wood removed from the underside of the plank would contain shakes and dry knots that would have seriously weakened the timber.

Tree sections and relative sizes

Figure 7.7 shows the relative sizes of trees needed for all boat components, and the tree sections used. It is assumed that the south end board (Timber 306; Fig 7.8) would be a very wide tangential plank, but that the end board to the north would be a narrower tangential plank across the width of the boat.

Conclusions

Analysing the data from the bottom planks and iles enables us to work out the following.

From the size of trunk cross section required to contain the boat planks, we can estimate the minimum size of the trunks needed to make that plank. The bottom

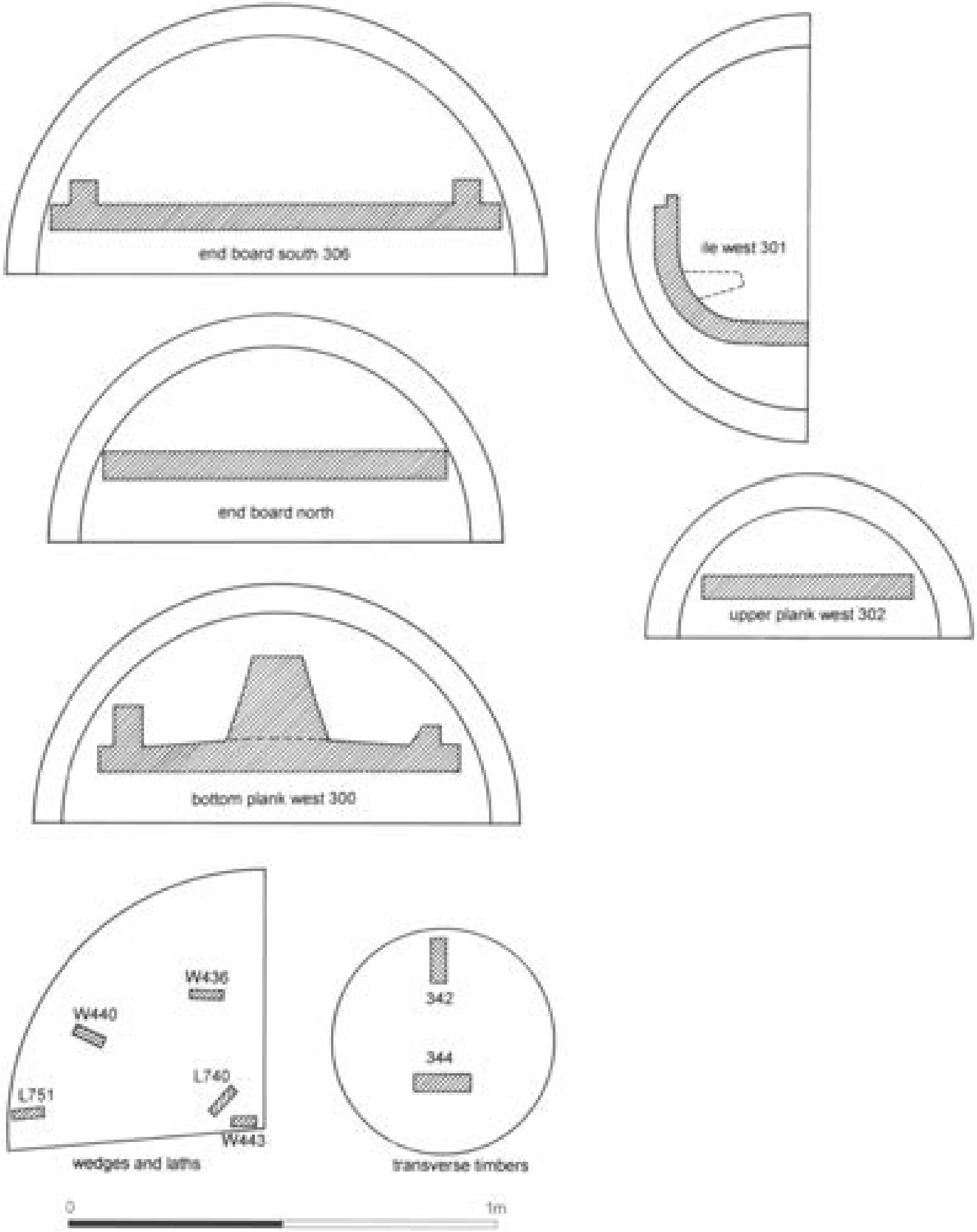


Figure 7.7
All the oak components used to build the boat are shown in the minimum size of tree cross sections from which they could have been made without using sapwood. The widths of the end plank, upper side plank and stern plank are taken from Owain Roberts' reconstruction (Chapter 10); the others are calculated from actual boat parts. Some of the wedges, laths and transverse timbers have been drawn in separate trunks to show the different positions and sections from which they may have been cut (although it is likely they would have been made from off cuts left from the shaping of the main planks of this boat or other similar sources).

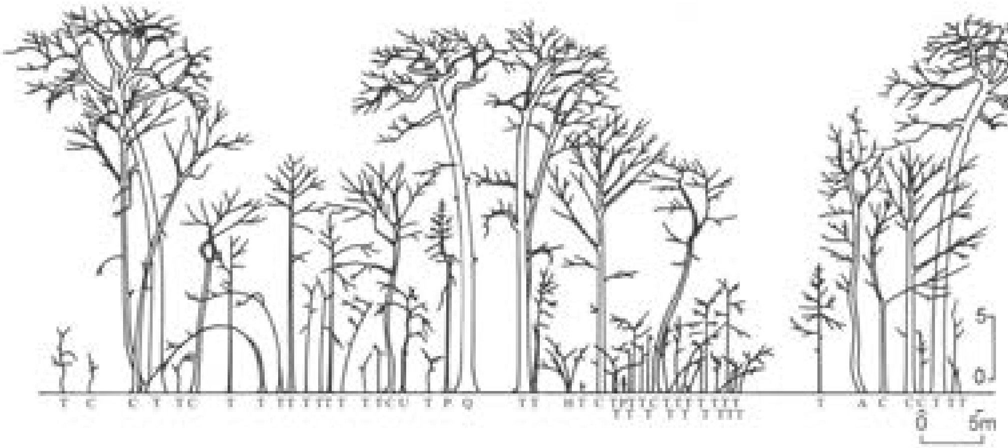


Figure 7.8
Section through Polish woodland showing the size and growth habit of tree that the builders of the Dover boat would have been searching for. The section is of a 2m wide transect of the trees growing in the Bialowieza Forest, Poland and clearly shows the size and height of the canopy trees, most of which are lime. Pollen evidence suggests that lime was more common than oak in woodlands of Southern Britain in the Neolithic and Early Bronze Age. The trees are closely spaced; the central oak (Q) and lime (T) are each approximately 1m in diameter, but are growing less than 6m apart. Note that two species, Acer platanoides *(A) and* Picea abies *(P), would not have been found in British woodland. Other species depicted include* Tilia cordata *(T);* Carpinus betulus *(C);* Ulmus glabra *(U);* Quercus robur *(Q) and* Corylus avellana *(H); after Piggott 1975.*

planks come from trees with trunks of at least 11.3m in height, and a diameter at breast height of 1.15m (with a girth of 3.61m). The ile planks come from trunks of at least 12.4m in height, and a diameter at breast height of at least 1.04m (with a girth of 3.23m).

In the west bottom plank, the position of the underside of the plank in relation to the geometric centre of the tree shows that the plank might have been carved with a curve towards the narrower end of the trunk, providing extra tensioning for the boat.

From the alignment of the vertical rays, we can confirm our assumption that the trunk was straight – at least in one plane.

The two bottom planks are each made from a half of a trunk, and the iles are each made from less than a third, but more than a quarter, of a trunk.

The shape of the iles and the bottom plank suggest that there was some bending and tensioning when the sections of the boat were joined together. This probably resulted in a slight rocker in the bottom of the boat.

Timber quality

Here, we attempt to define the quality of the oak timber used in the building of the Dover boat. The growth rates, medullary rays, direction of the grain, and the position and size of knots are discussed to provide evidence for the type and size of tree used, and available for use, at this period.

The knot and grain-direction information used for this section was gathered independently by the author (as annotated drawings and notes), and by Caroline Caldwell in her drawings of the timbers. The information was checked between the sets of information for accuracy.

The cross-section evidence, giving annual-ring widths, medullary-ray thicknesses and spacings was gathered by the author in note form. Alison Gale's tree-study report (1994) also provides some evidence of annual-ring counts and growth rates. However, some of the ring counts were taken where the wood was compressed and distorted, so that the original annual-ring widths will have been altered. Data from only the undistorted areas of the planks have been used. (These areas are defined as being where the medullary rays and that annual rings are still at right angles to each other.)

The lengths of the medullary rays were recorded by the author in note form from the surfaces of the planks before conservation. Compression of the surface layers does make reading of the grain direction very difficult. This was initially misleading, and the existence of compression must be appreciated before information is extracted in this way.

Individual timbers

Bottom plank west (300)
The surviving length of the trunk in this plank is 7.1m. Its maximum width is 0.81m at the north end (minimum width 0.67m); as no sapwood survives at any point on the plank, we have no evidence of the full width of the trunk. The direction of growth of the knots indicates that the top of the tree is to the south end. As the bottom 4.2m of the trunk is missing from the north end, the minimum original trunk length was 11.3m. The estimated minimum age of this tree is 350 years.

The grain is straight for the bottom 4m and spirals slightly in the top 3m of the plank. The early years of growth are missing, as the central part of the tree has been cut away (probably the first thirty to sixty years have been removed). The annual-ring width is 2.5mm (at this most central surviving point); growth continues evenly, but slowly declines until the rate is less than 1.5mm per year. It is impossible to measure the outer rings, as these have been squashed together by compression, but, even here, the growth rate is over 1mm per year. Medullary rays are about 0.5mm in width, and slender (Table 7.6).

There are three knots: A, B and C (Fig 7.11). Knot A is small and growing horizontally, suggesting that it is an epicormic growth rather than a branch. Only the top two knots are from real branches, growing at a steep angle of 30 degrees to the trunk (*see* Fig 7.12).

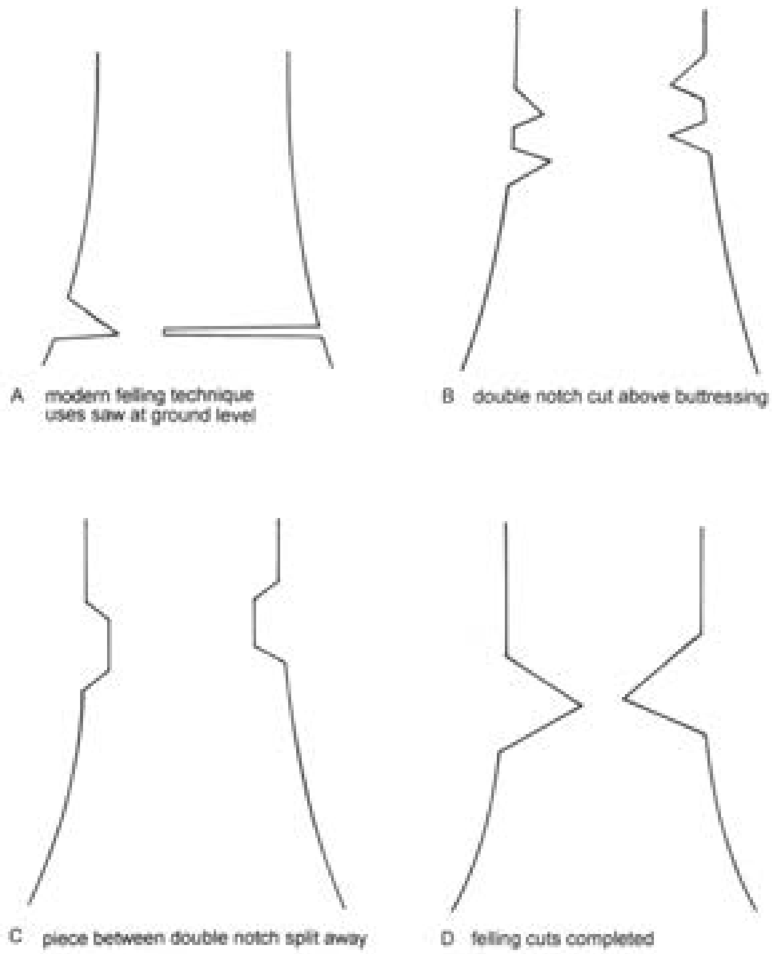


Figure 7.9
The felling process. The trees would be felled above the buttressing using bronze axes (weighing less than 1kg) to cut a double notch, before splitting out the piece between the notches.

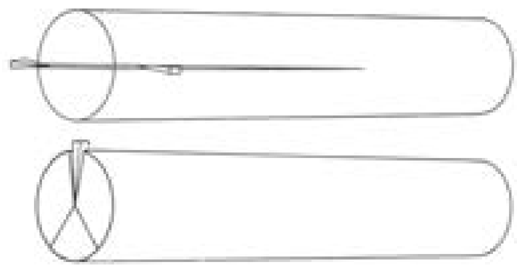


Figure 7.10
The position of the log when split. Splitting from both sides enables one to control the direction of the split; splitting from the top may cause the split to form at the centre.

Bottom plank east (303)
The surviving length of the trunk in this plank is 8.6m, and its maximum width is 0.86m near the north end (minimum width 0.67m). The direction of growth of the knots indicates that the top of the tree is to the south end. As the bottom 2.74m of the trunk is missing from the north end, the minimum original trunk length was 11.3m. The estimated minimum age of this tree is 375 years.

The grain is straight over the whole length of the plank. The early years of growth are missing, as the central part of the tree has been cut away (probably the first thirty to eighty years have been removed). The annual-ring width is 2mm nearest to the centre of the tree. Growth continues evenly, but the rate slowly declines to less than 1.5mm per annum. It is impossible to measure the outer rings, as these have been squashed together by compression, but, even here, the growth rate is over 1mm per year. Medullary rays are 1mm in width and broad – about 50mm long, going up the tree.

There are five small knots in this plank (A, B, C, D and E; *see* Fig 7.13), all less than 60mm in diameter. Knot B was seen in section in a crack in the boat timber; it was completely overgrown on the side of the plank inside the boat (the boatbuilders had acknowledged its presence by leaving the plank thicker at this point). This branch, like the branches on the west bottom plank, was growing at a steep angle to the trunk. The other small branches have not increased in size through the plank thickness, suggesting that they were either moribund or epicormic.

Comparison between timber quality of east and west bottom planks
The minimum size of the trees from which the two planks come is roughly the same. The east bottom plank is wider near the base, but this is because it is longer. The minimum age of the trees is similar. Both trees lie with their top ends towards the south end of the boat.

Table 7.6 Information on medullary ray thickness, length and characteristics

plank	*ray thickness (mm)*	*ray length* (mm)*	*ray description*
west bottom plank	0.5	(no measurement)	slender
east bottom plank	1.0	50	broad
west ile plank	0.5	100	very long
east ile plank (section M)	0.2	100	very thin
east ile plank (section O)	0.5	100	thin

* Ray length refers to the vertical length of the rays up the height of the trunk of the tree.

The grain of the west bottom plank is straight at the end nearest the base, but spirals slightly at its top end. The grain of the east bottom plank is straight all the way up. A similar width of timber has been removed from the centre of the tree on both planks, but as the growth of the east plank appears slower, this represents more years cut away. Annual ring width falls from 2.5mm in the west plank and from 2.0mm in the east plank to less than 1.5mm in each. Medullary rays are distinct, being thinner in the west plank.

Knots in both timbers were small and, where these represent branches, they are pointing upwards at a steep angle. All knots were smaller in their outermost sections, suggesting that they were branches in the process of being overgrown by the trunk.

There is a subtle distinction in the form of the spring vessels and the ratio of the spring vessels to the summerwood; the pattern on the two planks looks different.

Ile plank west (301)

The surviving length of the trunk in this plank is 6.8m, and the maximum diameter of the trunk it represents is 0.93m at the north end. As the piece is carved in a curved cross section, 0.93m is not the width of the plank, but the diameter of trunk from which it was carved. No sapwood survives at any point on the plank, so we have no evidence of the full diameter of the tree. The direction of growth of the knots indicates that the top of the tree is to the south end. As the bottom 5.6m of the trunk is missing from the north end, the minimum original length of the trunk would have been 12.4m. The estimated minimum age of this tree is 325 years.

The grain spirals slightly over the full length of the piece; it has moved 30 degrees round the circumference in 7m. As the iles are hollowed sections over the majority of their length, the rings nearer to the centre of the tree have been cut away. Clues to earlier growth of the tree come only from the south end and the cleats. Here, the growth rate is slightly faster than that further out in the ile. The annual rings show slow decline from 2mm to 1mm. The growth rate in this plank is slightly slower than in the bottom planks. The medullary rays were very long, up to 100mm, and slender (less than 0.5mm width).

There are three knots on this timber. These are small knots, less than 30mm in diameter, and smaller towards the outside of the tree, indicating moribund branches. Only knots A and B (*see* Fig 7.14) can be seen on both faces of the ile timber; these knots were growing at an angle of 45 degrees to the trunk.

Ile plank east (304)

The surviving length of the trunk in this plank is 8.7m, with a 1.3m section missing near to the north end of the boat. The maximum diameter of the trunk it represents is 0.9m at the north end. As the piece is carved in a curved cross section, 0.90m is not the width of the plank, but is the diameter of trunk from which it was carved. The direction of growth of the knots indicates that the top of the tree is to the south end. As 3.6m of the trunk is missing from the north end, the minimum original trunk length was 12.3m. The estimated minimum age of this tree is 325 years.

The grain may spiral slightly over the full length of the piece, but the evidence is not so clear here as it is in the west ile. The annual rings show a slow decline from 1.6m to 0.8mm, the growth rate being similar to the west ile plank. The growth rate in this plank is slightly slower than in the bottom planks. The rays were very long, up to 100mm, and slender, at less than 0.5mm in width, some as fine as 0.2mm.

There are three knots on this ile timber, all less than 30mm in diameter (although in different positions along the timber). Again, two of these knots can be seen on both sides of the timber but there is no information on the angles of these branches or growths.

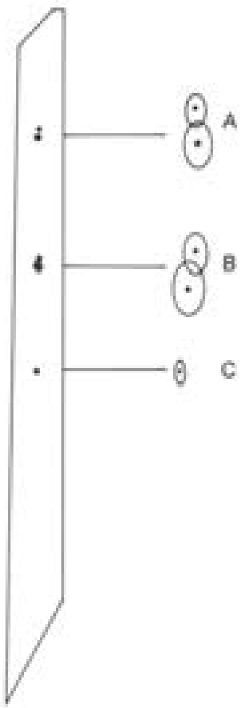
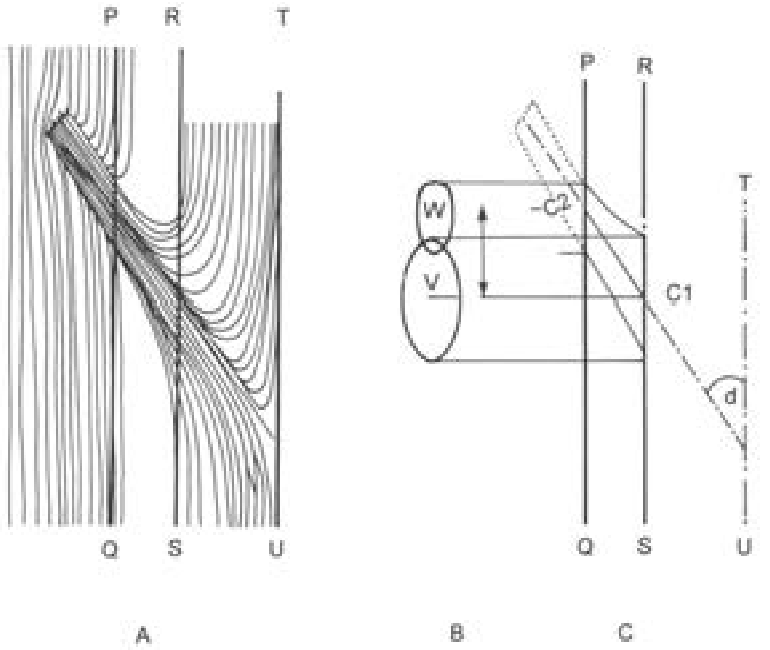


Figure 7.11
The positions of the knots in the west bottom plank. Knot A is small and growing horizontally, suggesting that it is an epicormic growth rather than a branch. Only the top two knots are from real branches, growing at a steep angle of thirty degrees to the trunk.



Key
PQ: the face of the bottom plank furthest from the tree centre pith line
RS: the face of the bottom plank closest to the tree centre (the underside of the plank)
PR: the thickness of the bottom plank (70mm ± 10mm)
TU: the pith line of the tree, the vertical direction of growth; d is the angle of the branch to the pith line, i.e. the angle of the branch to the trunk
V and W: the relative positions of the centres of the knot when superimposed on overlays, the ovals around them representing the maximum size of the knot
C1: the centre of the knot on the plank face nearest to the tree centre
C2: the centre of the knot on the plank face furthest from the tree centre

Figure 7.12
The method used to measure the angle of the branches. A: the section through the middle of the branch in the longitudinal cross section of the bottom plank with spring vessels sketched. B: the relative position of the knots in cross section as they appear on the overlays. C: in the same section as A without spring vessels. The line through the pith of the branch (C1–C2) can be extrapolated back to the pith of the trunk to give the angle at which the branch grows to the trunk. This angle can be calculated if the relative distance between the centres V and W is taken from overlays made from the scale drawings and the thickness of the plank PR is known. The distances between V and W for knots A and B on the west bottom plank are both 130mm ±10 mm; the thickness of the bottom plank is 70mm ±10mm.

Comparison between the timber quality of the ile timbers

The minimum lengths of the original trunks are very similar, as is the minimum diameter and the approximate age of the trees. The west ile has a clear spiral to the grain; this might be present in the east ile, but, as it is broken, the presence or absence of a spiral is less clear. The growth rate of both ile planks slowed with time, the eastern ile slowing more than the western. This could be because the east ile had been carved out of a younger section of the trunk (further from the centre of the tree). Both show long, slender medullary rays, and in both planks there are several small knots.

Discussion

The trunks used to make the four main boat planks are all similar; they were all straight oak trunks at least 11m long and 1m in diameter. They have few knots; those that are present are small, resulting from branches that do not appear to be growing and which (in the case of the bottom planks) had grown at a very steep angle to the trunk. In all four trunks the growth rates slowly decline, from about 2.5mm to 1.0mm per annum (Table 7.7).

The long trunk lengths, absence of side branches and slow growth rate, all point to these trees having grown in dense woodland, where absence of light causes lower branches to die while still small (this is seen clearly in knot B on the east bottom plank; Fig 7.13). The fact that all the branch cross sections are smaller further out from the centre of the trunk suggests that they might already have stopped growing and might have been about to die and drop off.

The two bottom planks are both made from straight-grained oaks with few branches. Could they represent two halves of the same tree? The differences in the characteristics of the two planks are in their growth rate near the centre, the slight spiral in the grain of the west plank, the different thicknesses of the medullary rays, and the difference in the spring and summer vessels of the annual rings.

The spiral in the grain of the west plank (absent in the east plank) could be explained by the two planks having been taken from different heights of the two split halves of the same trunk. It is also possible that the distinct medullary rays represent the adaptation of a single trunk to different stresses in different parts of the trunk (the medullary rays of a tree give it some of its strength, so that rays might be thicker near knots). It is more difficult to explain how two planks from one trunk could have such different patterns of spring and summer vessels in the annual rings, and such different initial growth rates; the west bottom plank has a growth rate of 2.5mm, whereas the east bottom plank has a growth rate of 2mm.

On balance, the evidence suggests that the two bottom planks in this boat were made from different trees.

The two ile planks both have very similar long, fine medullary rays, and the types of knot are similar. The growth rates are slightly different, but this could be explained by the two curved timbers having been carved at slightly different distances from the centre of the tree. The spiral in the grain of the two planks is more difficult to interpret (it is less clear in the eastern ile plank), but here the evidence suggests – though one cannot be certain – that these timbers could have been carved from the same tree.

The evidence that would be very helpful in determining whether the ile timbers or the bottom timbers were taken from the same trunks, from trunks growing near each other, or from trunks at distant locations from each other is the dendrochronology. Although the combination of radiocarbon dating and dendrochronological analysis has provided an estimate for the date of construction of the boat, the extra information obtained on the age, source and association of the timbers by dendrochronology would justify looking for unbroken sets of annual rings (Chapter 13).

Similar growth habits are found in the bog oaks of the Cambridgeshire fens. These were trees that were growing on the silts before the fens were flooded, so they represent the mature Atlantic woodland, remnants of which still survived through the Bronze Age. Peterken's (1981) description of one of these oaks is summarised below.

Apart from two short bursts of faster growth rate at years 27 and 56, the tree grew remarkably constantly, with an annual-ring width of less than 1.5mm per year. When the tree reached 200 years, the growth rate slowed down to under 1mm per year until it fell when it was more than 340 years old. This growth rate is similar to that seen in modern oaks growing in densely stocked high forest in France.

This tree was of the size of the trees used to build the Dover boat, as it had a heartwood diameter of 1m at 6.5m above ground level. The trees used to make the bottom planks had been growing appreciably faster than Peterken's oak. Their growth rate is not so even, but slowly declines from 2.5mm to 1mm over 300 years. This suggests a slightly different type of growth. It might represent a 'dominant tree', which outdoes its competitors and gets more than its share of the light, enabling it to grow faster than other trees. Its slow decline is caused by its laying down a similar amount of wood each year, but on a larger diameter of trunk. If these are the more successful trees of the forest, they are probably being used for the bottom planks because they have a larger diameter.

Peterken suggests that the size of the tree he describes is the limiting size of oak trees in this type of woodland. If this is the case, it might be that the maximum width of the bottom planks is determined not by boat design, but by the maximum plank width available.

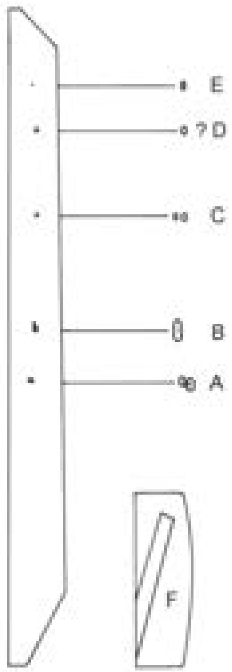


Figure 7.13
There are five small knots in the east bottom plank, all less than 60mm in diameter (A, B, C, D and E). Branch B was seen in section in F, a crack in the boat timber; it was completely overgrown on the side of the plank inside the boat (the boatbuilders had acknowledged its presence by leaving the plank thicker at this point). This branch, like the branches on the west bottom plank, was growing at a steep angle to the trunk when it died. The other small branches have not increased in size through the plank thickness, suggesting that they were either moribund or epicormic.

Table 7.7 Information on growth rate from annual rings

plank	*section*	*growth pattern*	*ring widths (mm)*	*average (mm)*
west bottom plank	D, near outside*	slow decline	1.9–1.6	1.83
west bottom plank	E, near outside*	slow decline	1.1–1.0	1.05
west bottom plank	R, near centre*	slow decline	2.2	–
west bottom plank	T, near centre*	slow decline	2.5	–
west bottom plank	T, over 165 rings (280mm)	slow decline	2.5–1.0	1.70
east bottom plank	R, near outside*	slow decline	1.9–1.2	1.56
east bottom plank	T, near centre, 30cm from centre*	slow decline	2.0	–
west ile plank	K, near centre*	slow decline	2.0–2.1	2.05
west ile plank	Q, near outside*	slow decline	2.0–2.25	2.1
east ile plank	B, near outside	–	1.3	–
east ile plank	J iii, near outside*	slow decline	1.6, 1.2–0.8	–

* Centre and outside refer to the position relative to the centre of the tree rather than the centre of the boat. The position of measurement of annual rings depends on the position of compression in the plank; no measurements are taken unless the annual rings are at right angles to the medullary rays.

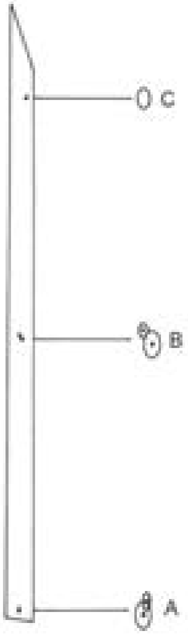


Figure 7.14
There are three knots on this ile timber. These are small knots, of less than 30mm diameter, and smaller towards the outside of the tree, indicting moribund branches. Only knots A and B can be seen on both faces of the ile timber, these knots were growing at an angle of forty-five degrees to the trunk.

Summary

1 The four main timbers used to create the Dover boat all lay with their top ends towards the south end of the boat.
2 Each of these four timbers shows a slow rate of decline in its growth rate over time.
3 The trees used to make these planks were each around 350 years old.
4 Most of the timber used was straight grained, but there was a slight spiral in the upper timber of the western bottom plank and the western ile timber (this spiralling would not be serious enough to prevent the splitting of the timbers along their length).
5 Only small knots were present in the four timbers, indicating an absence of large side branches and suggesting growth in dense woodland.
6 The slow, even growth rate is the type of growth rate associated with dense, high forest.
7 A faster rate of growth than that found in similar-sized bog oaks suggests that the timber for these planks came from especially vigorous or 'dominant' trees.
8 It is not clear whether the two bottom planks were cut from the same trunk or from different trunks. The evidence suggests that they were probably cut from different trunks.
9 Similarly, it is not clear whether the two ile planks were cut from the same tree. The evidence suggests that they were.
10 The iles could not have been made from the same trees as the bottom planks.

The source of the timber and its extraction

Here, we attempt to build up a description of the type of woodland that acted as the source for the boat timbers. It is important not to assume that the boat was found where it had been built, or even that it was built where the timber was grown.

Source of the trees

We do not know where the timber used to build the Dover boat was grown. It might be from southern Britain, or from any part of continental Europe. For the sake of discussion, we have assumed that the source was southern Britain, although this is far from certain. Some support for the assumption of a British source is that the only finds of Bronze Age, stitched-plank boats have been in Britain (from Yorkshire southwards).

The previous discussion established that the timber probably came from dominant trees growing in dense woodland. The main timbers were oak; we cannot tell from the timber alone whether the trees were sessile or pedunculate oak. Their trunks were straight, up to 1.2m in diameter at breast height, without side branches, and at least 12m long before the crown developed (*see* Fig 7.17). These trunks are longer and larger than almost all the oaks now growing in northern Europe (Rackham 1980).

The growth habit of the trees used to build the Dover boat strongly indicates that they started their lives in dense woodland (or rapidly regenerating dense woodland). It would not be possible to fell heavily around a tree of this size without dramatically increasing its risk of wind blow and altering its growth rate. The evidence suggests that these trees spent their lives in large patches of dense woodland over fifty hectares in extent.

The size of the boat timbers suggests that the prehistoric woodland used to make these boats was a remnant of the Atlantic period wildwood (Rackham 1980), still growing in areas not cleared by Bronze Age or Neolithic farming techniques. Our knowledge of this woodland is based on several separate sources, including: boat finds, surviving ancient woodlands, pollen evidence, bog oaks, submerged forests and barrows.

The timbers of the Dover boat, the Caldicot and Ferriby boats, and the Brigg raft (McGrail and Kentley 1985; Nayling 1993; Wright 1990) indicate that a boat-building tradition requiring these large trunks existed in the Bronze Age. The Hasholme log boat suggests that even larger trees continued to be available into the Iron Age (Millett and McGrail 1987).

Surviving ancient woodlands define the diversity of species and soil types that we might expect to find on sites that have never been ploughed or cleared of tree cover. They do not tell us about the genetic stock or growth habit of the trees that would have been found in climax prehistoric woodland. The genetic stock has been altered by the management of woodland, where repeated selective felling results in continual selection of the best trees (which tends to leave the poor stock to seed; Dimbleby 1967). This management frequently encouraged the development of an under storey at the expense of taller trees.

These woodlands do tell us that the species mix of woodland is very variable. This is supported by pollen evidence (Rackham 1980; Peterken 1981) that suggests that the woodlands (in southern England) were seldom more than 25-per-cent oak, with lime often being a commoner species. Even then, the dominant species may vary with time, but, as this variation is patchy, the overall mix of species remains constant.

A drawing by Pigott (1975) of a section through the almost undisturbed stands of the Bialowieza forest (an existing ancient woodland in Poland) shows a large oak with a canopy height of 30m and trunk in excess of 20m (*see* Fig 7.8). It shows exactly the variation in tree type, growth habit and size that the boatbuilder might have come across when searching for the trees from which to build the Dover boat. In this 50m-long, 2m-wide strip through the woodland, the close spacing of the trees can be seen; the central oak (Q) and lime (T) are each approximately 1m in diameter, but are growing less than 6m apart. Two species in the drawing, *Acer platanoides* and *Picea abies*, would not have been found in British woodland.

The modern image of the oak tree is of the free-standing tree, maybe from a hedgerow or parkland. These trees, not constrained by neighbours, have shorter trunks, side branches, and large crowns. In contrast, woodland trees are forced up by competition with neighbours, so they have long trunks and narrow crowns. Modern plantation woodlands are usually grown on rotations of under 150 years, so, even in plantation oaks in Britain, we do not see a parallel to the 350-year-old oaks used in the Dover boat. There might also be genetic differences, as discussed earlier.

Bog oaks from the fens indicate the size to which oak trees grew in the Atlantic period. Godwin (1975) mentions an example of bog-oak trunk that was 27.5m to the first large branch, and even modern foresters expect total tree heights of 30m in plantations. Thus, we might expect that, in patches of forest that had remained relatively undisturbed for 500 years (either one that began growth in the Atlantic forest or regenerated in the sub Boreal), we might find groves of large lime and oak trees with trunk diameters of about 1m and lengths in excess of 20m. Peterken sites an example of the life history of a forest oak that had a heartwood diameter of 1m at 6.5m above the ground.

Submerged forests are found throughout the coastal areas of Britain. These date from around 3000 Cal BC (*c* 4400 BP), rather earlier than the Bronze Age. They indicate that woodland containing large-diameter trees was common at this stage, and they support the pollen evidence for the presence of mixed species. These forests have not yet been thoroughly studied and so cannot tell us much about woodland at this time, although they represent a significant source of potential information.

Barrows, and other field monuments from the Bronze Age, indicate that the areas where they exist had been cleared of tree cover, as they were built for visibility. We know – from pollen evidence (Godwin 1962) – that there was woodland clearance in Kent in the Bronze Age, and that a large number of barrow sites existed. The presence of barrows in much of southern Britain suggests that there had been substantial clearance of woodland at this stage, but gives us no information about what remained.

Extraction of timber

Selection of trees

Bronze Age people would have regularly utilised wildwood resources (*see* Fig 7.15); there would have been people who knew where the best trees for any specific job were growing. The boatbuilder, or the person selecting the tree, would have knowledge of the shapes of the trees and their heights. The history of the trees and their qualities would be understood from the markings on the bark (without needing to fell the tree; *see* Fig 7.16). The fissures in the bark told the speed at which the tree had grown and how straight the grain (hence, whether or not the timber would split straight along its length). Scars on the bark showed any damage to the tree, and where and how big the branches had been (even if they had broken off many years before, leaving no other trace on the trunk).

Trunks of the quality used to build the Dover boat might have been selected previously and marked with an ownership mark. Selection of timber would have tended to occur in the winter, as visibility is much improved in the absence of leaves. It would be unlikely that the selected trees would have been growing side-by-side, and they could have been several miles apart.

Figure 7.15 (opposite) A reconstruction of the prehistoric wildwood; tree-felling would most likely have taken place during the winter, when the work would be less complicated by foliage.

Felling

The trees in high forest grow close together. If the selected tree was a dominant tree that overshadowed its fellows (as seems likely), it was probably necessary to climb the trunk and remove all the branches before felling, so that the tree did not become lodged in surrounding trees (*see* Fig 7.17). Removing the crown first would also make the felling easier to control and reduce the risk that the long trunk would be damaged by flexing as it hit the ground. The removal of the branches and crown would have taken a similar time to the felling itself (Table 7.8).

Bronze axes (including their handles) rarely weigh more than 1kg; they are much lighter than modern steel axes, and are hafted with shorter handles. This suggests that they were used with a shorter stroke (Coles 1979). The modern way of felling a tree is to cut two notches from opposite sides leaving a hinge of wood across the diameter of the tree; this controls the direction of felling and slows the rate at which the tree falls. Trunks from the river Trent indicate that this technique of cutting from two sides was in use in the Bronze Age (C Salisbury, pers comm). It is likely that these ancient tree-fellers would have felled the tree above the buttressing, by centring the cut at a height of about 1m. Ropes or poles might have been used to start the tree falling in the correct direction. Figure 7.9 shows this, including the double-notch technique that would have speeded up the felling process.

In post-medieval centuries, felling has tended to occur in the winter (Edlin 1949). This might also have been the case during the Bronze Age, as it is easier to work in woodland during the winter. If we had found some sapwood in the Dover boat we might have been able to discern the season of felling from the sap–bark interface (looking at whether the spring and summer vessels were complete), but, unfortunately, this was not the case.

From bucking (crosscutting) on the reconstruction (Chapter 9), we estimated that a tree of this size could have been felled by two people in a long day, if each cut out a notch on opposite sides of the tree. The complete felling process would have taken about 20 person-hours per tree (Table 7.8). It would not have been possible to fell it by burning, as oak does not burn when green (Rackham 1980).

Splitting the trunk in half

Once on the ground, the tree would have been examined in more detail. If it were found to be useable, it would be rolled over until the plane along which it was to be split was horizontal (Darrah 1982; *see* Fig 7.10). This plane would be chosen to be knot-free. The tree would then be split into two halves using wooden wedges and wooden mauls (Coles and Orme 1980).

When the tree was halved, the boat-builder would assess whether the timber was suitable for use in the boat or for some other purpose. The timber would then be cut to its final length, possibly by removing pieces from both ends of the 20m trunk.

It is not known how easy it was to work the type of oak used to construct the Dover boat. Modern oak, grown in conditions that result in a slow, even growth rate, will tend to be easier to work than faster-grown oak (which is often used today). The timber used to make the boat could have been easier to work than we would suppose.

The length of time that a split takes varies from tree to tree. Trunks of 10m or 12m can be split in a single day, so one might expect a tree of this size to take less than two days. It would take longer to make the wooden wedges and mauls, than it would take to split the tree into two halves (Table 7.8). In this boat, two different trees were used for the bottom planks, increasing the time needed for felling and splitting.

Extraction

Once the tree had been split and cut to length it would be ready for extraction from the wood to the site where the boat was to be built. This would be a site next to water,

Table 7.8 Estimates of the times taken to fell and convert a trunk of over 1m diameter and more than 12m long

task	*number of people*	*days*	*total days**
selecting the tree	1	1	1
cutting out the top	2	1	2
felling the tree	2	1	2
making wedges	2	1	2
splitting the tree	2	1	2
cutting the tree to length	2	1	2
moving the tree	20	1 per mile	20

* Estimated times where given are not intended to be the minimum time, but the time that experienced workers might take. A relay team of axe men could fell the tree in less time, or a community event with 200 people could extract the tree in a more impressive way. Here we have estimated 20 as a sensible number of people to drag a tree along a prepared track of rollers on bearers, moving the rollers as they went.

Figure 7.16
Examining the tree bark. Although the quality of timber would have been imperative, it seems likely that the selection of the trees for the boat would have been accompanied by ceremony and ritual.

so that the need for further movement on land might be reduced.

The weight of a freshly felled trunk, of 20m length and average diameter of 1.1m, is about 20 tonnes (the density of green oak is approximately 1.073 tonnes/m^3). The split half of this tree, reduced to 10m in length, would be about 5 tonnes.

The only way to extract timber of this weight from a wood is to haul it out. It is not possible to roll logs out of woodland because of the close spacing of the trees. As green oak sinks, the wood could not have been floated out. It is sensible to reduce the size of the log to a more convenient size, although further working of the log (in a long timber) might have caused it to split on extraction. The 'halve log and cut to length' stage is probably the optimal stage to move timber of this size. The timber could be extracted at any season, but ideally when the ground is dry or frozen.

Experience has shown that a track of bearers, like the rails of a railway line, with rollers on top of these, is an effective way to move large timbers. The advantage of bearers under the rollers is that the rollers do not dig into the ground or snag on tree roots. Many contemporary trackways use a similar technique. With ropes and levers, a team of twenty people (or several draught animals such as oxen) could move the timber out of the wood. Such a group could move the tree at up to one mile per day. Moving the timber to the site where the boat was to be built might well have taken more person hours than were needed to shape the timbers and assembling the boat. Jake Keen (1996) used seventy schoolchildren to move a 4-tonne log in this way. To move all eight split logs (for the major components of the boat) an average of one mile to the boatbuilding site, would probably require more than 100 person days.

Conclusions

1 It is not clear where the large oaks used in the construction of the Dover boat were grown, but large areas of dense woodland, growing trees bigger than any available in modern Europe, were utilised during the Bronze Age.
2 This woodland could be a remnant of the Atlantic wildwood; we know a little about this woodland and the evidence for its composition and structure is discussed above.
3 The oak timber for the Dover boat would have been carefully selected while it was standing in the woodland, the branches and crown removed before felling, and the tree felled with bronze axes.
4 The trees were each probably split into two halves with wooden wedges and mauls, then cut to length before being dragged out of the woodland to the place where the boat was constructed.
5 Felling, halving and cutting one tree to length would have taken approximately 100 skilled-person hours; extracting this timber would have required about 200 person hours per mile travelled (assuming draught animals were not used).

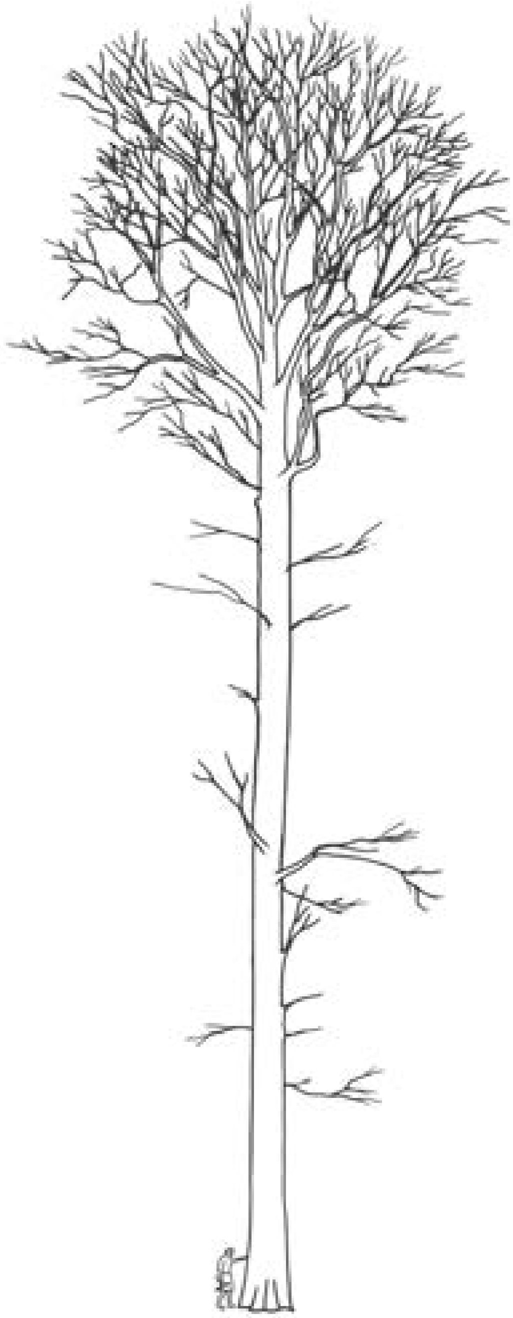


Figure 7.17
A dominant oak tree of a similar size to that required for the Dover boat. Trees such as this no longer exist in western Europe.

8
Assembly and construction techniques

by Damian Goodburn

This section of the report focuses on a practical analysis of the evidence for the construction techniques used to build the Dover boat in quite broad terms, covering aspects of the human, technological and environmental resources employed. It has been developed from the author's first-hand examination of the boat timbers, and from the primary records of the boat.

This analysis and interpretative comment is set against the practical experience of studying some broadly contemporary woodwork and large quantities from later periods, including relatively complete dugout vessels, and more fragmentary elements of larger plank-built craft (eg Goodburn and Redknap 1988; Goodburn 1991a; Goodburn 1996; Goodburn in press).

The Dover boat is seen here both as an outstanding example of complex Bronze Age structural woodwork, and, specifically, as a large boat built of sculpted planks. The analysis is tempered and refined by the practical experience of building technologically accurate replicas of several early dugout vessels, and the experimental cross section of the Dover boat as described below (Chapter 9).

The 'woodworking process': a framework for analysis

During the recording and analysis of any ancient wooden structure, fixed or movable, a number of key questions are apparent. These questions can be most readily addressed when set in a logical order that roughly corresponds to how the woodworking was probably carried out. A useful umbrella term for this recurring set of key activities is 'the woodworking process', and the author is indebted to S Allen for inventing the term. Any technological process takes place in a number of interrelated stages – sometimes sequentially; sometimes partially concurrently. Archaeologists have long been aware of the key stages leading up to the manufacture of metal artefacts, such as prospecting, mining, ore crushing, ore roasting, smelting and so forth. Each of these stages is recognised to leave distinctive traces in the archaeological record, and to have had social, economic and environmental impacts. Only very recently has it been realised that rather similar stages can be seen in the archaeological evidence for complex woodworking, of which the Dover boat is a particularly elaborate and important example (eg Frost 1985; Goodburn 1991b; 1992a; 1992b; Brigham *et al* 1995).

A coherent strategy for the recording and analysis of any ancient structure should therefore seek to find evidence for the following:

- The nature of the social, economic or ritual 'need' (or 'contract') that initiates the woodworking project – that is, what was the boat built for? Boats might be built for a range of explicit purposes, such as for carrying warriors to and from battles or other events (war canoes), or for fishing (fishing boats) and so forth. They might also often have had secondary practical purposes, such as moving high-value items for trade and exchange, or wildfowling. In addition to practical uses, they might also have had symbolic functions – for example to demonstrate the status of their owners, or provide a vehicle and container for burials. Often, answers to these fundamental issues become apparent only during or after interdisciplinary analysis that considers both constructional details and issues such as parameters of performance, labour investment, context of use, associated finds, date and so forth. However, we must not lose sight of the question 'why was the boat built?', as it would seem unlikely that a homestead's fishing boat and a chieftain's trading vessel would be built and fitted out in the same way.

- The nature of the 'prospecting' for materials – in this case huge, straight-grained oaks, yew withies, beeswax, moss and their likely provenance (Goodburn 1991c).
- The nature of the harvesting process, principally here the felling of large oaks and the cutting of small yew shoots. Questions about the seasonality of the work are also relevant.
- The 'lopping and topping' (removal of unwanted side and top branches) of the parent logs or stems for the final timbers or withies.
- The 'bucking' (cross-cutting) of the parent logs and stems.
- The primary processing or 'conversion' of the logs and stems towards the finished products. In this vessel, the method of primary conversion of the large timbers, wedges and laths was by controlled splitting or 'cleaving' (Darrah 1982; Chapter 7); the yew withies were used whole.
- The complex process of marking out and planning the work – in this case, the half logs used for the bottom planks and iles. Presumably, this would have been done by the most senior person involved in the building project. Here, issues such as the possible units of measurement and/or proportions used should be examined. In recent vernacular boatbuilding, these have been very important; the use of various 'ells', and fixed proportions of beam to depth to length, etc, are documented. Such use of measurement and proportion in boatbuilding is shown at least as far back as Roman times (Rule and Monaghan 1993, 25).
- The coarse shaping of the log halves, or 'roughing out', in the case of the larger hull elements, by notching and splitting and hewing. This is a very complex issue in the Dover boat, owing to the high degree of three-dimensional sculpting of the main timbers and to post-depositional distortion (Chapter 6).
- The issue of seasoning – whether periods for seasoning were allowed, or whether seasoning was slowed down and/or controlled, for example by the deliberate sinking of partially worked timbers.
- The transport of the roughed-out materials –the large oak timbers, trimmed withies, laths and wedges – to the final assembly area.
- The re-marking and finalising of the desired shapes for each element; this must also have included 'rules' of proportion and measurement (or mental templates) used by the builders. This is especially complex in the case of objects curved in three dimensions, such as the ile and bottom planks.
- The nature of the infrastructure of working areas, in this case for the roughing out of the larger elements as well as the final assembly area or 'boatyard'. The types of infrastructure might have included supports for timbers being worked on initially, a building platform, and possibly a simple 'slipway' for launching.
- The sequences of secondary trimming and finishing of all the components: bottom planks, iles, missing end and upper side timbers, cross-beams or thwarts, withies, laths, and wedges.
- The cutting of any necessary joints and fastening holes: in this case the stitch holes, rail rebates, sockets in the cleats and slots for the centre-line wedges.
- The making of the fastenings used: in this case twisted yew 'stitches'. The direction of twist, skills used, storage, etc.
- The application of essential surface treatments to control seasoning and reduce splitting, preserve materials and possibly enhance appearance, such as fat, oil or tars (McGrail 1987, 28).
- The final assembly of component parts; wedging, locking stitches, tightening, etc.
- The sealing or 'stopping' of potential leak points, such as the stitch holes.
- The making and installing of ancillary fittings and equipment, in this case thwarts, paddles, bailers, punt poles, etc.
- The size of the work force needed for the various stages.

An attempt is made here to reconstruct the woodworking process behind the building of the Dover boat, including evidence for the toolkits used and the order of construction.

Tool marks and toolkits

The analysis of early woodwork has long included attempts to record surviving tool marks and identify the tools that made them (Fox 1926). In the last few decades, the necessity for recording such traces of ancient working practices has been widely acknowledged in the nautical field (eg McGrail 1987, 150). Specifically, in the last ten years, a systematic approach to this recording work has been evolved, and has produced many new insights, including the use of tool-mark analysis for broad dating (Goodburn 1989; 1992a; 1992b; 1997; O'Sullivan 1997, Brunning 1996).

Occasionally, this field of analysis has resulted in the discovery of tool types that are not yet known in collections of implements from the period and place concerned (Goodburn 1989, 102).

The next stage of tool-mark analysis can be to reconstruct the mode of use of the reconstructed tools. Was a reconstructed axe, for example, used for fine trimming work, or for only the early roughing-out stages of hewing?

It is also possible for the nature of those tools, devices and building aids that leave no tangible traces but are clearly implied by practical considerations to be reconstructed. For example, if the construction system indicates fastenings worked from underneath a vessel, then the use of a raised building platform is clearly implied, except perhaps for light craft of rather specific forms that can be turned over during construction.

Finally, the discovery of edge tool marks – which can be distinguished from other similar marks by consistently recurring patterns of striations corresponding to nicks in the blade of an individual tool ('tool signatures') – can give us insights into the number of tools used to build a timber structure, and some other technical features (Sands 1997).

Methodology

Each of the boat pieces was examined specifically for tool marks and related features. Copies of the 1:1 drawings of the boat pieces were prepared, and these were then annotated with colour-coded notes and lines indicating clear tool marks and related features, modern damage, and so forth.

The annotated tracing copies were then used to update the draft tracings as the main archive record of these aspects of the vessel. At the same time, the large collection of record photographs was also reviewed, and notes made of those shots that showed woodworking details particularly clearly, accompanied by freehand notes and sketches that were also copied for the archive.

It was not possible for the author to examine all parts of the external faces of the timbers, as they had to be exposed one by one for short periods, owing to the logistics of conservation work (Chapter 17). However, a representative sample of the outside of the hull was seen and the nature of surviving tool marks recorded.

Condition of the tool marks

Unfortunately, the two oaks native to north-west Europe (and their hybrids) produce rather coarse-grained timber, on which the fine detail of tool marks such as signatures does not tend to preserve as well as it does on species with smoother grain, such as alder, yew or beech. Despite careful examination, no clear examples of recurring tool signatures were found on the Dover boat timbers, even on the end grain of the cleat timbers where such fine marks might be expected to have survived. This is significant, as it implies that the edges of the tools were carefully looked after and protected so they did not get substantially nicked by working dirty, gritty timber or by being banged against hard objects. Some form of edge wrapping or sheath might well have been used, as is the practice of most traditional woodworkers, both today and in medieval times in some contexts (Wood 1999, 7).

However, it was clear that some of the visible cut ends of the yew withies bore fine striations associated with the use of individual blades. In practice, it was not possible to see or examine the ends of all the yew withies used for the 'stitches' to see if matching tool signatures could be found. In any case, the small diameter of the lashing ends provides a rather limited area for the full tool marks of an axe or knife to be left.

The larger-scale features of the tool marks on the oak timbers – such as incuts, stop marks, facets and lines of facets – were variably preserved. As is usually the case, the best-preserved marks generally survived on end grain and in protected areas. In the Dover boat, the end grain on the cleats preserved many clear marks, the general patterns of which could be quite varied (Fig 8.1).

The protected areas of the Dover boat lay next to cleats and rails, or inside stitch, transverse timber or wedge holes. However, during excavation, slightly worn patterns of facets ('deliberate fluting'

Figure 8.1
The bottom of the boat inboard, showing the tool-marks on the bottom cleats.

discussed below; Fig 8.2) were still very clear on the wider, less-protected surfaces of the bottom planks, both inboard and outboard, and also, occasionally, on the inboard surfaces of the iles. Despite very careful handling of the timbers subsequent to exposure, some of these patterns of marks were less visible during off-site study, except on some parts of the outboard of the bottom planking. The partial survival of these patterns of marking is particularly significant and is discussed below. However, it would be reasonable to say that the tool-mark preservation on the Dover boat was much better than that noted for the Ferriby, Caldicot or Brigg prehistoric boat finds (Wright 1990; Nayling and Caseldine 1997; Heal 1981). It was not as good, however, as those recorded in detail on Late Bronze Age and Iron Age crannog timbers by Rob Sands (1997).

It should be emphasised here that one of the key objects of tool-mark analysis is to isolate the best-preserved examples of characteristic tool marks. In this context, the 'best preserved' means the largest stop or incut marks of a particular type. These marks will provide the most complete negative impression of the tool edge that produced them. In practice, it is rarely the case that early woodworkers used tools in such a way that they dug into the surface of the timber to leave a complete negative impression of their blades, except in felling and bucking. More commonly, the tools were used to cut in and out of the surface, leaving a partial negative impression in the 'stop marks' left on the timber surfaces. This is the case with most of the marks surviving on the Dover boat; thus we have to allow a small amount of extra width in the blades of tools used for much of the work. Owing to the marked curve of the ends of the blades used, even the incuts are unlikely to match the full width of the blade that made them. However, experimental work has shown that, when using palstaves with a rounded blade along the grain, the fluted lines created are actually a little wider than the width of the edge used (Chapter 9).

Many post-depositional factors worked to remove tool-mark traces, such as variable compression by the overburden and, locally, by individual stones, ancient superficial decay and abrasion during excavation and analysis. However, the very survival of tool marks on the more open surfaces of the bottom planks (inboard and outboard) gives us some insights into the life history of the vessel. Simply put, the logical assumption is the more abraded the tool marks are when first exposed, the longer the pre-deposition use of the vessel. Clearly, no very precise suggestion of how old the Dover boat was when abandoned can be given but some crude, qualitative estimates can be suggested. These estimates are informed by observation of the abrasion of similar tool marks on the oak hulls of dugout-boat replicas built in

Figure 8.2
The longitudinal fluting on the inboard surfaces of the boat was almost certainly created by the use of palstaves hafted as adzes to flatten the timbers.

recent years (Goodburn and Redknap 1988; Goodburn in press).

Clearly the use of protective dunnage or packing materials, such as wattle hurdles, over the surfaces of the timbers inboard would reduce wear due to the passage of muddy or sandy human feet (this is well known in medieval trading vessels; Redknap and Nayling 1997, 30).

The Ravensbourne Late Saxon oak dugout-boat replica has experienced one active summer of recreational use, together with very occasional use over five other summers in river and lake environments (Goodburn and Redknap 1988). This has included hauling out on abrasive muddy and sandy banks. The central area of the bottom outboard has been worn rather smooth and has been scratched, as have much of the side area outboard. Few clear tool facets survive on its bottom. The walking surface inside has been smoothed and the upstanding ridges between facets worn down, but many tool marks remain recognisable. It would seem that bailing out the hull using soft deciduous wood bailers has also caused some of the internal wear. This replica boat has not carried loose abrasive materials such as metal ores.

Bearing this sort of comparative evidence in mind, it is perhaps possible to suggest tentatively that the Dover boat might have been less than ten years old when abandoned. We can also suggest that dunnage was used, perhaps of wattle hurdles or brushwood. Three alternative explanations for the modest wear in the Dover boat are: that the vessel was used only occasionally in the manner of a ceremonial craft; that it carried only barefoot crews with little, if any, cargo; or that dunnage was used very carefully. It should be stressed here that the condition of the timber surfaces is such that the vessel cannot be considered a craft used for only one ceremonial journey and then abandoned, as has been suggested for some early-Egyptian boat finds (Haldane and Patch 1990).

Although the outside of the bottom of the craft was worn in places, in other areas wear was only moderate, with clear patterns of facets surviving. This lack of heavy wear again suggests the craft was not very old and had generally been very carefully beached either on soft mud, on brushwood 'hards' or on soft wooden skids (short lengths of poles were used under the Ferriby boats; Wright 1990, 48).

Thus, we can cautiously suggest that the vessel was probably less than ten years old when abandoned and partially dismantled. The evidence of large splits in the iles having been repaired, and moderate wear of some areas, does show clearly that the vessel was used for at least a couple of seasons, and was not made as an item for only ceremonial deposition.

The numbers of edge tools and their implied type

The tool marks surviving on the Dover boat indicate clearly the use of at least five types of edge tool. The sharpness of the following category of marks suggests that they were made with thin-edged tools of metal rather than with thicker-edged stone tools (but see below on shaving and scraping operations). It is important to note, however, that systematic work on distinguishing the marks left by ground, stone edge tools, and by tools of copper or bronze, is only just beginning. Although examples of marks made by relatively blunt-ended ground stone (here flint is considered a stone) and by rather thin-bladed copper-alloy tools can be distinguished relatively easily, the difference between less extreme examples in each raw material might be much harder to identify. Indeed, only systematic experiment with accurate replica tools will show whether the marks of the thicker-edged copper-alloy tools and the finer-edged ground-stone tools (still current in the earlier Bronze Age) can actually be distinguished (but *see* O'Sullivan 1997). Another relevant issue here is that the form of the cutting edges of many early British copper-alloy tools mimics ground-stone forms, which are often very strongly convex. Such round-ended edge tools automatically produce markedly concave facets, quite different to those of the Roman and later periods, a distinction useful for broad initial dating.

Hafting

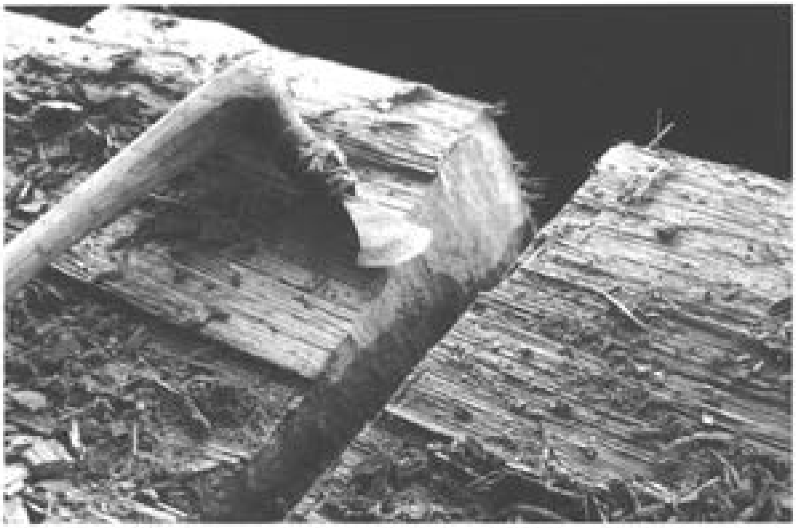
Archaeologists have traditionally focused on creating typologies of the stone and metal blades of early woodworking tools and have considered only very rarely how the tools were actually used and hafted. In preparation for the building of the experimental hull section (Chapter 9), very little information on the nature of the hafts of Bronze Age tools could be found. Even where isolated examples of tools with surviving wooden hafts have been found, they are rarely described in detail or illustrated clearly – exceptions are the axe of the 'Ice Man', with a yew haft and flat copper blade (Barfield 1994), and the Flag Fen socketed axe haft rough-out (Taylor 1992).

Where attention has been paid to hafts, the main concern has been to identify the species of wood used rather than the part of the tree used. Some listing of the species of wood used for hafts has been made (Green 1980), but this shows that, although oak and ash predominate, a wide variety of sometimes unlikely species was used, such as alder, which is a soft and weak wood never used for woodworking tool hafts today in Britain. The blade tools had to be hafted to work and indeed become 'tools' only when hafted. Thus, for the experimental reconstruction work, we were obliged to experiment using earlier and slightly later forms of haft, the principal concern being to produce strong, safe, practical tools that could be used to achieve similar results to those produced by the original builders (Chapter 9; Fig 8.3). During the project it soon became clear that many of our experimental tools would have become more effective and comfortable to use with longer hafts than those fitted.

The reconstructed tool kit

Evidence for the use of an adze with a blade width of about 60mm

Much of the freshly exposed inboard and outboard surface of the bottom planks and iles was covered with shallow, parallel, concave fluting. This was created by a series of blows from a tool, or tools, following the grain in fairly straight lines (*see* Fig 1.1). These flutes were abraded and, therefore, not quite their full width and depth. Where best preserved, as on the outboard face of the boat, the width of the flutes was approximately 60mm and the depth approximately 5mm. These lines of facets indicate the use of a convex cutting edge around 60mm wide, as no places were found where both corners of the tool had dug in. We can suggest that the blade width was probably about 60mm in total, and, allowing for some wear of the timber surfaces, rounded by at least 7mm. Some of the wedges also showed faint traces of shallow, parallel fluting, but here it appears that a fairly smooth surface was intended, rather than a corrugated one (Fig 8.4).



Palstaves hafted as adzes

The timbers worked show that the blade or blades used must have been hafted as adzes (Fig 8.5), rather than axes that could not have been manipulated to produce the accurately aligned facets on such wide surfaces. This is a significant finding, as

Figure 8.3 (top)
A replica palstave hafted as an axe, used in the reconstruction experiment (Section 9; photo by Damien Sanders).

Figure 8.4 (above)
A detail of the wedges, transverse timber and bottom cleats towards the southern end of the boat, showing the superb surviving tool marks.

Figure 8.5 (left)
Palstaves can be attached to handles in different ways to create different types of tools; here one is hafted as an adze.

palstave-type tools have generally been assumed to have been hafted only as axes. Stuart Piggott was one of the few prehistorians who recognised the likelihood of the hafting of palstaves and similar tools as adzes for woodworking (Piggott 1983, 31). It should be noted here that the precise form of the tool suggested is indicated by comparing the tool-mark evidence with surviving tools of the Middle Bronze Age period. During the experimental work, it was found that the most rounded palstaves (Type 'D'; Chapter 9), when hafted as an adze, left exactly similar marks to those found on the original vessel when used with repeated blows along the grain of the green oak. The method of use was also effective in removing relatively long, thick shavings, and reducing the timber relatively fast.

From the Iron Age onward, adzes were (and still are) commonly used across, rather than along, the grain for surface reduction and smoothing, particularly with green timber. This creates a fluted effect across the grain that can clearly be seen in the Iron Age Hasholme boat (Millett and McGrail 1987, plate XVIII) and later finds. Limited timed comparisons were carried out between a modern steel shipwright's adze weighing 1.7kg and a D-type replica palstave-adze with a head weighing 0.44kg. Remarkably, there was little difference in the speed of working along the grain, which, of course, the modern adze is not really designed to do. The action is one of both cutting and controlled splitting at the same time, rather than the slicing/shaving action usually used with a modern steel shipwright's adze.

Interestingly, a similar surface finish might have been used on at least one of the Ferriby boats, where Wright describes one of the plank surfaces as having 'lengthwise streaking' (1990, 135). It might also have been used for the finishing of the surfaces of the planking on the Brigg raft of the later Bronze Age, to judge from some of the photographs produced in the report (McGrail 1981, figs 2, 3, 6). Similar fluting has also been recorded inside a Late Bronze Age Swiss dugout (Arnold 2000).

A decorative effect?

It is clear from the regularity of the marks that the carefully made fluting along the grain was intended as the final textured finish to the timbers. The removal of all tool marks from the timbers of boat hulls by planing, sanding and finishing is a quite recent phenomenon. In some traditional boatbuilding of recent times, regularly fluted surfaces were produced during final finishing as decorative effects (Best 1925 of Maori techniques; Stewart 1984 of north-west native American techniques). Slightly less-regular concave fluting can be seen on some other types of Bronze Age woodwork, for example on pile tips at Flag Fen, seen on display in water tanks in 1995 at that site.

Experimentally, it was shown that a much smoother finish could be produced with the same tools if desired, even by relatively inexperienced workers such as ourselves. It must, therefore, be considered an intended effect.

The origin of the finishing technique

Initial empirical testing shows that cutting cleanly across the grain with typical British-style, convex-ended, ground stone axes or adzes is very difficult with much tearing, even in green timber. Detailed tool-mark analysis of Swiss Neolithic dugout boats by Béat Arnold has shown that most finishing blows were carried out along the grain (Arnold 1993, 7). He recorded lines of concave facets in a Neolithic dugout boat that, despite less sharp outlines and regularity, do resemble the fluted effect recorded on the Dover boat timbers. The thinner edges of many copper alloy tools actually permit the cross-grain working more familiar today, but the tools were not (in the case of the Dover boat) used in that mode most of the time.

Therefore, it might be reasonable to suggest that the particular pattern of fluting along the grain used by the builders of the Dover boat is probably the continuation of an earlier Neolithic tradition of timber finishing. It is also clear that production of such regular fluting could be achieved only very deliberately, by moderately skilled hands.

Conversely, it should also be pointed out that it would be virtually impossible to produce very smooth hewn surfaces with narrow-bladed Bronze Age tools, although the more experienced members of the reconstruction team were soon able to produce a smoother and more regular finish than the original builders had set out to achieve. Indeed, it was necessary to go back and 'roughen up' some areas so that they were more in keeping with those of the original boat.

It is, however, very significant that no incuts or scores (see below) from the earlier phases of hewing the flat surfaces of the lowest faces of the bottom planks were found. It clearly implies careful marking out and stopping well short of the intended final surface, to allow it to be given an even, fluted finish. In other words, additional skilled labour was directed towards achieving the decorative textural effect.

Evidence for axe(s) with a rounded blade about 70mm wide

In several places on the inboard faces of the bottom planks, incut marks 65–70mm wide were found. These incut marks represent slight over-cuts made while cutting grooves just before the final finishing of the inboard faces of the bottom timbers. This type and size of tool might also have been used with a paring blow at shallow angles for final trimming, but no complete stop marks left by such a blade have been found.

Except in cases of the preservation of large numbers of tool marks on relatively large timbers, it can be difficult to distinguish the marks left by blades used as adzes or axes. However, in the case of complex sculpted timbers, such as the hulls of dugout boats or the larger Dover boat timbers, the orientation of stop marks, indicating the direction of the blow, can sometimes indicate the use of either an axe or an adze (Goodburn 1989).

In the case of the stop marks on the vertical sides of the hewn rails in the bottom planks of the Dover boat, the angle of the marks suggests the use of a blade hafted as an axe used at an angle across the grain (Fig 8.6). It is unlikely such marks could have been left by the use of a blade hafted as an adze, as this would have been rather awkward, and impossible near the cleats. The marks indicate the careful and controlled use of the tool(s) for paring and final trimming of the vertical faces of features hewn in solid, such as the rebates. The type of metal blade used for most of this work was closely similar to that used for producing the fluted finish on the main hull timbers.

Evidence for smaller axe blades

However, there are some places where very narrow fluting was visible, worked along the grain on the small vertical faces of the central rails. The fluting is only about 20mm wide and was probably created by the use of a small metal axe with a rounded

Figure 8.6
A palstave hafted as an axe.

blade. The surviving stop marks on the upper rebates of the iles also suggest that the vertical surfaces were trimmed with a small axe-type tool, if the rebated seam was worked with the ile fitted in its final position. Conversely, the horizontal part of the rebate would have been easier to trim with a blade hafted as an adze. The stop marks were incomplete, fairly curved, with a maximum width of about 20mm and could have been left either by the lower half of a larger tool or most of the blade of a small blade, perhaps 35–40mm wide. The angle of the marks, and their incomplete scalloped nature, suggests that the rebates were not chiselled out, as might be expected, but very carefully hewn out with larger tools.

During the experimental work, the rebates were hewn out with palstaves hafted in both modes as described above. The cutting of such regular rebates would have followed marked lines and required concentration, but was not unduly difficult for a worker with experience of cutting similar joints with medieval-style steel tools.

Thus, we might suggest that similar palstave-type blades, between 65mm and 70mm wide, were used hafted either as adzes and/or as axes for some of the finishing and trimming work on the larger boat timbers. However, some of the more awkward areas and the rebates were trimmed with similar tools of a smaller size.

Figure 8.7
A palstave hafted as an axe, being used to cut a notch in a log prior to splitting off waste timber.

The use of larger axe and or adze type tools for initial shaping work

It is also extremely likely that the larger tools were used for the heavier hewing work involved in rough cutting the main hull timbers before offering up to each other, as well as final trimming and fitting. As we might expect, much of the evidence for these stages of work has been removed almost entirely during the final trimming and smoothing. However, clues to the mode of use of axes (and possibly adzes) in the removal of the bulk of unwanted timber are given by the survival of a few incut marks and scores. These are left by the slight over-cutting of grooves or nicks in the surface of the timbers being shaped. Only if work is very roughly carried out will such incuts reflect the full width of the tool used to produce them. More commonly, only part of the axe or adze blades sinks in a little too deeply, leaving a trace, when the timber surface is smoothed, that is rather narrower than the tool blade that produced it. Clearly, the over-cutting of scores represents wasted energy and badly prepared work. The deeply penetrating nature of incuts from hewing operations often ensures their survival on surfaces that have been subject to decay and abrasion, so it can be taken as a testament to the skill of the builders of the Dover boat that there are relatively few areas on the main hull timbers where large, deep incuts survive. Most are small, associated with the final trimming of features such as the cleats with smaller tools.

One of the few exceptions to the general pattern was noted on the inboard face of the western ile plank (301). Here incuts were found that form a distinct line, close to the end of cleat 820 and adjacent to an area of torn grain. The meaning of these surface traces is explored below, but we can record here that such a line of incuts must have originally lain at the base of a deep V-shaped groove (or score), cut to one side of the intended raised cleat a little too deeply (Fig 8.7). These marks show clearly that the principal method of removing waste timber was a form of grooving and splitting, working in a similar way to the 'notch-and-chop' hewing of later times (Darrah 1982; Goodburn 1989; 1992a, 113). However, owing to the light weight of Bronze Age hewing tools, it is likely that driven wedges were used to split off larger blocks of waste, rather than the axes or adzes themselves (*see* Fig 9.15).

Indeed, the experimental work indicated that only rather small chunks of waste can be split off by blows from axe-type tools (Chapter 9). The equivalent work with a recent steel felling-type axe was found to be about four times faster, while the difference in work rates for other processes are far less marked. From the perspective of a woodworker used to the much larger, heavier tools typical of early historic and medieval tool kits, the modest size and weight of Bronze Age axes and adzes (from about 0.3kg to just over 0.5kg) must be seen as the principal disadvantage in their use, particularly when cross-cutting and cutting deep scores. Initial results from the reconstruction show that for this type of score cutting, the replica Middle Bronze Age axes are roughly half as quick as heavier, recent steel axes. When cutting shallow scores, and using an axe or adze to split off the bulk of the waste, the scores had to be cut about half the distance apart, doubling that part of the work. This resulted in a work rate of about a quarter the speed of the same task performed with modern hand tools.

One might also expect that the comparatively weak haft shape necessary for palstaves would reduce the impact that could have been delivered with each blow. This is particularly true of palstaves, where the blade can potentially act as a wedge, splitting its haft. However, it is clear that such tools could be used for heavy work, such as felling and cross-cutting large oak logs. For example, curved, 70mm-wide stop marks, probably from a palstave, have been found on the flat-hewn ends of large oak logs in a London trackway (Goodburn 1996, 242). The depth of individual facets, representing individual blows, shows that the tools were swung relatively hard and must have had relatively secure heads to survive such impacts. The experimental work shows that cross-cutting large timbers with axes is the operation that stresses the hafts most; working along the grain is much less jarring. However, few haft breakages were recorded and it was possible to use considerable force for this type of operation.

Smaller adzes and axe(s)
Rounded stop marks were found on the end grain of the cleats on the bottom planks and adjacent to cleats and the complex rail junction at the southern end of the boat. These marks were about 40mm wide and also markedly convex. They appear to have been made with smaller hewing tools, probably hafted as both axes and adzes. These smaller tools would have been easier to manipulate for fine work in awkward corners. Those on the sides of the rails appear to have been made with an edge tool hafted as an axe, while those on the upper face of the bottom were made with an adze.

Small chisel-type tool(s)
The stitch holes in the Dover boat timbers were clearly cut, rather than bored out. This appears to have been a characteristic feature of Bronze Age woodwork, suggesting that auger-type boring tools were unknown in Britain. Incut marks were occasionally seen in the end grain of these roughly oval slots. In some cases, the slots had rather angular ends where the marks of an 18mm wide chisel-type blade could be seen.

The straightness and flatness of these cuts suggests the use of a metal tool, rather than one of bone or stone. Presumably this was a small palstave-type bronze chisel, such as are known from the British Middle Bronze Age.

The end grain of the slots for the wedges in the central rails and the transverse timbers was also cut with small chisels of exactly similar type. The experimental work has shown that narrow chisels with a palstave-like hafting are easy to use, effective tools only slightly less efficient than similar sized steel chisels (Chapter 9). The hourglass shape of the wedge slots in cross section shows that the chisel was worked from both sides of the rail, leaving a ridge in the middle. This would have reduced the tendency of the wedges to split the rail off from the main body of the bottom planks. Working from both sides would also lessen the labour required and reduce the chance of splitting timber around the edges of the hole

The use of a chisel, or chisels, for the cutting of the oval stitch holes might indicate that the workforce was short of gouges, which are clearly more suited to the task.

Small gouge(s)
In most of the stitch holes, the end-grain cuts were rounded, and the fairly clear incuts from slight over-cutting with a gouge 22mm wide could been seen in some – for example at the southern extremity of the western ile 301 inboard. The fineness of these marks suggests the use of a metal edge, rather than one of bone or stone. It is likely that this was a bronze socketed gouge similar to the example in Dover Museum (Accession Number DOVRMO.1392).

The technique found to be most effective involved using a simple mallet to drive the gouge in deeply at either end of the stitch hole and then gently splitting out a waste plug (Fig 8.8). The technique resembles (in some respects) that used by hurdle makers to cut rough oval mortises in recent times. The resultant oval plugs of oak – up to 20mm thick and the length of the stitch hole – are very distinctive debris; the finding of such plugs in woodworking debris *in situ* would clearly imply stitch-hole cutting for repair or new building. Ted Wright suggested the use of some type of auger to drill out the stitch holes for the Ferriby boats (Wright 1990, 136). However, no suitable tools of Bronze Age date for this type of work have yet come to light in Britain. The marks on the Dover boat stitch holes clearly show the use of gouges and chisels, not augers.

Figure 8.8
The stitch holes were cut using a gouge, driven in with a simple mallet at either end of the hole before splitting out the waste plug.

Cutting the yew withies

The untwisted butt ends of some yew withies (where visible) had clearly been cleanly cut with an oblique blow. The flatness and smoothness of these cuts suggests the use of a metal blade used with a chopping action, probably a small axe, rather than a knife. These cuts might represent the recutting of the butt ends of the yew branches or shoots. In practise, a smooth cut during harvesting would have been hard to achieve because of the springiness of the material. Indeed some withies (such as stitch 556) were just torn off. Experimental work shows that yew withies are a hard material to cross-cut, even when in totally green condition. The side branches would also have to be removed, probably using the same tool, working resting on a surface such as a large branch.

The use of fine shaving tools

The laths driven under the stitches inboard had to be made smoothly convex on their upper faces (and perhaps slightly convex on their undersides), so as not to catch when driven home. Most of the laths were made of cleft oak timber, which naturally has a rough, corrugated surface. These corrugations and the facets of any trimming blows had been largely removed, which implies the use of fine shaving tools of some type. It is quite possible that these were flint blades or large flakes used either with a shaving or scraping action, as suitable tools in copper alloy have not been found. A very sharp bronze axe or adze could perhaps have been pushed along to shave off high spots; during the reconstruction experiment, rather smooth laths were made by gentle hewing with a palstave axe alone (Chapter 9).

Figure 8.9
Using a holly maul and wedges to split off waste wood in the reconstruction experiment.

Experimentation has shown that, given a robust but sharp edge, simple flint tools are effective shaving implements (Goodburn 1984). If the work were executed carefully, very small facets and 'chatter marks' would result, which are unlikely to have survived the slight abrasion, decay and compression of the surfaces of the boat timbers. Indeed, the nearest modern equivalent to flint with primary fractured edges – broken glass – is still used by some cabinet-makers today for fine smoothing jobs on rounded surfaces. It is probable that the laths were smoothed and shaped initially with small adzes and axes.

Tool marks of demolition and repair

In addition to the tool marks surviving from the building of the vessel, others survived from later phases of work.

Tool marks from alterations during the life of the craft

The only clear, visible alteration made during the life of the vessel was the cutting of the central rail (Chapter 5).

Tool marks from the breaking of the vessel

The lashings holding on the original second side planks had all been chopped through to facilitate their removal, but the frayed yew fibres did not bear clear tool marks. The top rebated edges of the iles, however, were clearly cut into during the removal of the second planks. The nature of the axe cuts on the wedges that secured the end board shows that it was removed with some care.

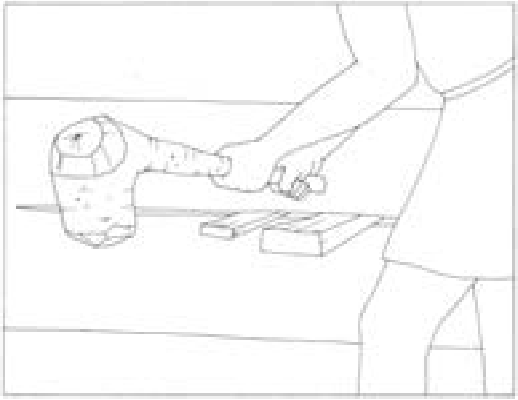
Implied tools and building aids

Although not leaving distinct traces on the surfaces of timbers from the Dover boat, the use of several types of tool and building aid can reasonably be inferred; these are described briefly below.

Tools inferred for cleaving and splitting out waste

Mauls

Large mallets (mauls) would have to have been used to drive wedges for the initial conversion of the parent oak logs by cleaving in half and also for subsequent splitting out of large blocks of waste (Figs 8.9; 8.10). It is likely that these were of dense, tough woods and probably made in one piece using a branch stem junction. An example of such a one-piece maul (of



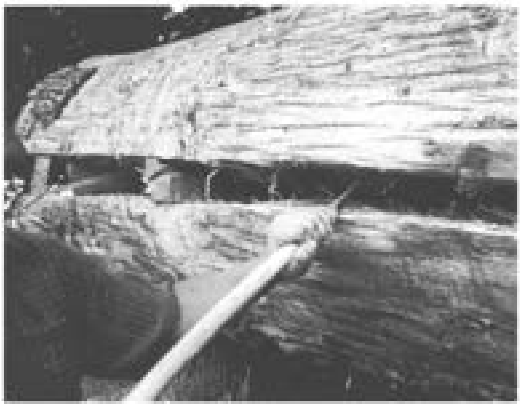


Figure 8.10 (far left) The logs were split by hammering in wooden wedges, probably using a heavy wooden maul.

Figure 8.11 (left) Using a long-hafted bronze chisel to help split the logs.

yew) was recovered next to the Meare Heath track of Middle Bronze Age date (Coles and Orme 1982, 33). A simple, single-piece maul of holly was used during the experimental work for heavy wedge driving. It shattered eventually, but was found more effective than a more modern-style, two-piece beetle against which it was tried. In some cultures, carefully made stone mauls were made for this type of work and the heads of the wedges were bound to prevent spreading (Stewart 1984; Croes 1993, plate 6.4); we have no evidence of these refinements yet for the British Bronze Age.

Wedges

The wedges were also probably of tough semi-seasoned or seasoned wood, although wedges of bone or antler might also have been use. The use of these materials has been documented ethnographically elsewhere and this might have been the case in earlier prehistoric times (Goodburn 1984; Stewart 1984). For cleaving oak timber with wooden mauls and wedges, this author has found – from practical work – that the fruit woods, fast-grown oak, and ash work well. It also appears that wood that is still slightly green takes impact better than fully seasoned timber, which is more prone to splitting on driving.

These wedges would have to have been made in a variety of sizes – from small ones, for starting the controlled splits (less than 150mm long and up to 40mm thick, with a width of about 70mm), through medium-sized examples, to larger wedges, perhaps 1m long and over 200mm thick, for the later stages of opening a large split. Simple-pointed pole levers are also likely to have been useful in levering open large splits when cleaving the oak logs, and would have been essential for moving the huge timbers around. It is likely that poles would also have been used as skids on which to slide and turn timbers during construction.

Experimental work shows that during the cleaving of large logs of oak, tough, fibrous slivers of wood sometimes hold a split together with surprising strength. In straight, even-growth oak, these slivers are less common, but the occasional knotty areas in the timber used for the bottom and ile timbers of the Dover boat would probably have presented some problems. Thin blades of some form are likely to have been used to sever these awkward fibres. The experimental reconstruction showed that palstaves are too bulky to reach into the splits easily, but palstave-like bronze chisels, bound onto long hafts, are quite effective in this role (Fig 8.11).

Evidence for the use of a building platform

It is highly unlikely that the partly worked bottom and side planks were allowed to touch the earth before completion of the boat, as the adhering dirt would then dull tools applied to the timber surfaces. Apart from that, the fitting of the bottom transverse timbers required that the two bottom planks be gently but accurately positioned in relation to each other while being supported on cross-beams or poles in a level position. During stitching, a raised platform would have been essential, with a minimum height of 0.3m.

Symmetry

It is quite clear that perfect symmetry was not considered crucial for the Dover boat, as is often the case in boatbuilding before the twentieth century; the two halves of the boat are not perfect mirror images of each other, cleats are not perfectly aligned, and so forth. This might be a relict of the fashioning of each duplicate element a little distance from each other, where comparative locations could not be easily matched. There is very clear evidence that parts of the southern end were reshaped shortly before the timbers were finished. However, it is quite clear that a line was used to mark the centre-line seam, perhaps by 'snapping' with a pigment. This seam between the two bottom planks is perfectly straight within the tolerances possible with large hewn timbers. In many sewn or lashed craft of recent times, one plank is scribed to the edge of another and straight seams do not occur. It is likely that some form of scribing was used for the marking and final fitting of the edges of the upper planks to the iles and end timbers. This could have been carried out with very simple tools (Horridge 1982).

The thickness of the principal timbers also varies considerably; some of this variation (between 30mm and 60mm) would appear to have been original. Again, a very regular thickness across the width and along the length of the bottom planks and iles was not considered crucial by the boatbuilder. No 'thickness gauge holes' (McGrail 1978, 31) were used to check the thickness of the dugout ile elements. The thickness might have been gauged by feeling, by knocking, or by using a simple split-stick gauge, as used by some dugout builders of recent times (Goodburn in press).

Weight

Judging from practical experience, and a knowledge of the history and ethnography of small-scale plank boatbuilding, the approximate size of a building team can be suggested with reference to the weight and awkwardness of movement of the largest element that required manhandling. In recent boatbuilding in Britain, the operations that would involve the whole workforce of a boatyard would be tasks such as the 'hanging' of a long, heavy, wale timber in a vessel's ends. Such timbers had to be moved fast, while hot from the steam chest, and clamped round an awkward curve as quickly as possible – a job that required all hands (Frost 1985). In the case of the Dover boat there was no clear requirement for very rapid work, but the surviving bottom planking and ile timbers were very heavy and cumbersome items that would have required many hands to manoeuvre them.

Calculating an accurate weight for the individual elements is clearly impossible, as the overall lengths of the timbers are unknown. Another problematic factor is that the original volume of the timbers is hard to reconstruct exactly, owing to compression and collapse (Chapter 6).

As an interim statement, we could work with some very rough figures relevant to a minimum hypothesis for reconstruction. Here the length of the boat is assumed to have been approximately 12m (as a minimum length; Chapter 10). The length of the bottom planks, therefore, would have been just under that figure. Given a maximum width and original thickness of about 0.8m × 0.075m, the total weight of the finished (but still green) elements would have been approximately 0.78 tonnes. This is using a green-oak heartwood density figure of 1.073 tonnes/m^3 (Millett and McGrail 1987, 106); slow-grown wildwood oak might weigh a bit less. The iles would have weighed approximately 0.35 tonnes each in a similar condition.

The parent log for the bottom planks – at about 1.0–1.2m in diameter at mid-length (or possibly more) and 11m long – would have weighed a minimum of 8.8 tonnes after branch lopping and bucking, but before any other shaping. The slightly longer parent log for the iles would have weighed about 7.0 tonnes. The huge difference in weight between the finished elements and the parent logs shows the enormous advantages that roughing-out the timbers on the spot would have provided.

It has sometimes been suggested that long wildwood-oak logs could have been moved some distance by rolling (Millett and McGrail 1987, 128). However, this is not a practical alternative in the European wildwood, as a roadway a little wider than the length of the log would have had to have been built to achieve the work – entailing an impractical amount of felling and clearing.

In practice, the final shaping of the elements clearly took place in stages after checking the comparative shapes against each other by 'offering up'. This being so, the timbers would have been a little heavier at this stage than their final weights. We can perhaps envisage the moving of the roughed-out bottom planking at a stage when each plank weighed about two tonnes. The iles, in similar condition, each might have weighed about 1 tonne. A consideration here is that the bottom timbers appear to have been given a final parallel fluted finish prior to the finishing of the centre-line seam, which truncates the fluting pattern. This might be because the bottom would become smeared with dirt and grit imbedded with grit during transport. This dirt would include hard matter that could damage the edge tools.

The workforce

Suggestions of the size of the workforce can be made based on the practical experience of moving oak timbers by simple means in recent woodland, multiplied by the size of the timbers concerned (Goodburn and Redknap 1988, 20).

For moving rough-outs with the weights suggested above, a workforce of about 40 people would be needed for the dragging alone, with perhaps another ten for preparing the route. This figure is broadly in line with ethnographic data (eg Best 1925, 103) and experience with smaller replica dugouts. However, the number of haulers could be halved on a well-made corduroy track on level ground. It is almost certain that the simple expedient of laying log skids under the timbers would have been used. With the moving of small dugout boat reconstructions, it has been found useful to keep up momentum once the load started to move. It is likely that substantial sections of track were laid and relaid in bursts as a large-scale communal effort. The wheeled vehicles known from the Middle Bronze Age of Europe are not of a size or form that could have coped with the transport of such heavy, bulky items as the Dover boat timbers (Piggott 1983). Some form of water transport to the building or final assembly site seems the most likely possibility, unless that site was close to the site of felling the major timbers. The green oak timbers would not have floated alone, but simple buoyancy aids could have been used to make rafting feasible, such as inflated skins or dry logs of light timber. Once in the water, a small number of people could have moved the timbers to the assembly site.

If these timbers then had to be hauled a short way up a beach, larger numbers of hands and skids would again be needed. The mysterious crooked timber found by Wright (1990), and interpreted as evidence of the use of beach windlasses in the Middle Bronze Age, is clearly relevant here. Should they have existed, the mechanical advantage provided would have made further hauling work much easier. The work of Stuart Piggott and others shows that the possibility of hauling by cattle must also be considered (Piggott 1983). Oxen teams were much used into the present century to haul large wild-wood logs along corduroy tracks in the north-west USA (Andrews 1960, 94). It is likely that the roughed-out major timbers were then manoeuvred onto the building platform by skidding and levering with poles, and the processes of final trimming and offering up carried out. Here, the periodic assistance of a workforce of a minimum of perhaps ten adults would have been required. The most difficult jobs of all are likely to have been the offering up and fitting of the upper planks on each side, unless they were of much lighter scantling than the other major hull elements. It seems very likely that they would have to be lifted rather than skidded into position. However, as their form is not known, any further conjecture seems of little validity, although they might, in any case, have been made in three parts, owing to the shaping requirement.

The yew withy stitches

Boats built of several elements lashed or sewn together are known archaeologically and ethnographically from several parts of Europe. Indeed, 'There is world-wide evidence for sewn fastenings in plank boats' (McGrail 1987, 132). However, in no other craft was (or is) such a tough, stiff material used for the bindings as the twisted yew fastenings in British Bronze Age planked-boat finds (Wright 1990, 129; Nayling and Caseldine 1997, 214). Neither has the production of twisted yew withies survived into recent times in Britain, where twisted withies of hazel and willow are still being made. In Norway, which had a very strong tradition of making withy bindings from medieval (if not earlier) times, yew was very occasionally used (Schølberg 1988, 80). Thus, the craft of finding, harvesting, preparing and fitting the stitches, documented in the Dover boat, is not easily understood, despite some experimental work carried out by Ted Wright (1984; 1990, 129). The description and discussion presented below has been distilled from various sources: close examination of stitches in the vessel, including the dismantlement of two stitches in 1997; the detailed records of the boat; practical experimentation, from the harvesting to the fitting of experimental lashings in the replica hull section (Chapter 9); the botanical analysis of sample withies from the boat; and initial studies of broadly contemporary waterlogged prehistoric yews from the Lower Thames Valley peats. Discussions with practical woodsmen and arboriculturalists have also been extremely useful in this attempt to unravel this obscure aspect of Bronze Age woodworking technology.

A key problem here has been that the thinner sections of the original stitch material were found to be very fragile, and often dislodged or damaged in antiquity or during handling in the difficult conditions on site. Conversely, the thicker, untwisted butt ends were well preserved. Whole, intact stitches were rare and could not generally be dismantled to ascertain how they had been fitted and secured. This problem was even more severe in the case of the Ferriby finds (Wright 1990, 140), where the experimental solution offered for locking the withy ends looks rather implausible, and, clearly, originally differed from that used in the Dover boat.

Summary description

The most intact stitches between the iles and bottom planks are those dealt with here, as the upper examples were heavily mutilated by the breaking up of the vessel. The withy bindings were between 12mm and 20mm in maximum butt diameter, and between 1.4m and 1.8m long. The botanically examined samples were cut in spring, after a quarter of a year's growth, and were between 6.25 and 16.25 years old. Preferred spring cutting of conifer stems destined for twisted withy use is also documented for red cedar lateral branchlets in the Pacific northwest area (Stewart 1984, 162). In England, deciduous rods destined for winding were (and are) cut in winter rather than spring. In retrospect, two other features of the stems used could have been recorded to better characterise the material:

- the length between the nodes of knots, which is indicative of the speed of growth of a shoot, and might relate to its origin;
- the orientation of the small knots, that is whether they are disposed all around the stem (as in seedlings) or on one side only (as in the upper side of the lateral branches).

The thicker, untwisted butts were left protruding outboard at the seam between the ile and bottom plank, by up to 100mm in some cases. This must have caused some drag during the use of the vessel, but some protuberance is essential for the locking of the stitch itself. The twisted parts were passed through the oval stitch holes three, or sometimes four, times.

Harvesting the withies

The number needed

If one were to take even the most conservative estimate of the original length of the Dover boat at *c* 11m, a minimum of about 60 stitches would have been needed for the bottom-to-ile seams and perhaps 66 stitches for the ile-to-upper-strake seams. Allowing some for inevitable breakages, at least 150 suitable yew stems would have been required overall. Even in the most suitable form of parent woodland, this would probably have involved several person/days work. Clearly, a good knowledge of the whereabouts of particularly suitable trees would have been useful.

It would appear that partly prepared material can be stored for several years if need be, when it can be revitalised before use by being soaked in fluids (Stewart 1984, 162; Schølberg 1988, 80). Thus it might be that the materials were gathered gradually prior to building or repair work.

Cutting the stems

In practice, cutting the thin, very flexible, but hard stems of yew (often over 1.75m long) in the air is awkward. A small club placed behind and supporting the stem to be cut makes cutting – with a bronze axe – easier. Several experimental stems were cut this way, but most were cut with secateurs to avoid damage to the living trees. Clearly, a few of the stems had simply been torn off from a junction in a stem. Experimentally, this was easy to achieve if a convenient junction point existed, but virtually impossible otherwise, owing to the strength of the material. This toughness suggests that an axe would have been the likely cutting tool, rather than a knife.

Trimming the stems

The butt ends of the vast majority of the stitches were obliquely cut, having one or two facets indicating perhaps one to four blows. As the experimental ends left from cutting up in the air were invariably ragged, it is probable they were recut on a wooden block. In practice, some of the smallest side branchlets can be pulled off, but most require cutting off with an edge tool, such as an axe or a robust knife. In the experimental work, this frequently took about ten minutes, but, with less-branched material and experienced hands, perhaps this would have been nearer five minutes. All the branchlets on the original bindings had been removed, as clearly they would hinder passage through the lashing holes.

To reduce bulk, the stems would probably have been trimmed of branchlets at the harvesting site.

How the withies were twisted

The practice of winding withy stems while they are still attached to the parent tree is documented for native cedar withy-making in north-western America (Stewart 1984, 163), but yew branches seem at first too brittle or inconveniently placed to be attached using this technique. However, experimentation just prior to the final assembly of the replica hull section in March 1999 showed that winding the growing saplings or branches *in situ* was easier than any other method. The foliage and the small, soft side branches protected the hands during winding, and (together with the bark) could be broken and cut off after winding without difficulty.

The relatively knot-free stems had been given an 'S' twist, which occurs automatically when a right-handed worker winds a withy either by placing the thick end under the left foot, steadying the withy with the left hand and winding it with the right, or by winding on the tree. The former technique is still used to make willow and hazel withy-bindings in Britain today. During the experimental work, it took about ten minutes to wind each withy successfully; this is quite likely to have been much less in more-experienced hands. The bark normally became detached during the twisting, and this was particularly true when the sap was highest in the spring-cut material.

The small L-shaped piece of oak found by Wright, thought to be associated with working stitches at Ferriby (Wright 1990, 156), was reconstructed and tried out. Its only practical application in the case of the Dover vessel might have been in making it easier for the left hand to hold the withy during winding. However, the advantage gained was slight.

Figure 8.12
Driving a twisted yew withy through a stitch hole with the aid of a bodkin.

Other ethnographically recorded methods of holding withy material during winding include using the hands alone, or employing the mouth as a vice (singularly inappropriate with toxic yew wood; Stewart 1984, 162).

The use of heat

The use of heat is not recorded (or necessary) in British practice for the making of withy bindings from deciduous stems, but might be in Scandinavia (Schølberg 1988, 90) and in the Pacific north-west (Stewart 1984, 162), where conifer stems were used. The heat was used to loosen the bark and help in the winding of the material. The use of heat in preparing the experimental yew withies has not yet been thoroughly investigated, but informal experiments elsewhere indicate that it might be useful (D Sanders pers comm).

In recent times, after winding, withy-bindings were usually used immediately or stored as bent twisted hoops.

Final preparations of the trimmed and wound withies

Ethnographic sources describe various methods of softening prepared withies just prior to use, soaking in water or urine, or steaming (Stewart 1984, 164–5; Schølberg 1988, 80). Very fresh-cut, green twisted withies were sometimes used without other preparation (Stewart 1984, 164), which is what was initially attempted in the reconstruction experiment (Chapter 9). However, overnight soaking of the twisted green and dried withies in cool freshwater was enough to transform a resistant hard material into a far softer, thick cord that resembled thin wet raw hide in its pliability. A graphic illustration of the usefulness of the soaking was the difference in time it took to make a stitch; over one hour with the green, unsoaked withy, and eight minutes with the soaked version! Hot-water soaking just prior to the use of wet twisted withies seemed to ease the work further. Clearly, the original builders would have soaked the material.

Experimentally, withies with areas containing several knots would often not wind so that the fibres separated; this created rigid sections that made the withy jam in the holes as it was being worked. We found that gentle beating with a small oak maul on an oak block sometimes caused the hard spots to soften and the fibres to separate. A similar technique was used in parts of the Pacific north-west of America in withy-rope-making to get extra pliability (Stewart 1984, 165). Major hard spots might have been softened in this way by the original builders. However, close examination showed that some original stitches still had small, unseparated hard areas around knot groups. These hard areas were clearly a problem only if over about 20–30mm long.

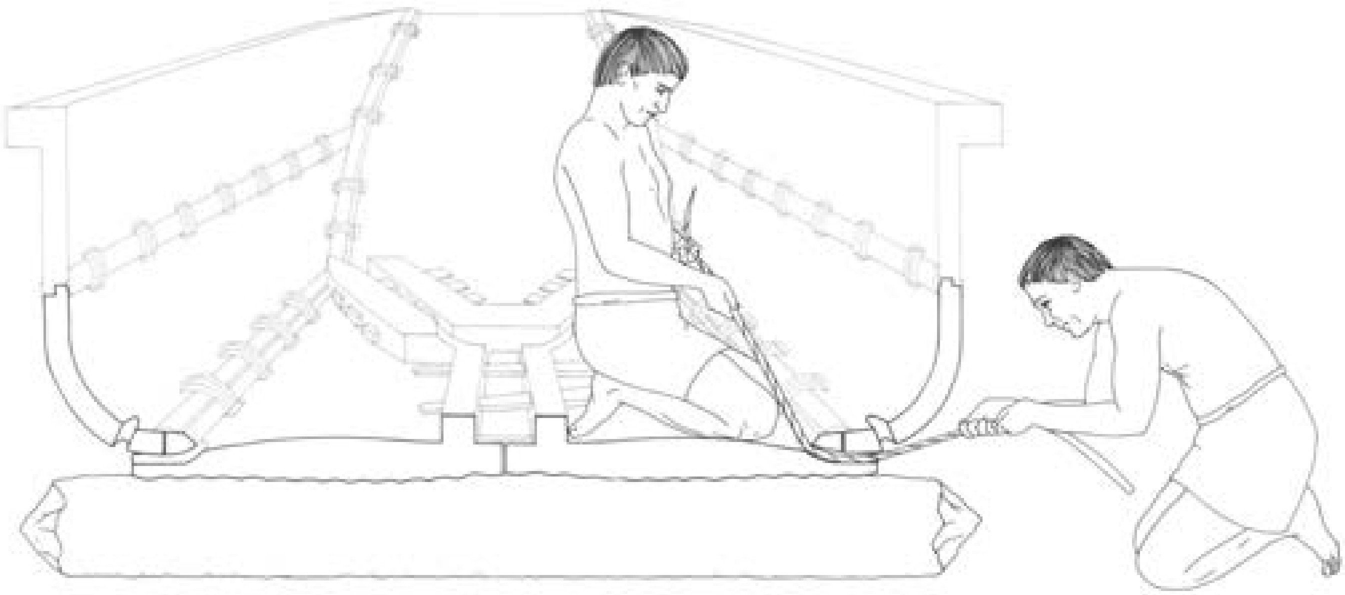
Fitting, locking and tensioning

There has been much debate among the analysis team and others as to how the yew withy stitches were fitted, secured and tensioned. Earlier analysis and experimental work by Wright (1990, 138) indicated how foreign this lost technique of boat fastening was and emphasised the need for serious experiment. The reconstruction of the stitching process here is mainly derived from the experimental work, set within the context of the recorded original stitches.

A tentative step-by-step reconstruction of the working of the stitches is presented below.

- Make the final offering up of the planks to be stitched and adjust the stitch holes if needed; trim the bottom plank rail and inboard upper corner of the lower edge of the ile until they are level, to provide a good landing for the seam lath.
- Wedge the ile hard against the bottom plank rabbet, and start to work on the stitches, with one person inboard and one outboard.
- Insert the thin end of each stitch as a leader from outboard, the inboard worker passing it back through the hole, repeating until the three or four turns required have been made, but left slightly slack. In practice, a bodkin was useful to ease the way for the final turns (Figs 8.12; 8.13). The need to hold the withy firmly militates against the use of a lubricant as suggested for the Ferriby craft (Wright 1990, 140).
- Secure, by passing the thin end between the turns and the underside of the ile outboard and pulling tight with it wrapped around a stick. The untwisted butt jams in the hole and the thin end is jammed against the hull. Sometimes it was, apparently, additionally wrapped

Figure 8.13
Stitching the ile planks to the bottom planks. This was probably best done by two workers, one feeding the thin end of the withy through the stitch hole from the outboard, the other pulling it through and passing it back through the hole repeatedly until the stitch was complete.



round the butt end. This method of jamming appears to work and does not contradict the recorded evidence, which, as explained above, was not well preserved.

- Tension and seal the seam. A waterproof stopping of unknown composition (but apparently not containing beeswax or resin; Chapter 5) was pressed into the top of the seam between the bottom planks and iles. Having worked a group of stitches, it appears that the slightly tapering seam laths were then driven underneath the slightly proud loops of the stitches. The tapering end of the lath eventually lay over the splayed end of the previously fitted lath and the stitches drawn tighter still. A generous layer of moss was placed under the lath before (and during) driving and, surprisingly, this moves with the lath as long as the facing surfaces are smooth, level and slick with animal fat or oil. The thicker butt end of the lath was then dubbed off with an adze ready to receive the end of the next lath. In some of the repair laths, this driven butt end was left on.

The choice of yew

Practical experiment will show the reader that making twisted withies out of any wood, other than the smallest basket willow stems, is both physically demanding and requires practice. In recent times, it was often noted that 'only a trained person could do it properly' (Schølberg 1988, 80). Yew stems are far harder to work than other documented withy materials, such as the willow used to sew together the Brigg rafts' planking (McGrail 1981, fig. 4.1). This raises the question, why did the Dover boat's builders choose it? The quality of survival of yew – owing to its natural decay-inhibiting toxins – is remarkable; often it survives as solid reusable timber from the Neolithic and Early Bronze Age in the London peats and elsewhere (Nelson and Walsh 1993, 224). The fibres of much of this wood are still flexible, even after 4,000 years' burial. The wood is also extremely strong and elastic, even in relatively small stems. Therefore, the durability and strength of the material might have recommended it to the Middle Bronze Age woodworkers.

It is also clear that yew trees and their wood have had ritual connotations all over northern Europe in antiquity (Nelson and Walsh 1993, 224; Hartzel 1991, 3–33; O'Sullivan 1994). Yew was used for clearly ritual objects such as figurines, including one, the Roos Carr example, of Bronze Age date, which depicts a boat and crew (B Coles 1993). It is possible that the choice of yew for the Dover boat had a ritual element.

The strength and durability of the yew stitches would have allowed them to last many seasons. Thus, if the seams remained tight, the vessel might not have to have been dismantled and restitched regularly, as was the tradition with some recent sewn craft.

The parent trees for the withies

It is well known that the way trees have grown in England over the last 3,500 years has changed, both dramatically and, sometimes, subtly (Rackham 1976; Goodburn 1991c; 1992a; 1994; 1996). Recent work in the London region has used records of the solid buried remains of woodland, worked wood and timber found during rescue excavations, to reconstruct extinct 'treeland' ecology and aspects of woodland management (Goodburn 1994; 1996; 1998; Meddens 1996). Much of this work is in progress at the Museum of London, the Institute of Archaeology, University College London and elsewhere, but some trends in the data are already clear.

Several excavations and watching briefs in east London, north and south of the river, have shown that previously unknown forms of dense wildwood existed in these low-lying wet areas, often comprising a mix of oak, yew, alder and ash (Goodburn 1998). A number of relatively complete, well-preserved, late Neolithic and Bronze Age yews and oaks have been excavated, sampled and recorded. The yews typically appear to have a very 'fastigated' form (vertical growth with many vertical shoots) rather than the spreading, bushy form typical of natural yews found in south-east England today, mainly, but not exclusively, on the chalk downs. This form of very fastigated yew, extinct in England before the post-medieval period, might have survived in Fermanagh, Ireland until the nineteenth century, since when it has been widely propagated and reintroduced to England (Nelson and Walsh 1993, 221). This type of yew is known as *Taxus baccata fastigiata* ('Irish yew') a subspecies of the common yew, *Taxus baccata*.

It would appear quite likely that a fastigated form of wetland yew, which would probably have been growing conveniently near water courses, could have been selectively pruned of rather thin, branchless vertical stems to make the Dover Boat's stitches. It might well also have been growing close to the large straight oaks needed for the main hull timbers.

Alternative sources
Initially, the raw material for the experimental withy-making was sought in the lower lateral branches of yews growing on the downs in north central Kent. A few selected lateral stems, cut in spring, were experimented with. It proved possible with the best of them to make a twisted binding similar to those in the boat, but most broke. Twisting immediately, or with a few weeks' storage (as often done with hazel used in a similar way), seemed to make little difference. A key lack of congruity with the examples in the boat was that the pith in the laterals is normally, though not always, towards the branches' upper surface. The characteristics of the experimental raw materials harvested from different sources were recorded to help in the characterisation of the original materials.

Seedling maiden shoots were also experimented with, but, although the pith was central, they were all too knotty, and tended to taper more than the originals (though later some seedling yews of suitable form were found). A number of shoots emerging from the upper face of wind-felled yews were also tried, but were generally too branched. A very few vertical shoots were also found from the dark interior of some bushy downland yews. These had the correct shape and form and could be wound, but often had chafed hard spots. With only moderate to poor success in replicating the yew stitches, another possibility was considered apparent and subject to limited investigation. Perhaps deliberately managed yews could (and did) provide an easily-harvested quantity of suitable stems?

Woodland management
The woodmanship practice of coppicing, where small stems are repeatedly cut from the same stump or root system every few years, is documented in some form from the Neolithic onward in Somerset (Rackham 1976, 48). There, it was used to provide large supplies of long, regular, small stems for some brushwood and woven wattle trackways. Similar material of alder also seems to have been used in some of the recent Bronze Age London trackway finds lying only about 50 miles from where the Dover boat was found (Meddens 1996; Goodburn 1996; unpublished; 1998).

Thus, it is quite possible that some form of coppicing, or perhaps pollarding (cutting the stems growing up from the top of a short larger stem or boling), might have been developed to produce suitable yew stems in quantity. Today, observation shows that yew coppices rather weakly and is not, by tradition, pollarded in England. However, a damaged yew was recently pollarded near the author's home and has regrown fairly strongly, as do heavily pruned hedges of yew, though the regrowth is generally too branched to be suitable. A small number of recently coppiced yew stools exist in some north Kent downland woods, specifically on the east bank of the Medway. These stools do produce regular straight stems that have been used experimentally, but rapidly become overshadowed by other, faster-growing trees.

Summary
We are still not entirely sure what types of yew stems were being used, but, on balance, selected vertical shoots from fastigated wetland yews seem the most likely ancient source. We cannot replicate exactly the ecological conditions that must have existed for the Dover boat's builders, as such natural wildwood is now extinct in Britain. For the experimental work, we have had to use the closest yew stem types we can find today (Chapter 9).

Building the Dover boat

A hypothetical order for stages in the work of building the boat

Detailed analysis of the woodworking evidence, the form and layout of the vessel and the experimental reconstruction, suggests the following order of assembly.

- After the decision was made to build the vessel, the materials had to be located, possibly growing close together or at scattered locations. Ethnographic sources suggest that rituals thought to augur well for the project might have been carried out at this stage (Stewart 1984, 39; Horridge 1982). Presumably the builders had permission to use the trees by right; later boatbuilders often had to buy their timber from many separate sources (eg Friel 1995, 49).
- The working areas would then be cleared, temporary work camps set up,

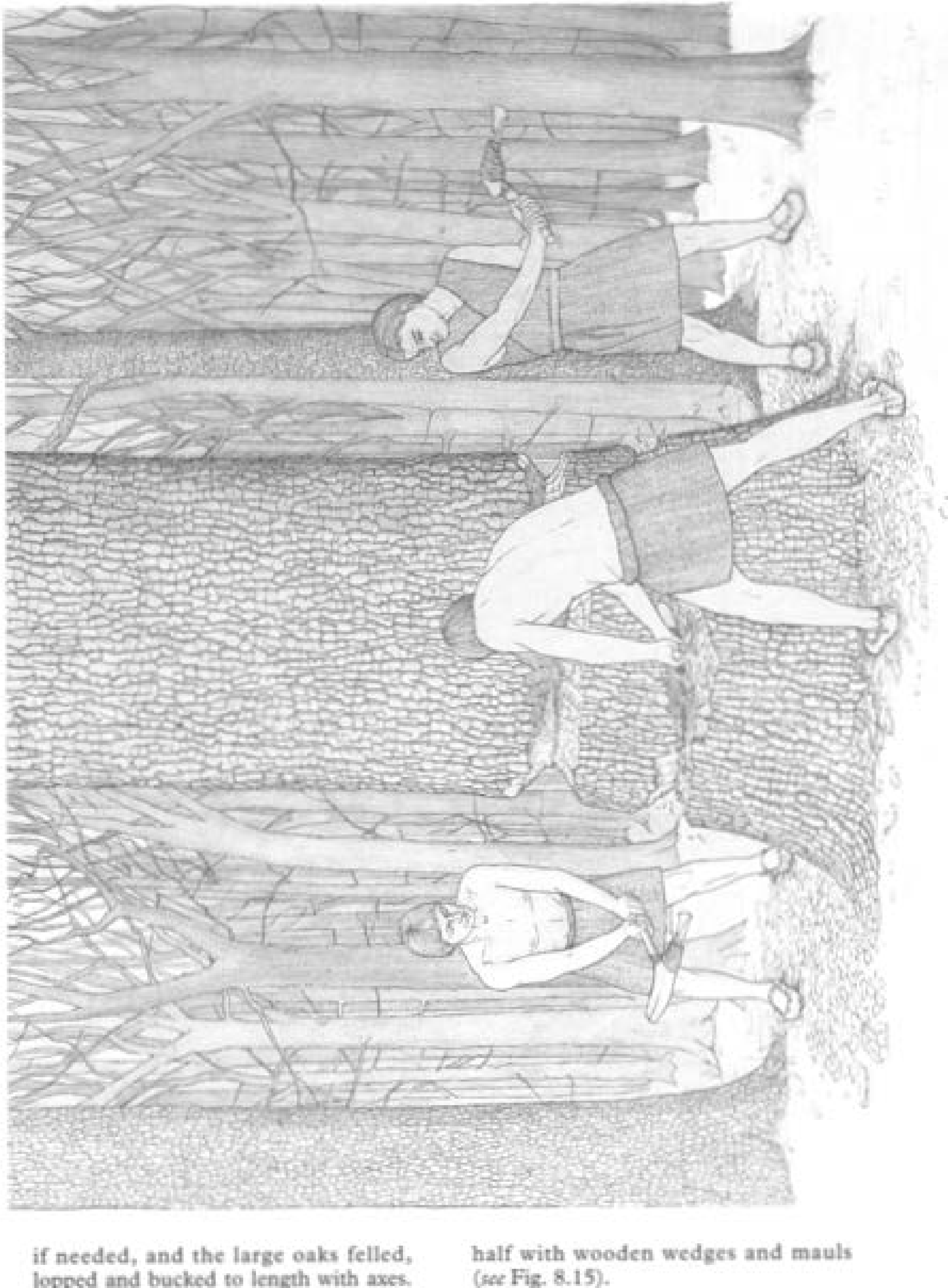


Figure 8.14
Chopping down a tree using bronze axes. These light tools (usually less than 1kg) are far less effective than modern heavy steel axes. A double notch was probably cut into the trunk, and the wood between these notches split away, thus speeding up the felling process.

if needed, and the large oaks felled, lopped and bucked to length with axes. The yew stems were also cut and trimmed with axes (Fig 8.14).

- The parent trees would then be primarily converted by cleaving in half with wooden wedges and mauls (*see* Fig. 8.15).
- The split faces would then be hewn down flat and to the required twist and curve where needed, leaving the distinctive parallel fluted surface (*see* Fig 8.16)

- The split logs would then be rolled over onto the flattened face (*see* Fig 8.17); they would then have to be roughly marked out by the most senior workers and roughing out begun by notch-and-chop hewing and controlled cleaving (*see* Figs 8.18; 8.19).
- When the timbers were suitably reduced in weight they would have been hauled to the building and assembly site on skids over a cleared route, possibly with the help of some form of water transport (green oak heartwood sinks, even in salt water, so simple rafting is not possible for very freshly felled timber). This would have been a communal effort (*see* Fig 8.20).
- The roughed-out elements would be assembled, and a low building platform built, probably of stout poles. The timbers would be offered up, with substantial trimming and a secondary phase of marking out.
- Further trimming, offering up, scribing, remarking and so forth, would be carried out. Fittings such as laths, wedges and transverse timbers would be prepared (*see* Fig 8.21). Previously harvested withies would be stripped of side branchlets and soaked, although this might have been carried out much earlier in the process (*see* Fig 8.22). Raw materials, such as moss and beeswax, would be harvested and prepared (*see* Fig 8.23)
- Wedge slots, stitch holes and slots in cleats would be cut, perhaps with some trial fitting of relevant parts.
- The bottom planks would be joined with wedges and the transverse timbers, driven into place over the outer rails (*see* Fig 8.24). Experiment showed this was possible with the original slack fit of the timbers, good lubrication and bending by foot pressure during driving. The central laths would also have been put into position, overlying pads of moss. Whether the wedges and transverse timbers were driven over the laths or *vice versa* is unclear, although the former seems more likely.
- The end boards would then be trimmed and fitted, well supported by shores (*see* Fig 8.25). The wedges locating the southern board (Chapter 5; Timber 306) could not have been fitted after the iles were in place.
- The ile planks could then be offered up and trimmed, stopping pressed into the seams, stitches twisted and fitted (*see* Figs 8.26; 8.27), and the moss and seam laths driven into position (*see* Fig 8.28).
- The upper side strakes were then offered up and trimmed, and the side timbers inserted into the side cleats on both the upper side planks and the iles.
- The upper side planks could then be stitched into place, presumably with stopping, moss wadding and laths driven into place, although there is no evidence of this (*see* Fig. 8.29).
- Other fittings, such as thwarts or beams, could then be installed.
- It might be that all the stitch holes were waterproofed with a stopping containing animal fats and beeswax when all the stitches were completed (Chapter 5). A protective coating, such as animal fat, might have been applied to the timbers to protect the partially dried timbers against excessive drying and splitting or perhaps water absorption, although there is no evidence of this. Repairing defects such as splits in the iles might already have been required at this stage. Finally, the boat might have been decorated and perhaps undergone some kind of ritual 'blessing' prior to launch.

Rough estimates for building time

Clearly, as much of the original boat was not found, and the typical working habits of Bronze Age folk are not known, any approximations of the labour time that the work might have taken are merely speculative. However, some valuable information is provided by the records of the building of the 3m-long experimental midships section (Chapter 9). It took a team of moderately skilled woodworkers – initially unfamiliar with bronze tools – four weeks to build the hull section to a stage nearly ready to fit the finished iles, working a total of 85 person days. Further experimentation showed that the fitting of those ile sections might have taken perhaps another half a week. Perhaps we might estimate another week and a half to make and fit the top strakes and other timbers for the 3m-long section. This brings us to a total of approximately six weeks for four people per 3m length. For a minimum reconstruction of 12m in length, this figure could simply be multiplied four times to twenty-four (five day?) weeks for four people, or perhaps twelve for eight workers. This would, however, provide a quite false impression, for

Figure 8.15
The felled trees would have been split at the place they were cut down, using wooden wedges hammered in with heavy wooden mauls. Much of the primary preparation of the logs was done here in order to reduce the weight of the timbers, which had to be dragged from the wildwood to the final assembly point.

Figure 8.16
The bottoms of the split logs were flattened using bronze adzes, finally working along the grain, creating shallow longitudinal grooves that could be seen on the bottom of the Dover boat. On the right, a worker is trimming the edge of a log with an axe. In the centre, workers brush the wood with fat or oil, to help prevent the wood from drying out and splitting.

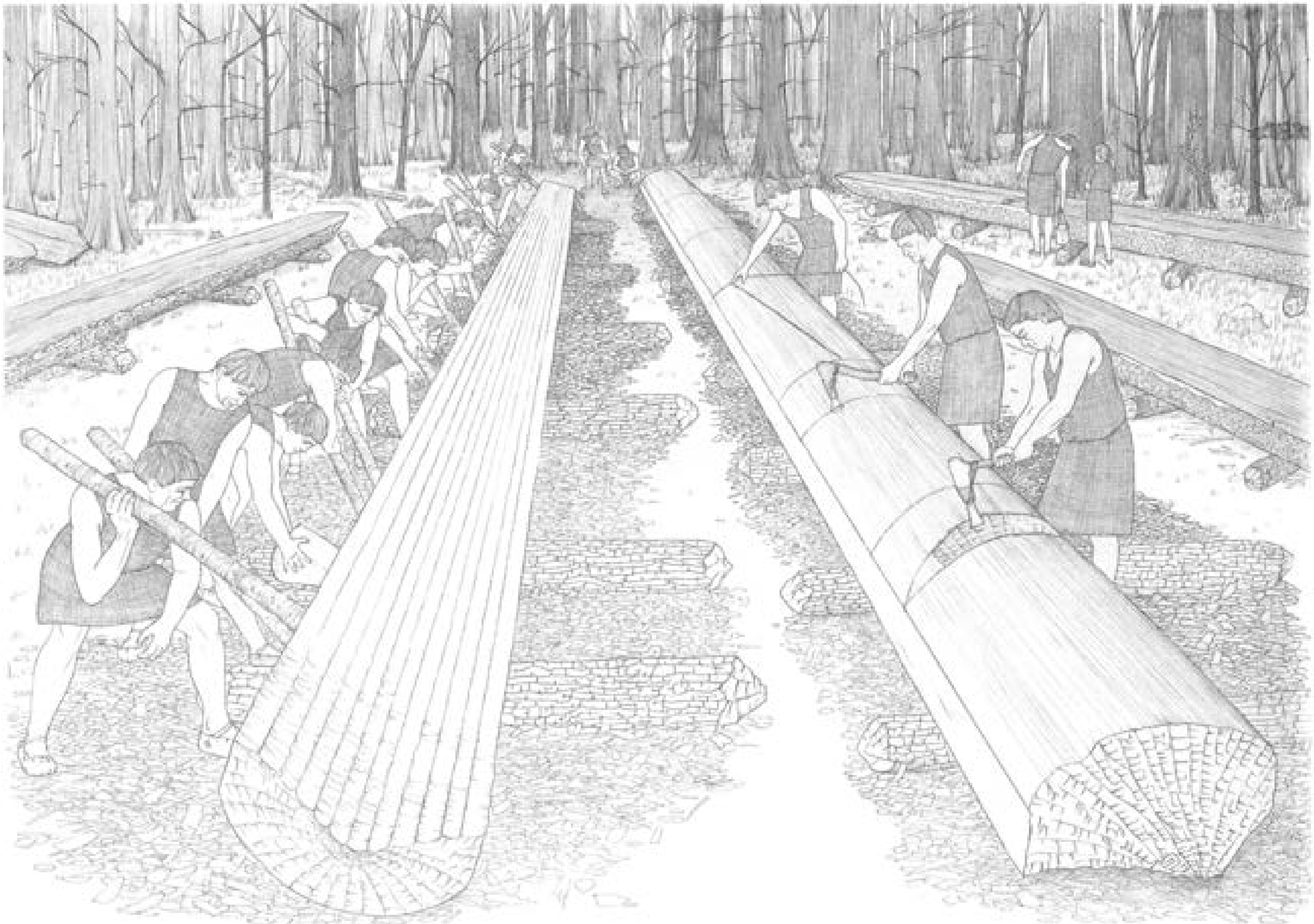


Figure 8.17

Once the bottom had been flattened and the sides trimmed, the logs could be turned over so that work could begin on what was to be the inboard surface of the planks. On the right, a worker is marking out the log, showing where internal features such as cleats are to be left upstanding. Others have started the laborious process of cutting notches into the logs with bronze axes.

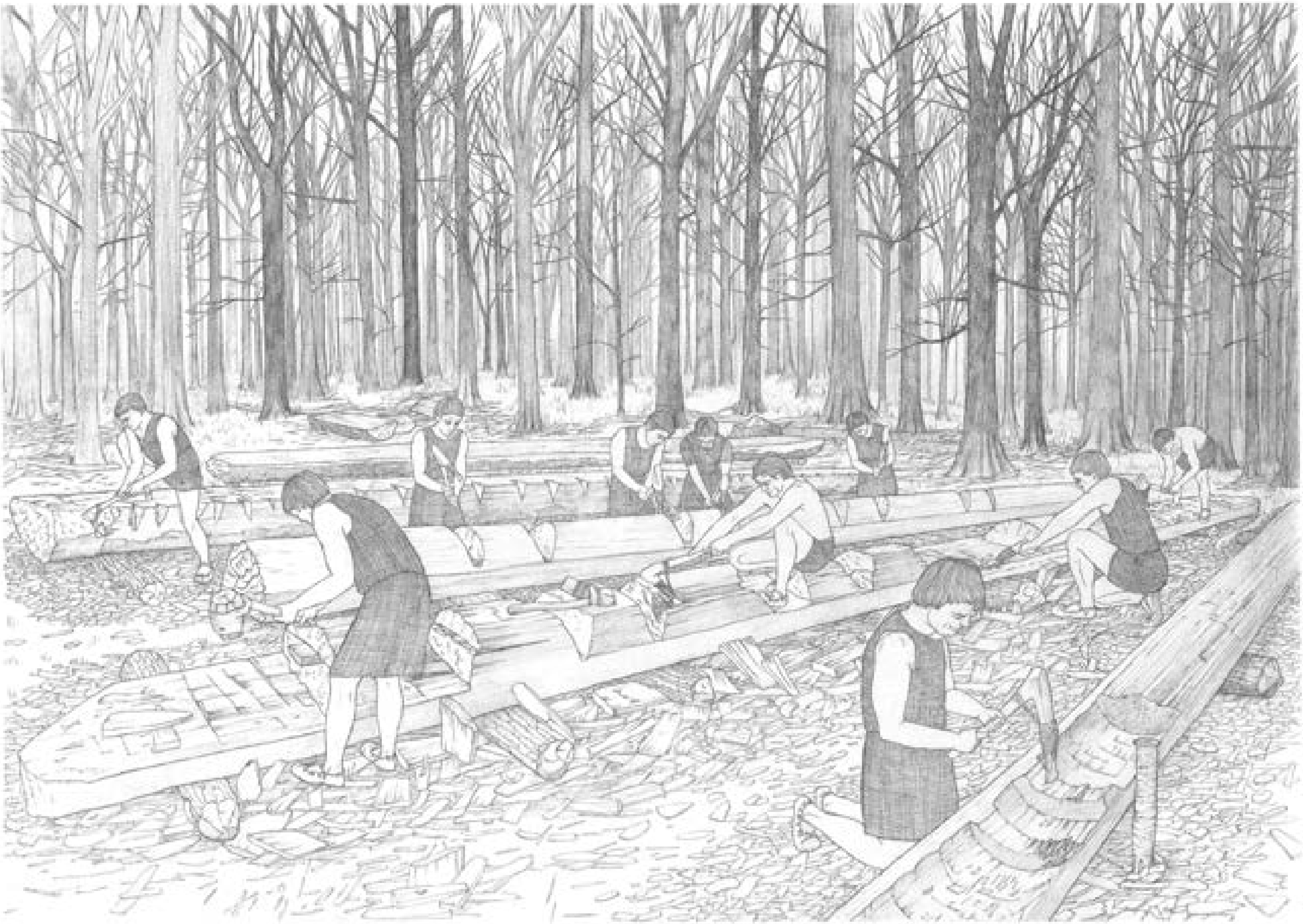


Figure 8.18
Notches were cut into the upper surfaces of the logs and then unwanted wood was split away with wooden wedges. Great care had to be taken not to split off timber that was needed for features essential for the construction of the boat, such as the central rails and cleats. The two massive bottom planks can be seen taking shape in the centre of the picture; in the background and foreground the curving ile planks are being fashioned in a similar way.

Figure 8.19
Roughing out the inboard surfaces of the planks with adze and axe; a master boatbuilder supervises the work.

Figure 8.20

The heavy planks needed to be removed from the forest and taken to a place close to the sea where the boat could be built. Even though the logs had been greatly reduced in weight by the preliminary roughing out, their removal would still require many hands, pulling the plank atop timber rollers along a track of bearers.

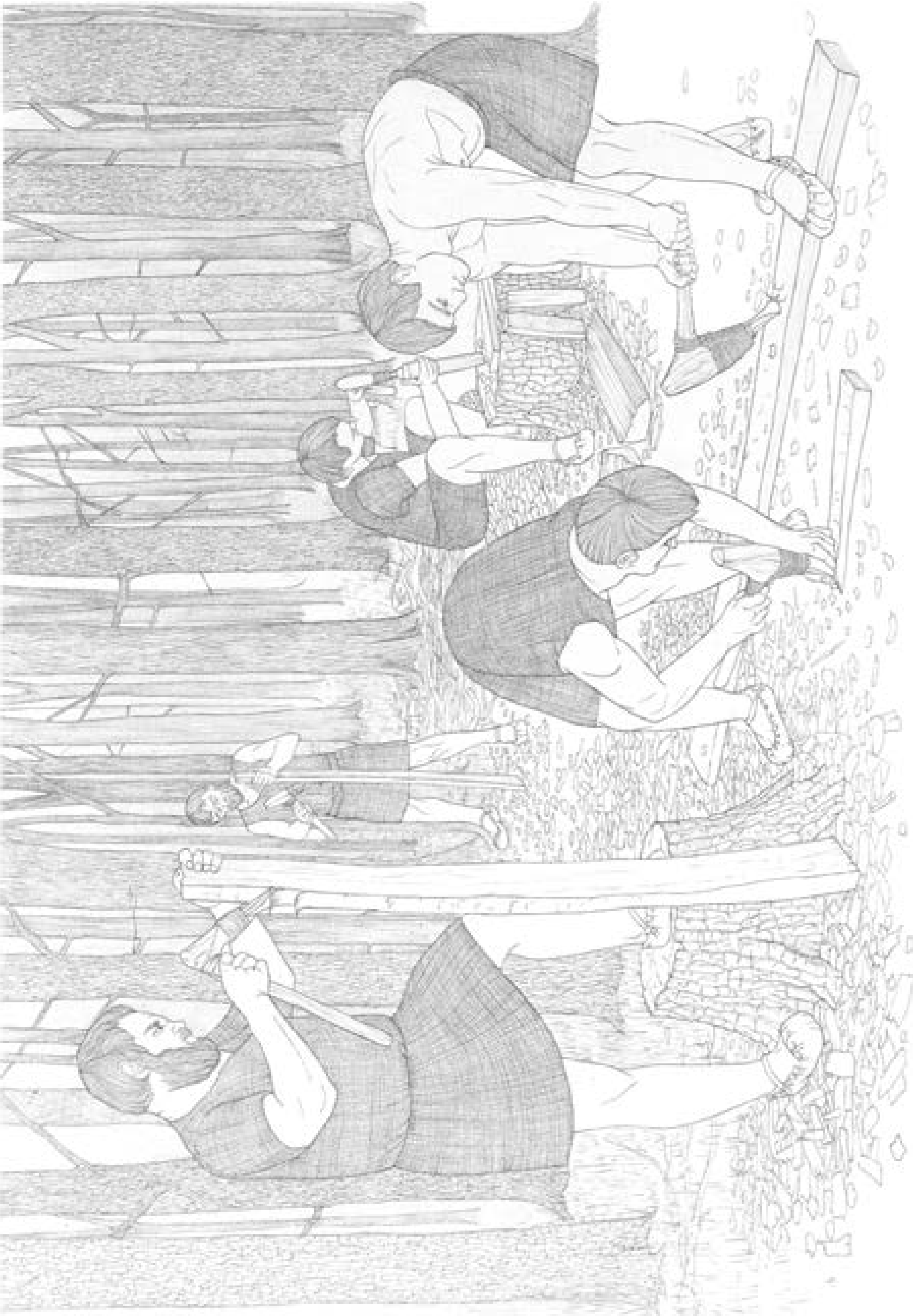


Figure 8.21
Making transverse timbers and wedges. Apart from the major planks, many other fittings were required: transverse timbers, wedges, laths, etc. Many of these could be fashioned from the waste wood split off the logs, and then taken to the assembly site.

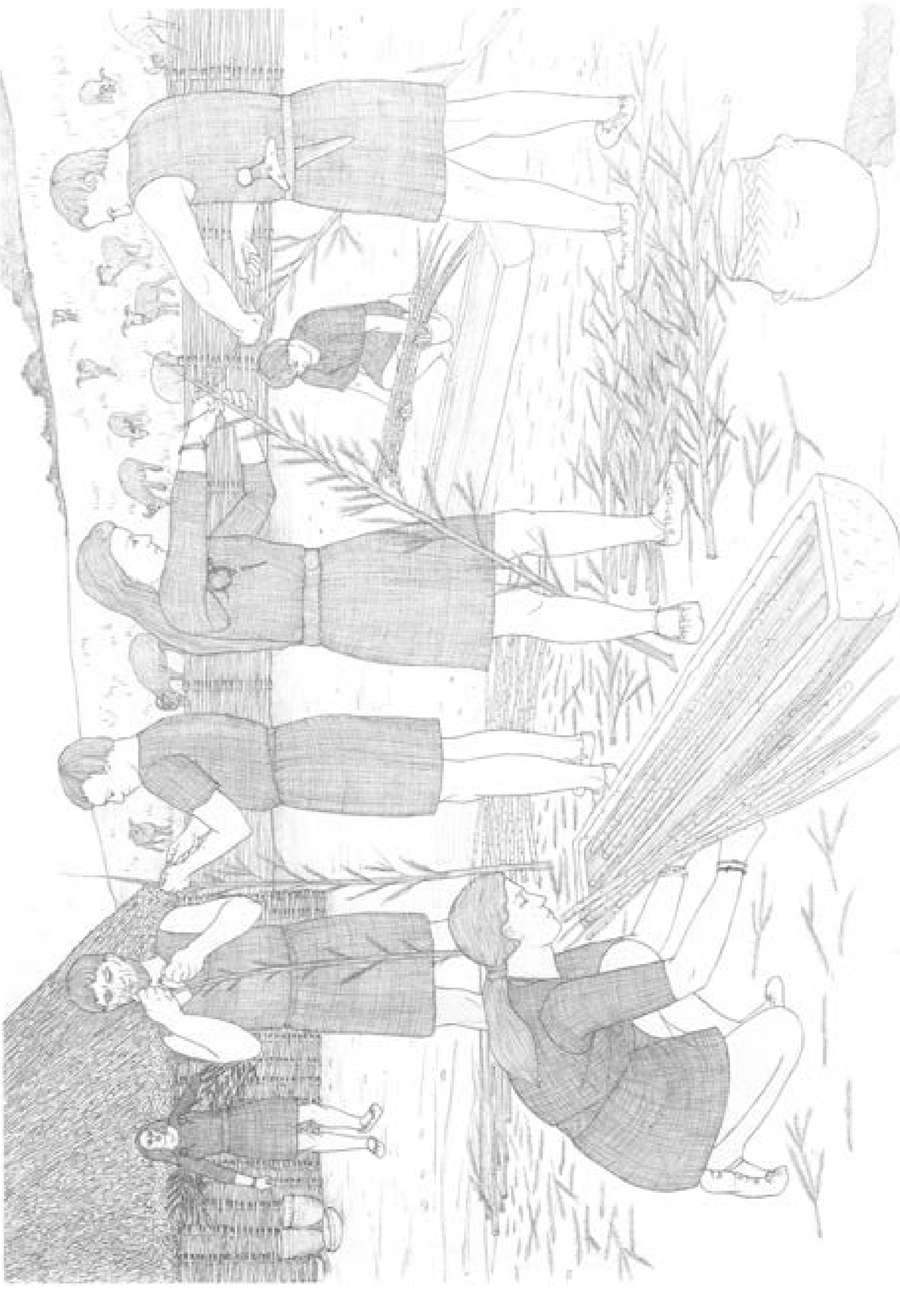


Figure 8.22
Collecting, stripping and soaking the yew withies needed for stitching the boat planks together. The boat required well over a hundred withies of suitable size, thickness and quality.

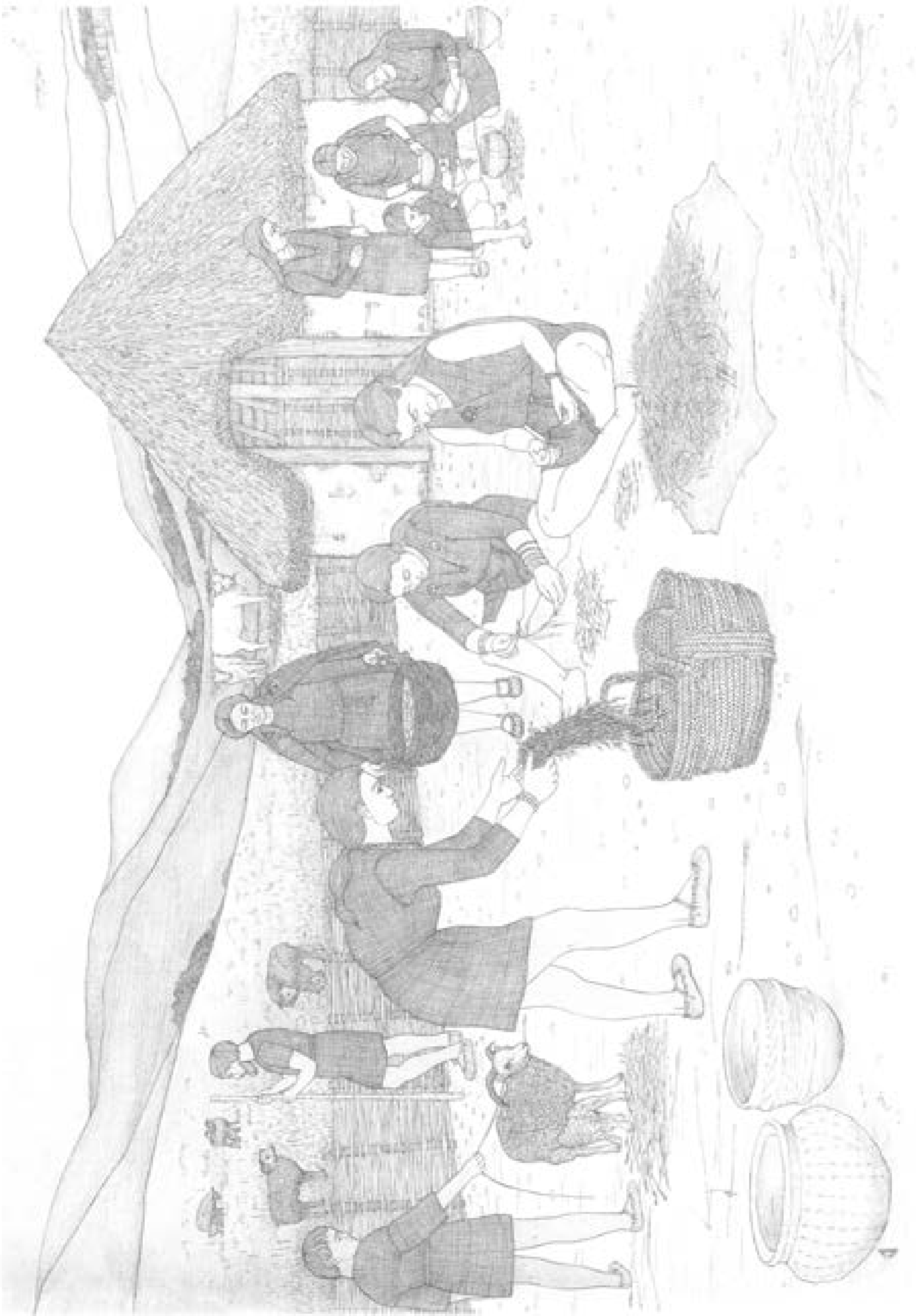


Figure 8.23
Large quantities of moss had to be collected and cleaned for use to make the boat watertight.

Figure 8.24
At the construction site, work could begin on building the boat in earnest. First, the two bottom planks were offered up, wedge holes and stitch holes cut with bronze gouges and chisels and the transverse timbers hammered through the cleats and central rails.

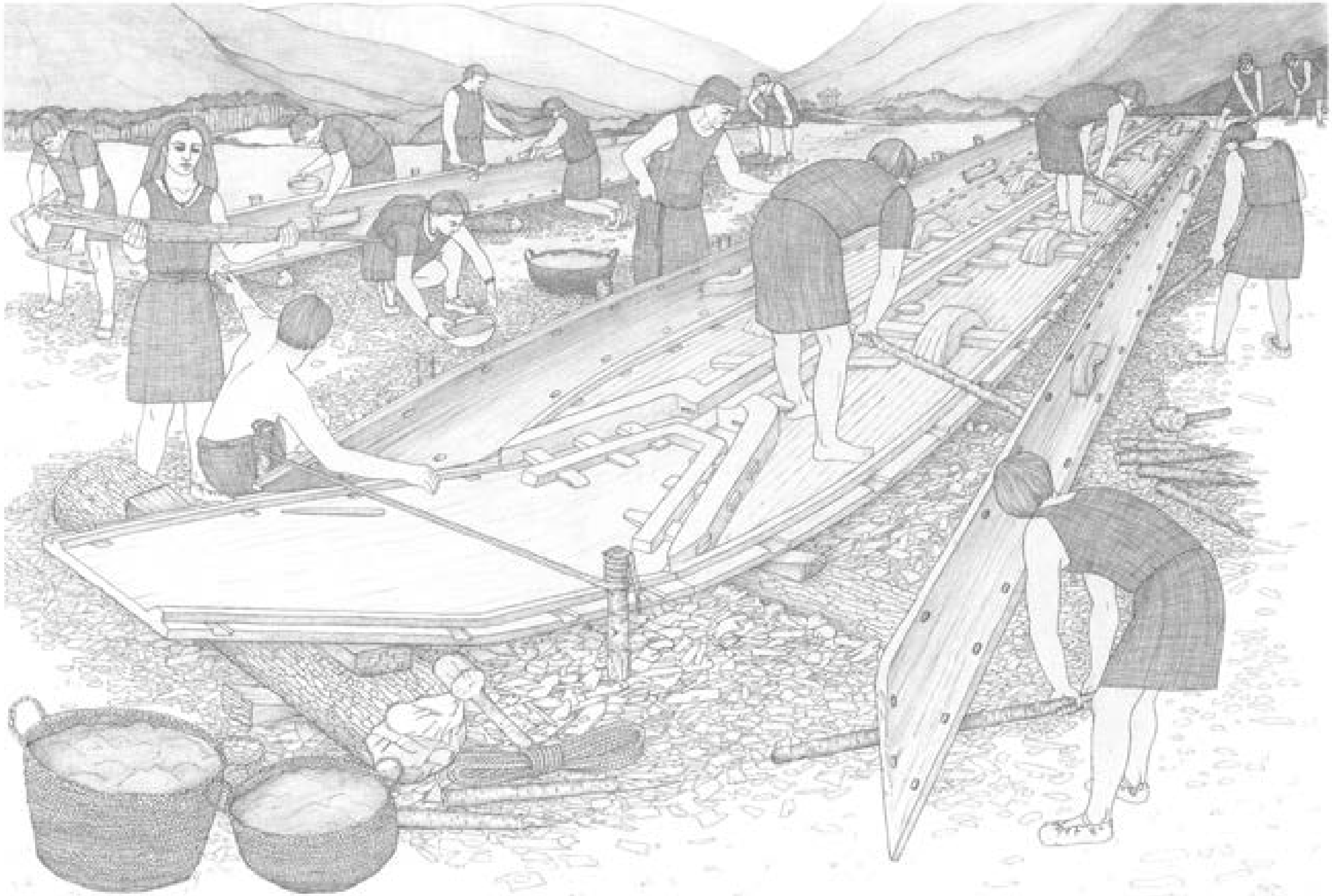


Figure 8.25
With the bottom planks joined together, the end board could be inserted – propped in position while the ile planks were offered up. The yew withies for stitching the iles to the bottom planks were assembled, together with baskets of moss and bowls of waterproof stopping. The worker on the left has a bodkin close at hand to help feed the withies through the stitch holes to create the stitches.

Figure 8.26

Withy twisting; the slender yew branches had to be twisted to break the fibres of the wood and make them flexible enough to be thread through the stitch holes to create stitches. The most efficient way to do this appears to be to anchor the thick butt end of the withy with the foot while twisting the branch with the bare hands.

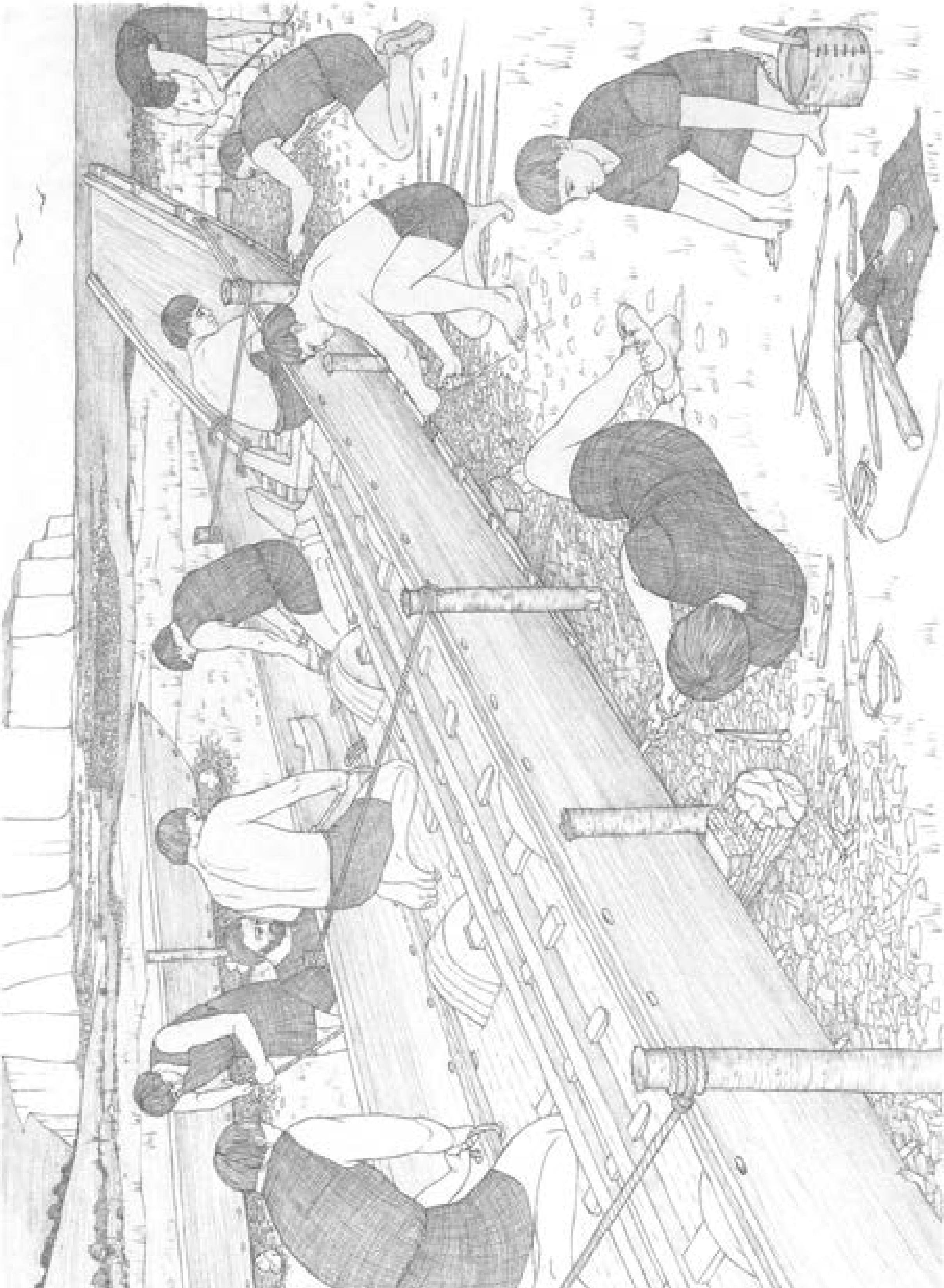


Figure 8.27
The ile planks – when offered up and supported by stakes and wedges – could be stitched onto the bottom planks. In the background is an upper side plank, ready to be attached after the iles were attached.

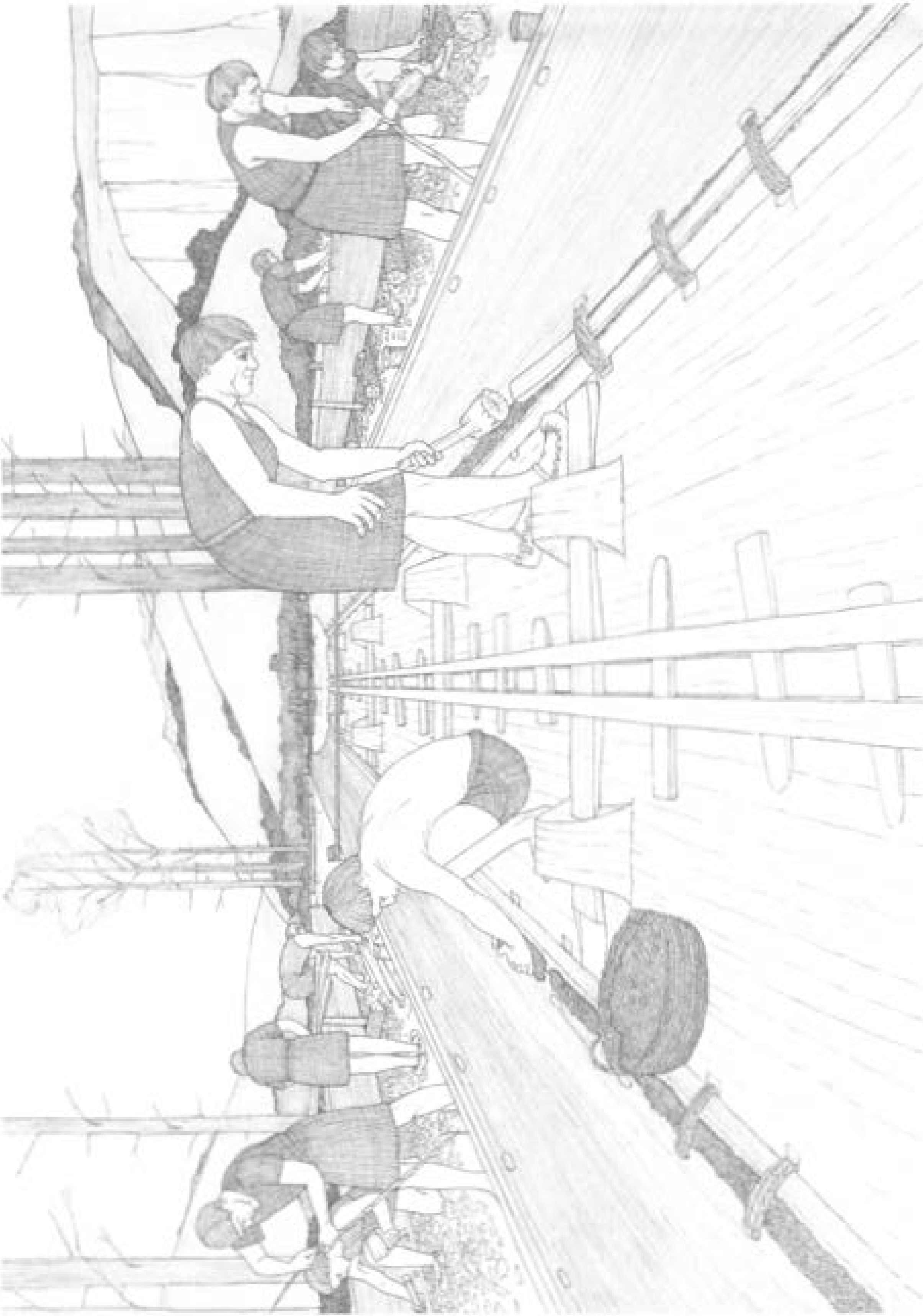


Figure 8.28
On the left, a worker is placing pads of moss along the seam between the ile and bottom plank. The worker on the right is hammering a lath under the stitches, tightening them and compressing the underlying moss to help make a watertight seam.

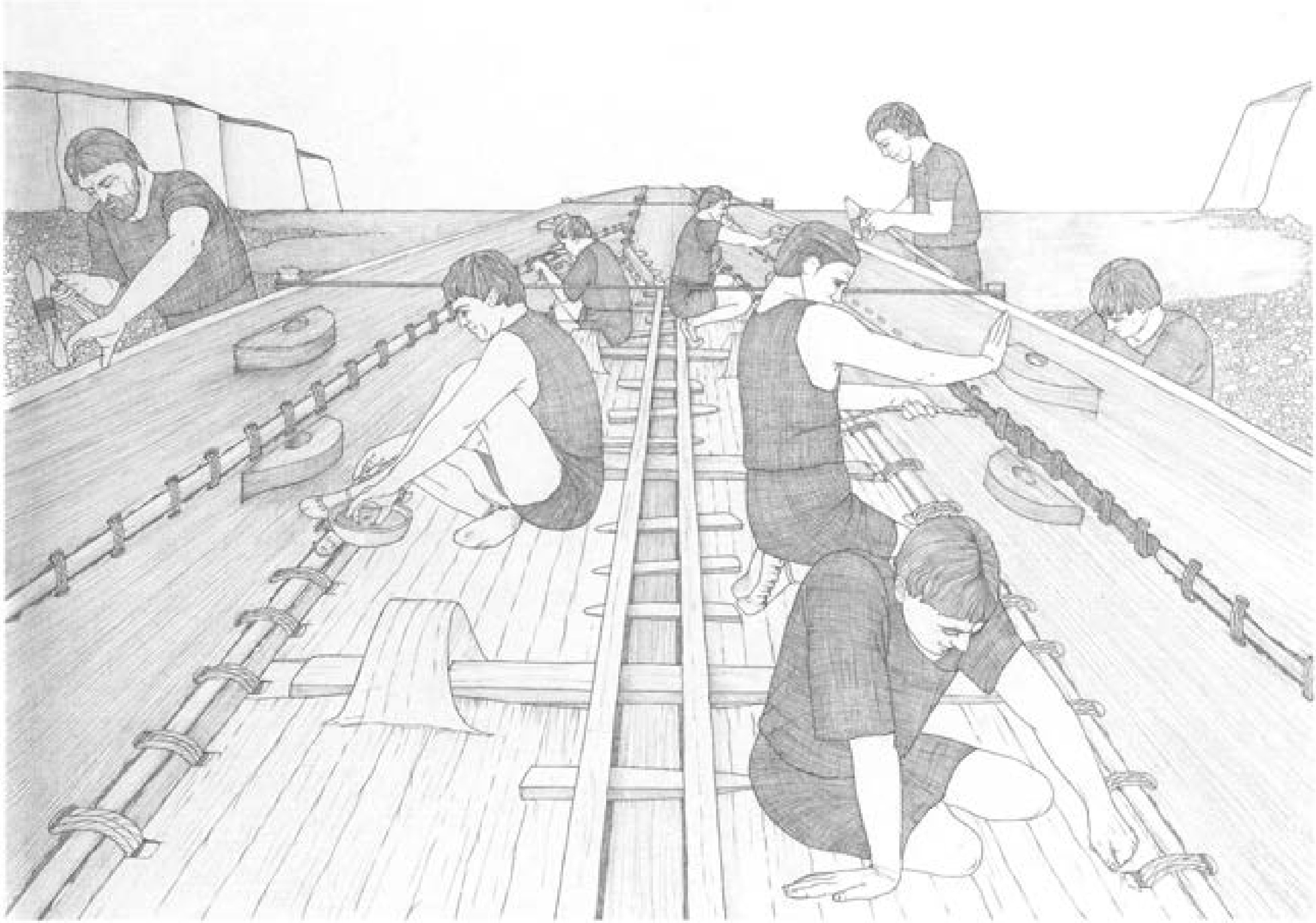


Figure 8.29

The upper side planks are nearly stitched in position. A waterproof stopping of beeswax, animal fat and resin is pressed into the stitch holes to help make them watertight. Ropes and stakes hold the upper sides of the boat in position, prior to the insertion of side timbers through the side cleats and the provision of thwarts across the hull.

several reasons. First, the complex, more curving end sections would take much longer than the midship section to make and fit, and the full-length timbers would have been far more difficult to manoeuvre and work on, particularly for the upper strakes. Also, the time required for finding, felling, lopping, bucking and moving the huge timbers, and obtaining the withies and other materials by simple means, would require potentially weeks of labour for a large team.

The early stages of the work are extremely hard on the body, and even strong, fit Bronze Age woodworkers could not have worked continuously; rest periods, other work and bad weather would no doubt have intervened. However, during a prolonged building period, the tendency of the timber to harden between bouts of work, and for splits to develop in the large pieces of oak, would encourage a steady flow of work. In sum, it is suggested that the original vessel was probably built from the late autumn to late spring, by a team varying in size and skill depending on the work in hand. The total person days required might have been of the order of 500–600, including all of the varied work required, other than making paddles and so forth (other estimates have been suggested; Chapter 9).

Comparisons

Comparisons can be made with the evidence for woodworking recorded for other Bronze Age timber structures.

The Ferriby finds

Ted Wright's pioneering work in finding, recovering, recording and analysing the Ferriby finds took place almost entirely before the relatively recent advances in methodology and understanding in the study of early woodwork. Despite this, a number of aspects of the woodworking processes involved were considered in outline, and the value of practical experimentation with this little understood technology was suggested (Wright 1990, 118). However, after lifting the boat timbers, few tool marks or other surface details remained for study, although some features can be reinterpreted in the light of work on the Dover find. The complexity of the rabbeted seams and lashing arrangements was of a similar order to those of the Dover boat, as was the standard of their execution. Similar levels of labour and skill must have been involved in building these vessels.

Other British prehistoric planked boat finds

Very little of detail has been recorded or published in this connection beyond the basic data of the size and species of elements and the section of log used. Few tool marks have either survived – as in the case of the Brigg raft and recent Welsh finds (Heal 1981, 254; Nayling and Caseldine 1997, 211) – or have not apparently been recognised. However, it is clear that the Dover boat's builders were not a uniquely skilled team; many communities around Britain built such craft in the Bronze Age.

Cheops ships

As to the scale, finish and decoration of these vessels, they must be considered more elaborate, as befits workers working in a huge, complex, integrated imperial society such as ancient Egypt (Jenkins 1980). However, at the level of basic woodworking techniques there are many similarities, such as the hewing of the plank elements in three dimensions, and the use of lashing and seam battens. In one key area, the Egyptian woodworkers had a technological advantage, the saw, though the tool was apparently used in the making of deck furniture rather than the main hull timbers.

Trackways

Many peat bogs all over Europe have yielded the remains of walkways, or even roadways of woody materials dating to the Bronze Age (Coles and Lawson 1987; Meddens 1996; Thomas and Rackham 1996). Most of these structures were made of small roundwood, where the woodworking involved was felling, cross-cutting and lopping with axes, and pointing small stakes. Tool marks from these operations have recently been studied in detail and have provided several new insights into Bronze Age woodworking, such as dating the use of successive tool types and the rapid abandonment of stone axes (O'Sullivan 1997, 314). A small number of the structures were constructed of larger logs or timbers converted by cleaving in both tangential and radial planes. Some of these were pierced by axe-cut through holes (wrongly termed mortises) for fitting anchor stakes (Coles and Orme 1982). These were generally more crudely cut out than the through holes in the Dover boat. Speedily made holes were the aim, rather than regularly cut, moderately accurate joints such as the wedge slots or rabbets in the Dover boat.

In sum, the trackway structures have told us a great deal about the environment of Bronze Age northern Europe, and a considerable amount about certain fundamental aspects of woodworking such as felling, cleaving and socket cutting. However, they leave gaps as regards how more elaborate work was carried out.

Portable objects

Finds of Bronze Age implements, containers and ritual objects of worked wood from Britain have recently been subject to more detailed scrutiny (Earwood 1993; B Coles 1993). However, these studies have mainly focused on the formal attributes, date and possible functions of the objects, rather than how they were made. Techniques appropriate to small-scale woodwork are noted, such as the use of inscribed lines, glue, and inlaying with other materials. Some of the drinking-vessel finds were made of several pieces of cleft timber, very carefully carved and fitted so as to be watertight, with a quality of fit not achievable in large sections of oak like those used in the Dover boat.

Buildings and related structures

In Britain, the remains of timber buildings from the Bronze Age have not been found in good states of preservation, but reused timbers apparently from buildings have been recovered from excavations of waterfront and ritual sites such as Caldicot and Flag Fen (Nayling and Caseldine 1997; Taylor 1992). In these cases, the forms of woodwork evidenced were rather similar to that seen in trackways, with split and hewn timbers of various types occurring, often having hewn-through sockets. However, other features, such as the trimming of grown forks, or the hewing of crude forms of tusk tenon for the tops of posts, are also recorded.

Very importantly, no evidence of the use of withies or other cordage as fastenings has been found to our knowledge. Thus, the edge fastening of timbers with withies might be a distinctive feature of nautical woodwork at this time, not commonly seen elsewhere.

Dugout boats

Many of the techniques used to build vessels very largely of one log (ie dugout boats) would clearly have been very similar to those used in the building of the Dover boat, particularly the hollowed ile timbers. Unfortunately, no detailed studies of British Bronze Age finds have been made. One detail recorded in the Bronze Age Appleby boat related to repairing a split, differs from the evidence for the planked boat finds. A roughly dovetail-shaped recess was cut across a split to receive a snugly fitted clamp of timber (McGrail 1987, 66).

Wheels and wheeled vehicles

It is perhaps only in the construction of wheels and wheeled vehicles that we glimpse woodwork of similar complexity to that of the Dover boat in the European Bronze Age (Piggott 1983). Here, large slabs of cleft timber were hewn with adzes and axes to form solid and tripartite wheels, usually joined with edge pegs or keys set in chiselled or gouged holes. The bodies of the vehicles were accurately hewn and joined, often incorporating grown timbers. Some of the carts, wagons and chariots were clearly both functional and material statements of power and status. The woodworkers who built these vehicles were apparently of a similar level of skill to those who built the Dover boat, and had to employ lighter, stronger systems of construction to suit land travel before the existence of smooth metalled roads.

Woodworking in the Bronze Age

The Dover boat is currently (2004) the most elaborate example of large-scale woodworking known from Bronze Age Britain. It is also the best-preserved plank built boat known from Europe at this period, and has been studied in considerable detail. The results of that study have been summarised in this volume and have been given three-dimensional form in the new Dover Bronze Age Boat gallery at Dover Museum. It is fair to say that our knowledge of Bronze Age woodworking as a whole has been moved forward by this study at several levels. At the technical level, the comparative efficiency and otherwise of typical Middle Bronze Age tool types (palstaves hafted either as axes or adzes) has been demonstrated both in the analysis of the original find and work on the experimental hull section. Some of the results, such as the comparative speed of timber removal using the larger adze-type palstaves along the grain have come as a surprise.

Other types of insight concern subtle issues of a socio-economic nature, such as the level of care taken by the original workers in finishing the vessel. The vessel was carefully built, and the finish deliberate and fairly regular on the whole, but could easily have been more regular and/or smoother. In other words, the vessel was clearly a massive labour investment for a small community, but was not given the same level of attention as some contemporary metalwork or some vessels of later periods, such as the Øseberg ship (Sjøvold 1985). It was not built to work primarily as a manifestation of high status, or as some form of 'royal vehicle'. However, as an archaeologist dealing with large quantities of early woodwork and with some practical experience of boatbuilding in various styles, the cutting of the curving rabbets of the plank edges puts one in awe of the experienced and skilful hands of the builders. The most demanding of the rabbeted areas to cut was the seating of the end timber and its rail and lath fittings; fortunately, we were not obliged to attempt to replicate that part of the vessel!

The use of the deliberately fluted finish was distinctive, but has now been recognised on other examples of Bronze Age woodwork. Ironically, it was in some senses a throwback to the period of stone-tool use, which has a curious modern survival in the fluting of many neo-classical-style stone columns – clear skeuomorphs of earlier wooden examples.

A technological dead end?

Although the vessel was elaborate and clearly functional in moderate sea conditions, it is also an example of a style of planked boatbuilding that was a technological 'dead end' in most respects. In some areas, the boatbuilders seemed to ignore the natural strength characteristics of the oak timber they used, such as the placing of stressed wedges in lines along the grain and the use of rather heavy sections. A key feature here was the clear lack of an auger-type tool for hole boring, which effectively prevented the widespread use of treenails, or nail-type fastenings (even if the metal had been available). Clearly, the prodigious use of materials and high level of labour investment could not be sustained, even in a Classical economy with slave labour. The boat, in that sense, is not the product of what we would recognise now as rational minds (formal economics), except to the extent that the builders were clearly concerned to extend the carrying capacity, stability and seaworthiness of single-hulled dugouts, the more typical wooden vessels of the period.

9
The reconstruction experiment

by Richard Darrah

In the summer of 1996, a 3m-long reconstruction of the midsection of the Dover boat was made from two oak logs, using copies of original Bronze Age tools. In planning this reconstruction, it was necessary to have a clear idea of what was to be achieved. Either we could reconstruct a boat within the structures imposed by Bronze Age society, or we could create an 'exact' copy of a boat using power tools. In the event, a middle ground was chosen. We chose to be modern people with skills and knowledge of the use of axes and adzes on green oak. Financial and time constraints led us to fell the oak with power tools and transport it by lorry, but the work on the timbers was otherwise carried out with modern copies of tools available in the Bronze Age. We worked outside, but arrived in cars and covered the boat overnight with a plastic sheet. The reconstruction was a compromise between the work of the original builders and the theories about this process held by the reconstruction team.

The main aims of this reconstruction were to:

- recreate a 3m length (full scale) of the central section of the Dover boat;
- explore how it would have been possible to remove cubic metres of oak with simple bronze and wooden tools;
- show how the boat shape could have been marked up;
- investigate the stages of construction of the original boat;
- explore how long the original boat may have taken to construct;
- demonstrate how the sets of cleats, rails and wedges interact to hold the timbers rigid and control the shape of the boat;
- investigate how the waterproof joints worked;
- investigate the sourcing, preparation and fitting of the yew withy stitches.

The task was to take two green-oak logs, together weighing about 3 tonnes, and, with tools weighing less than 1kg each, carve out complicated three-dimensional shapes with a final weight of less than half a tonne.

Following the initial discovery and excavation of the Dover boat, work was carried out to ascertain the original size and shape of the boat timbers, and the parent trees (Chapter 7). The process of reconstruction started with finding appropriate trees, tools and other materials and working back to producing a boat. A year before the intensive boatbuilding took place, the process of casting tools and sourcing materials began.

This process involved finding oak trees of the right size, selecting those with grain straight enough to split, collecting branches with appropriate crooks to make tool handles (Chapter 8), pretreating the timbers (by rubbing lard into the sawn ends), collecting yew withies, casting bronze axe heads and hafting them, making oak wedges, planning a work schedule, locating a suitable site for reconstruction, assembling a team of woodworkers, arranging security, health and safety, delivery and storage facilities, and arranging public access for viewing the work in progress.

The original boatbuilders, like the reconstruction team, would have had a clear idea of the trees required to build the boat. The selection criteria were: appropriate size, straightness of trunks, straightness of grain, absence of large knots, availability and ease of transport. For the Dover boat, the original, straight trunk lengths would have been in excess of 11m, with a breast-height diameter of 1.15m. Such trees no longer exist in the British Isles, but, in reconstructing only a short length of the boat, trunk lengths of only 3m were sufficient.

Two large oak trees were donated by Philip Smith for use in the reconstruction. The lowest 4m of these two trees were taken for the boat, although the bottom metre was removed as it contained the buttressing of the tree and was not workable. The diameter of the larger tree was 1.1m at 1m from the ground, the other was 0.8m at the same height. Trees on this scale are not commonly available in modern British woodland.

The process of reconstruction

Stage 1: making the tools

In this stage of work, palstaves, socketed axes, chisels and gouges were cast in bronze (Fig 9.1), suitable tool handles were selected, hafted and sharpened (Fig 9.2), wooden wedges were shaped and wooden mauls were made.

The bronze tools used in the reconstruction were copies of original Bronze Age tools (most of which came from east Kent; Table 9.1). Twenty-one bronze tools were used during the reconstruction (one blade was re-hafted; Table 9.2); these had been

Table 9.1 Original bronze tools[1]

tool type	*where found*[2]	*type*[3]	*condition*	*weight (g)*
palstave	east Kent	A	unused	506
narrow looped palstave	Norfolk	B	unused	420
narrow palstave	east Kent (MM5; Malmains)	C	unused?	500
palstave	east Kent (Ripple)	D	edge hammered	475
socketed axe	east Kent (DOVRM 0.1383)	E	unused?	320
chisel	east Kent (MM4; Malmains)	F	edge hammered	180
socketed gouge	east Kent (DOVRM 0.1392)	G	unused	79
socketed gouge	Flag Fen, Peterborough	H	worn out, socket burred	69
small socket axe	east Kent	J	unused	80

[1] These are the original tools copied to form the tools used for the reconstruction.

[2] Museum accession numbers are given where known.

[3] Letters refer to blade types (so that tool A2 from the reconstruction tool box was one of the tools cast as a copy of blade A, the palstave from east Kent).

Table 9.2 Tools used in the reconstruction

blade[1]	*weight*[2] *(kg)*	*final weight*[3] *(kg)*	*type*	*notes*
A2	_	0.995	axe	
A5	1.095	1.09	adze	
A6	_	_	adze	
A6(2)	_	1.065	adze	original handle of A6 with a C-type blade
B1	1.145	1.13	axe?	
B2	_	0.895	axe/adze	
C1	_	0.92	adze	
C3	_	1.03	adze	
C3	_	_	adze	
D1	1.055	1.045	axe	
D2	1.48	_	adze	broken on 5 August
D2(2)	_	1.115	adze	blade D2 with a new handle
D3	_	1.105	axe/adze	
D5	_	_	adze	
D7	_	1.39	adze	
E1	_	0.995	axe	
F1	_	0.365	chisel	
F2	_	0.49	chisel	long handle, 0.45m long
F3	_	0.365	chisel	
G1	_	0.31	gouge	
H2	_	0.17	gouge	
H3	_	0.18	gouge	
wooden	2.81	_	holly maul	
wooden	4.8	_	elm beetle	

[1] Letters relate to the original Bronze Age tools.

[2] Weight includes handle.

[3] Final weight recorded at the end of the reconstruction; weight was lost as handles were reshaped and re-tied.

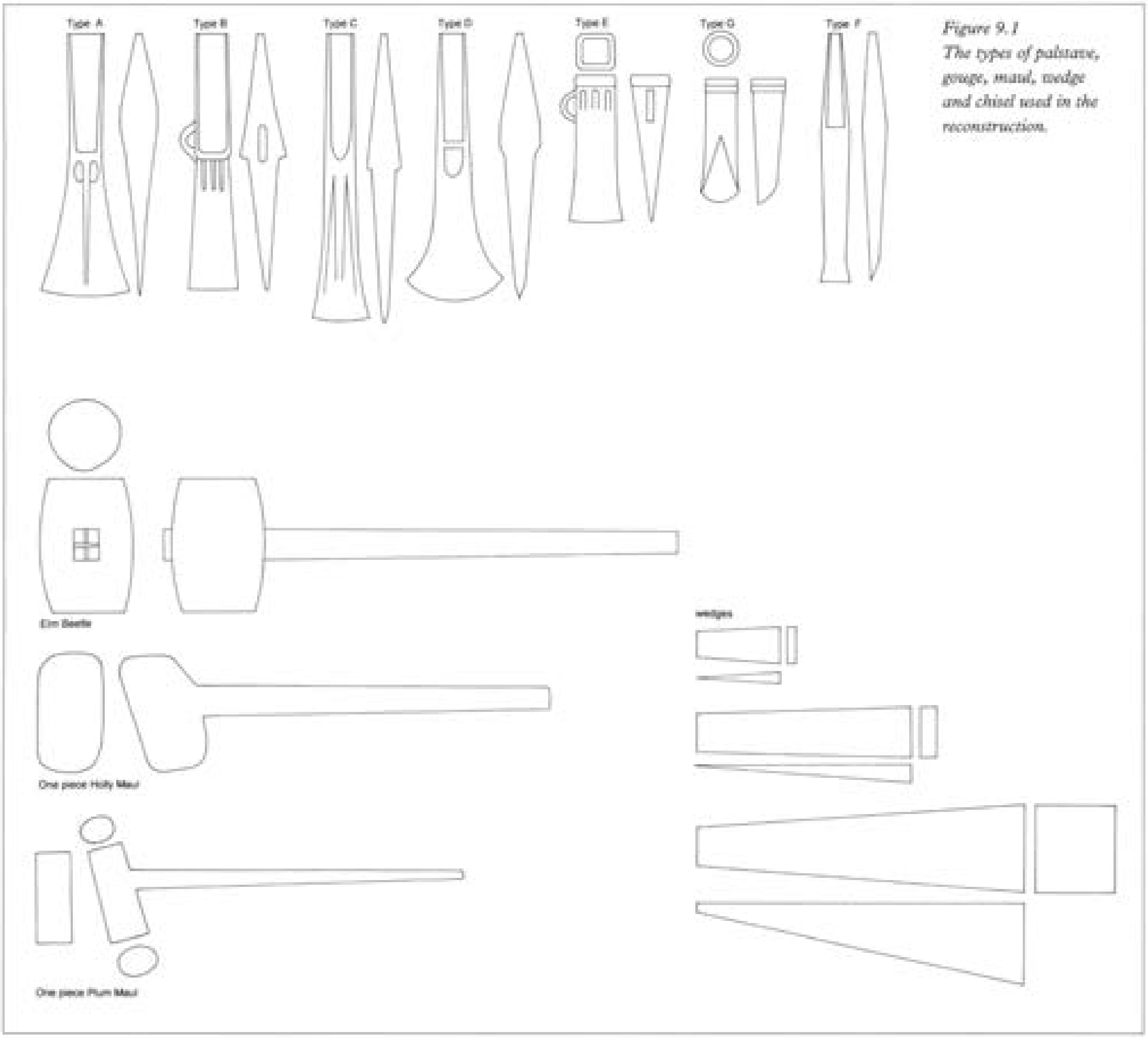


Figure 9.1
The types of palstave, gouge, maul, wedge and chisel used in the reconstruction.

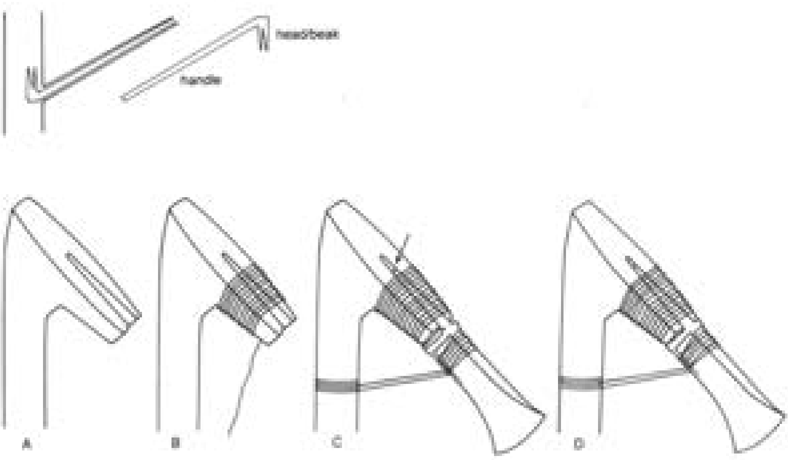


Figure 9.2
Hafting tools. A length of trunk is selected with a suitable angled branch to act as the handle. A: the head is shaped from the trunk, cutting a notch that fits the palstave butt accurately. B: the beak is lashed with a series of half hitches in 3mm diameter flax string; this lashing closes the notch slightly. C: the butt of the palstave is then hammered in, as the butt tapers slightly it jams in the tightening lashing. The arrow shows that it jams before the end of the beak reaches the stop ridge. Over several days of working it will continue to seal itself further into the notch. D: when the end of the beak bears on the stop ridge it is important that the butt does not bear on the wood at the top of the notch or the haft will split.

Figure 9.3
Shaping a haft for an axe. The natural junction between branch and trunk makes the haft surprisingly strong.

Figure 9.4
Shaping a haft for an axe. A notch is cut into the beak of the haft to receive a palstave.

cast in sand by a professional foundry, using scrap bronze. When analysed, the metal used in these copies was found to be of a similar composition and hardness to that of Bronze Age tools. The copies were somewhat softer than prehistoric samples, and would have needed sharpening more frequently than those used to build the Dover boat (Goodburn-Brown 1998).

The tool heads were fitted onto crooked wooden handles, using flax and hemp string. The handles were based on evidence from Flag Fen (Taylor 1992), which indicates that the beak of the handle that holds the head of the blade is cut from a piece of trunk, and the handle is formed from a straight section of branch coming out of this trunk.

During the reconstruction, it was found that the angle of the branch to the trunk was very important in how the tool functioned, especially for adzes. Most angles of the adze and axe handles that worked well were between 70 and 80 degrees at the elbow. One adze handle, with an angle of 90 degrees, was almost useless as a hewing adze, although when this handle was used later with a different blade (type C), it made an excellent adze for splitting the waste between notches when hollowing the ile planks.

The technique of hafting palstaves that worked best began with cutting a notch in the beak so that it fitted the blade accurately. The head was then removed from the notch, the beak lashed tightly (with a series of half hitches), and the notch closed slightly so that the arms of the fork were pulled together. The head was then hammered into the notch. The wedge-shaped head forced its way in, further tightening the lashing until it jammed between the two arms of the fork (Figs 9.2–9.6). If the head went right into the fork it tended to split the fork. Tool handles used in the reconstruction were made from oak, holly, apple, pear, plum and cherry wood (these species being available from gardens and ancient woodland in Kent). Known Bronze Age tool handles are of oak (Flag Fen; Taylor 1992), yew (the 'Ice Man'; Barfield 1994), birch, ash and many other species (Green 1980).

Occasionally, heads came loose – a minor problem that continued throughout the reconstruction. This usually happened when tools were being used for a new job or by someone not experienced with the tool. It was noted that, when cutting the wood across the grain with an axe, the blade had to be at an angle of 70 degrees or less to the surface in order to prevent its loosening.

Each blade copy was numbered individually (*see* Table 9.2). Several of the tools suffered damage in use; blade D2 was bent slightly while adzing a surface, and blade A5 was nicked on a knot. Although individual tool marks were seen on the original boat, no evidence of damaged blades was seen, suggesting that they took better care of their blades than some of us did! The D-type adzes could be over-sharp for fluting, causing them to dig into the wood rather than split it off. The edge of one D-type adze blade broke as soon as it was used,

possibly owing to embrittling from too much hammer-hardening. It was noted that the edges of the palstaves that were worn by use and sharpening subsequently appeared more brassy.

The handle of blade D2 broke after twenty-eight hours of hard use; it was rehafted as D2(2) (Fig 9.7). The heads of both the holly and plum mauls eventually broke during use, and were rebound with twine to prevent complete disintegration. At least 100 wedges were broken and discarded during the reconstruction. There was also some human damage from working with the unfamiliar tools; several working days were lost as a result of wrist strain caused by working intensively with the bronzes axes and adzes. Sharpening the tool blades was a good opportunity to have a constructive rest from the job of hewing (*see* Fig 9.8).

Figure 9.5 (left)
Making an adze. The beak is lashed tightly (with a series of half hitches), closing the notch slightly so that the arms of the fork are pulled together.

Figure 9.6 (below left)
Making an axe. The palstave is hammered into the notch cut in the beak, further tightening the lashing until it jams between the two arms of the fork.

Figure 9.7 (below)
A replica adze used in the reconstruction experiment (type D2).

Figure 9.8
Honing an adze blade. The tools used in the reconstruction had to be repeatedly resharpened to maintain their edge.

Chisel F1 was used to make 16 stitch holes without requiring resharpening (Fig 9.9). These holes were much more regular than those on the original boat, suggesting that the original boatbuilders took much less care than we did in cutting holes. This, like the tool marks on the cleats, suggests that the boat was built quickly.

Wedges were made in two separate stages. Before the reconstruction, some wedges were made from seasoned oak, ash, apple, elm and yew, using steel tools. During the reconstruction, others were made out of radially split offcuts from the boat timbers, using bronze tools. The wedges were made by hewing down the faces of a rectangular split section. Middle Bronze Age oak-splitting wedges have recently been excavated in London and are closely similar to those used during the reconstruction (D Goodburn, pers comm).

In the course of the reconstruction, 15 hours were spent making wedges (as each wedge took less than six minutes, approximately 150 wedges were made). Although our first wedges were made with seasoned oak, offcuts from the reconstruction were used to make serviceable wedges (by eight days from the start of the reconstruction these offcuts had air dried sufficiently to be used). Axe D1 was used for making wedges (Fig 9.10).

One-piece mauls were made from short lengths of holly or plum trunk. The trunks had branches, at about 80 degrees to the trunks, that served as handles (*see* Fig 9.11).

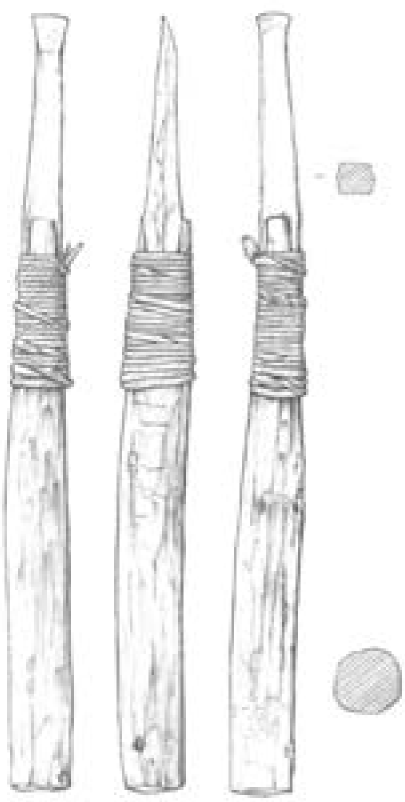


Figure 9.9
A replica chisel used in the reconstruction experiment; a copy of a real example found in east Kent.

Stage 2: splitting the logs

Stage 2 involved studying the bark and selecting the diameter for the split. The tree was rolled so that the chosen diameter was horizontal, and the bark was removed. (There are some historic precedents for splitting logs vertically.) The tree was split by hammering wooden wedges into the sides (*see* Fig 9.12; 9.13).

Each oak trunk was laid horizontally on round, wooden bearers, and then rolled over until the best plane for the split was selected.

The bark was stripped from the sides of each tree, along the line of the intended split, with axes and adzes. As the trees had been felled the previous winter, much of the bark was already loose, but most of the damage to the bronze blade edges of the tools was made in debarking (from the grit and sand buried in the bark).

The oak was split down its length by hammering seasoned oak wedges into both sides of the tree at the bottom end with a wooden maul (*see* Fig 9.12). When the split from both sides had met at the pith, further wedges were hammered in along the line of the split running in front of the wedges down each side of the tree. The smaller starting wedges weighed less than 100g, while the largest backing wedges weighed more than 2kg. Although the split was started with a traditional two-piece wooden beetle weighing 4.8kg, a one-piece holly maul (2.8kg) – similar to the yew maul found in the Somerset Levels – was found to be more effective (Coles and Orme 1980; *see* Fig 9.11).

The first trunk – over 1.1m in diameter and 3m long – was extremely difficult to split, as a large number of strands spanned the split in the centre of the tree, holding the two halves together. The largest of these measured about 200mm × 40mm and had to be cut away with a bronze chisel (F2). These strands took several hours to remove; the trunk took ten hours to split into two halves (which were numbered I and II). The final stage in splitting was to roll the trunk so that the split was vertical, and then finish the split so that the two halves rolled apart with the split surfaces uppermost. Throughout the reconstruction, further splitting took place, reducing half logs to their final shape using this radial splitting technique.

The smaller log – 0.8m in diameter and 3m long– took 4 hours to split into halves III and IV. The process was somewhat lengthened as filming had to be accommodated; without this, it may have taken between 1.5 and 2 hours to split.

Stage 3: flattening the outboard face and sides of the bottom planks

In stage 3, a flat surface was created for the boat bottom (working on a horizontal face) and the sides of the bottom plank were shaped (working on a vertical face).

The flat surface for the boat bottom was achieved by marking out (*see* Figs 9.14a; 9.14b) and cutting notches across the grain with axes and adzes (where the grain was straight) to within 25mm of the marked surface (*see* Fig 9.14c). The wood between the notches was then split off with wedges (*see* Figs 9.14d; 9.15). This was possible only where the wood was thick and straight-grained enough; where the grain was uneven or ran into the marked surface, the wood between the notches was cut away with adzes. Where only thin pieces of wood needed to be removed, it was possible to score across the grain with adzes or axes, then hew off the loosened wood with adzes (*see* Fig 9.16). Finally, adzing along the grain produced the final, fluted finish of the surface (*see* Fig 9.17).

The sides of the bottom plank were shaped by marking out and cutting notches with axes (*see* Fig 9.14e), then splitting off the pieces between the notches with axes (this process is called slabbing when carried out in a vertical plane). The surface was then scored with axes, the loosened wood hewn off and the surface flattened, again with axes.

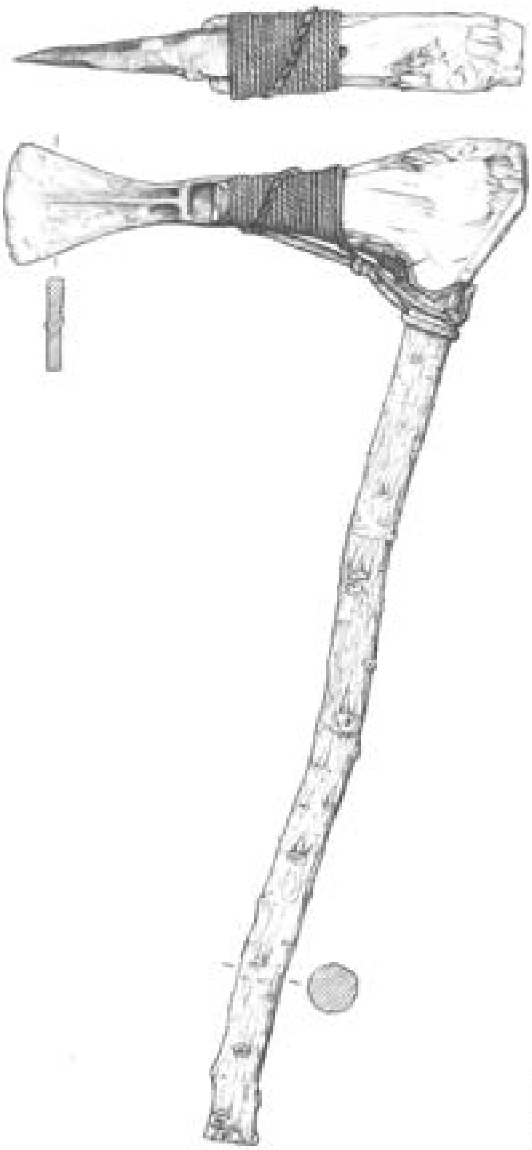


Figure 9.10
A replica axe used in the reconstruction experiment.

Flattening the outboard face of the bottom plank

Marking out

After the trunks had been split into halves, a flat surface was cut on the split diameter to become the bottom face of the bottom plank. This surface was 0.15m from the pith line and had to be a flat plane. This imaginary plane within the trunk was marked onto the timber surfaces.

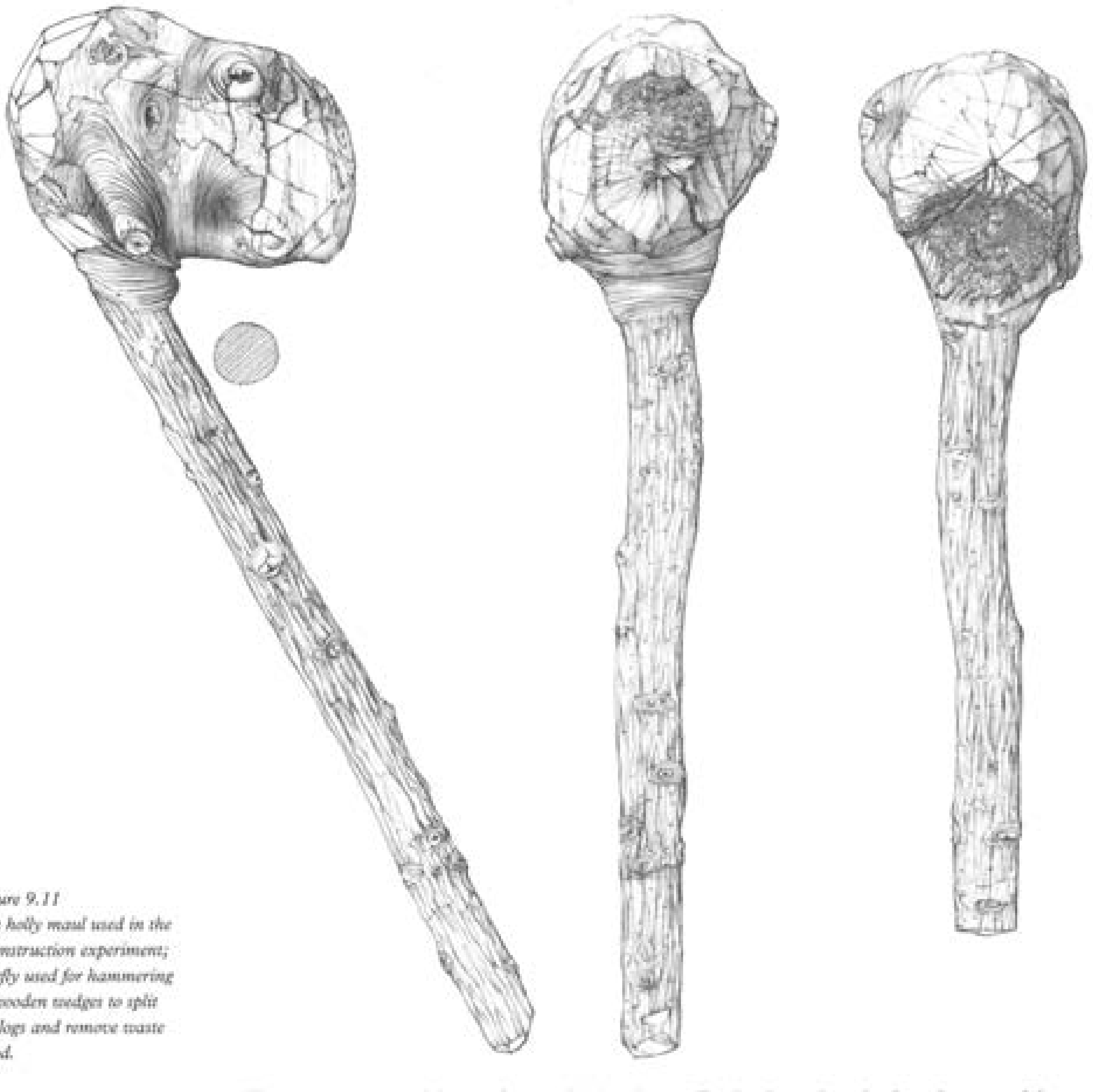


Figure 9.11
The holly maul used in the reconstruction experiment; chiefly used for hammering in wooden wedges to split the logs and remove waste wood.

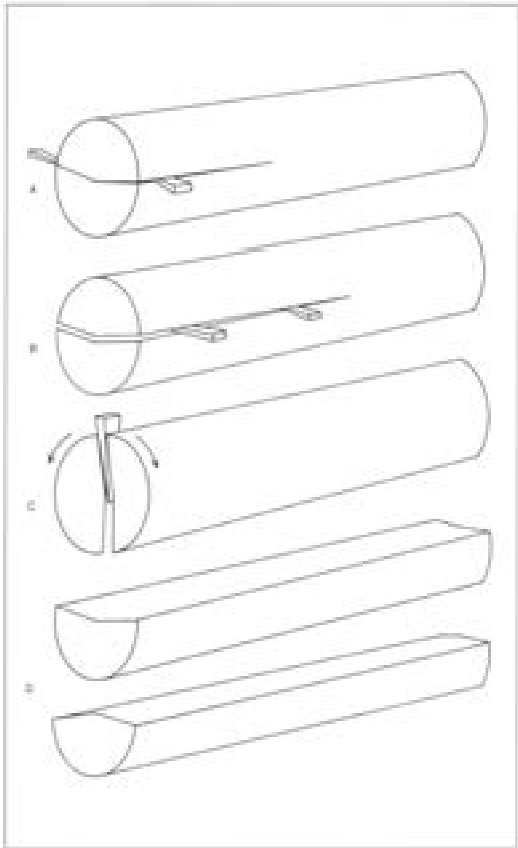
To ensure that this surface within the halved log was a plane, and not twisted over its length, straight edges were placed across each end so that they stuck out on either side of the trunk. These were aligned by eye to ensure that they were parallel, and then the parallel lines copied onto the ends of the half logs (Fig 9.14).

The easiest way to create a straight line is to snap a string covered with chalk or charcoal onto a surface. This technique was used throughout the reconstruction to mark out the timbers, except the cleats and ile profiles, which were drawn freehand in charcoal. Once the ends of the log had been marked up, the sides were marked with the string technique.

Reducing the timber by notching, splitting and hewing

Once the timber had been marked up, notches were cut across the grain to within 25mm of the line. Depending on the depth of wood to be removed, these notches could be shallow or deep, or tapered along their length. The wood between these notches was then split off with wedges, which were hammered into the end grain where possible. Where the notches were closer together (where the grain was uneven), the wood was split off between the notches with adzes.

Following notching, in one example it took fifteen minutes to split off a piece of oak weighing 4.71kg using two mauls (0.98kg and 2.79kg) and six wedges (weighing



0.025kg, 0.050kg, 0.060kg, 0.085kg, 0.360kg, and 0.755kg). In other instances three similar pieces took only six minutes to split off. This time includes preparation such as collecting the wedges and mauls.

The weights of wedges used varied between 25g (150mm × 50mm × 10mm) and 2 kg (500mm × 100mm × 100mm); the pieces of wood removed weighed between 50kg and 1kg. Below 1kg, the time taken to make the wedges exceeds the time taken to hew away the wood. However, there is a great psychological advantage in splitting, as the rough shape of the boat can be reached quickly. In the bottom planks, a tonne of wood was removed in this way.

Figure 9.12 (left)
Splitting the log.
A: split started with small wedges (< 100g).
B: split supported with larger wedges.
C: timber rolled so split vertical.
D: two halves ready for flattening.

Figure 9.13 (above)
Splitting a log using wedges.

Removing the timber by scoring and adzing

Where it was not possible to notch and split or hew, the wood was removed by scoring and adzing. This was in areas where the grain ran into the surface, or where very little wood needed to be removed. This could be done in several ways; one way involved steep parallel cuts made into the surface across the grain every 100mm (thus weakening the grain); the wood was then removed by adzing along the grain (Fig 9.14a).

In scoring the underside of plank II with adze D2, then adzing away the weakened wood, 2.8kg of wood were removed in eight minutes.

Producing the fluted surface

On the horizontal bottom surface, the final flattening was achieved almost entirely with adze D2, adzing down the length of the timber along the grain, producing a series of parallel flutes in the surface. Comparing

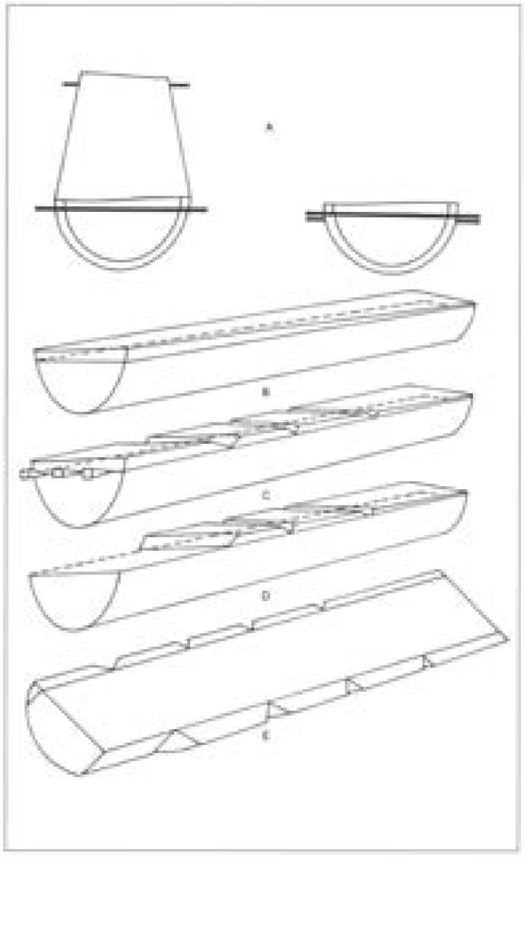


Figure 9.14 (left)
Flattening the half logs.
A: placing straight winding sticks at each end of log and checking they are parallel.
B: marking the line of the winding sticks across the ends and joining down the sides to create a flat plane.
C: cutting notches in the split surface down to within 25mm of the marked plane and splitting off the wood in-between the notches.
D: flattening off the bottom down to the lines with adzes.
E: marking the line of the sides, splitting off the slabs between the notches and hewing the sides flat.

Figure 9.15 (right) Cutting notches into the curved side of a half log prior to splitting off unwanted timber with wedges. Note the edges of the half log have already been trimmed and flattened.

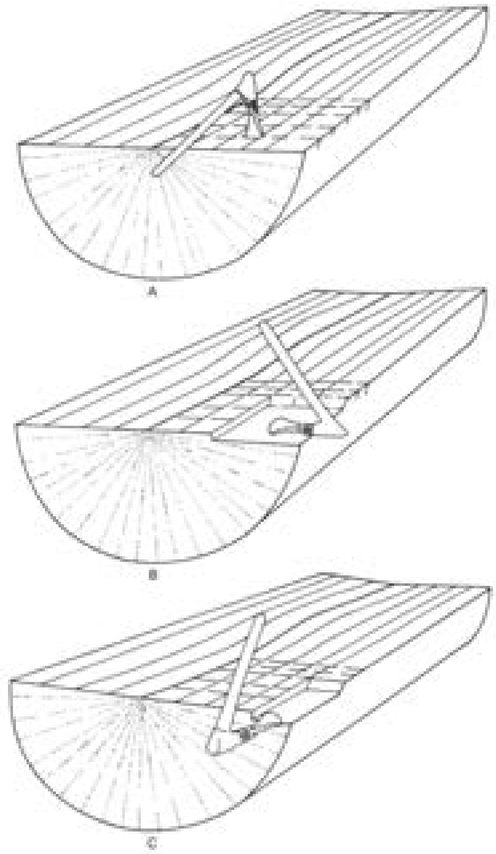


Figure 9.16 (far right) Scoring and rough adzing. A: a series of cuts is made into the wood across the grain in lines 50–200mm apart (depending on how even the grain is). The adze cuts the surface at an angle of 70 degrees or less and loosens the wood. The loosened wood is then adzed away, either from the side (B) or, more frequently, along the grain (C).

Figure 9.17 Adzing along the grain. The characteristic fluting created by the adze on the bottom of the planks was exactly the same as that seen on the bottom of the boat.

our work with that of the original boat surface, we found that the flutes were exactly the same width. Interestingly, these flutes were up to 5mm wider than the D-adze blade used to produce them.

In two minutes of timed fluting of the underside of plank II, there were two bursts of adzing for forty-five seconds (one burst of 81 blows, the other of 79 blows). This produced a total of sixteen large chips (weighing 340g in total) and nine small shavings (weighing 5g).

The large shavings averaged 200mm long and 65mm wide.

Shaping the sides of the bottom planks

After the bottom had been fluted, the sides of the bottom plank were marked with a line and charcoal. Notches were cut in to the line with axes D1 and A2 (Fig 9.18), and then the slabs were removed with axes. Because the bronze axes weighed only 1kg, they did not split off these lumps very easily; the notches had to be cut only 0.2m apart. After the slabs had been removed, the sides could be smoothed, again with axes. We could then check that the bottom was flat and remove any high points after remarking with lines against the flattened sides.

Partial drying of the sapwood of the bottom planks made notching and slabbing more difficult than they would have been if the wood had been freshly felled.

The fluting on the bottom of the original boat does not recognise the sides of the plank, suggesting that the bottom was finished before the sides were cut. We did not do this, instead finishing the bottom after we had cut the sides. This suggests that the original boatbuilders were more competent at producing a flat surface first time than the reconstruction team were.

After the sides were cut, the height of the seam rail and central rail were marked onto the sides with a string line. The finished face was rubbed with linseed oil (to prevent cracking and drying), and the timber was turned over so that roughing-out of the top surface could begin. It took twenty-one hours to flatten the underside of the smaller half of the log (plank II), thirty-one hours to flatten bottom plank I, and seven hours to smooth the sides of bottom plank II. It took four people to turn the timber over at this stage.

Stage 4: roughing-out and shaping the inboard face and cleats of the bottom planks

The roughing-out of the inboard face and cleats was achieved through a series of stages. To begin with, the position of the cleats was marked out and notches were cut on either side of the cleats down to the lines marking the tops of the rails (Figs 9.15; 9.19a). The wood both above and between the cleats was split off, using curved wedges (Figs 9.19b; 9.19c), notching along the grain and splitting off the wood beside the cleats (Fig 9.19c). The surface along the top of the rails was smoothed by fluting with an adze, and the position of the rails was marked in, notching inside the rail and splitting out wood with curved wooden wedges, and scoring and adzing down to the level of the inboard face, between and alongside the cleats.

Shaping the inboard face and cleats involved marking up and shaping the cleats with axes, fluting the inboard face and cutting the holes in the cleats.

Roughing-out the inboard face of the bottom planks

With the flat underside resting on bearers, the curved upper side of the log was uppermost and the height of the rails was marked

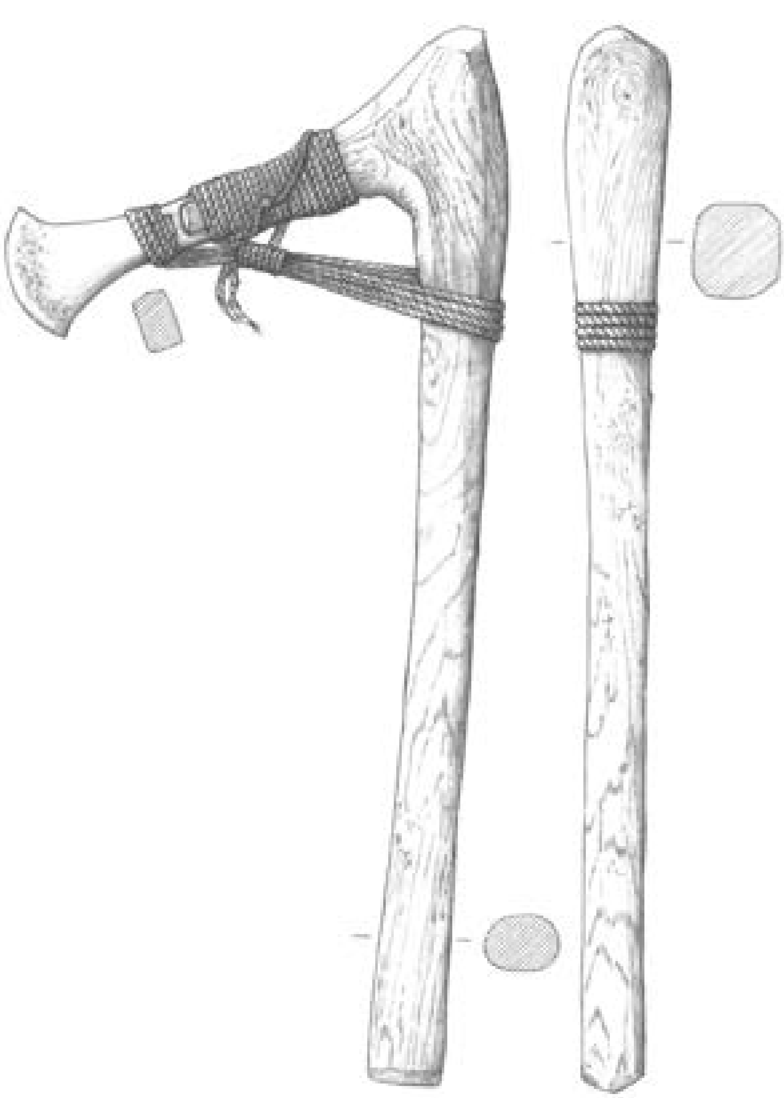


Figure 9.18 (above)
A replica axe used in the reconstruction experiment (type A)

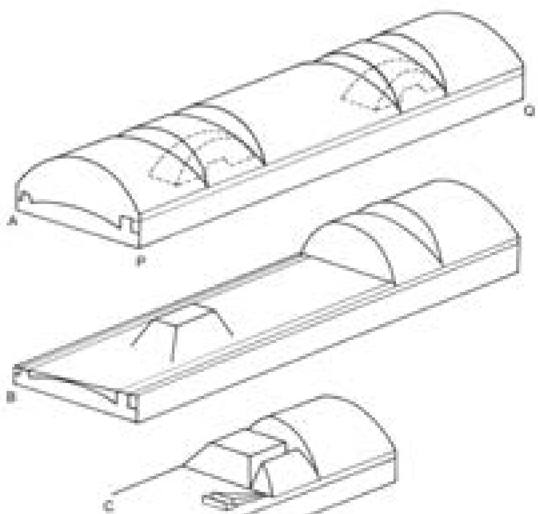


Figure 9.19
Notching and splitting.
A: notches cut down to line PQ marked on the sides.
B: wood split off around cleats, and the lines of the tops of the rails were marked on the surface (the whole surface would be flattened before these lines were marked in). C: notches were cut on either side of the cleats and the waste split off with curved wedges.

on the sides. Bark was removed from this surface and the position and heights of the cleats were marked in. Deep notches were cut down on either side of the cleats so that the wood inbetween could be split out. Each of these notches was 0.23m deep, 0.75m long and 0.2m wide at the top and took between one-and-a-half and two hours to cut with axes (*see* Fig 9.19). The wood between these notches was split out with wedges. Further pieces were removed by cutting more notches and by scoring. It took thirty-one hours to rough-out this upper surface on plank I, 14 hours of which was spent cutting notches. The final green plank weighed approximately one fifth of the weight of the half trunk from which it was shaped. Three quarters of that wood was removed by notching and splitting off as pieces weighing between 20kg and 1kg.

The area inside the rails had to be taken down by a further 100mm; this was difficult because it was surrounded with rails and cleats. Some of this wood could be split away with curved wedges after further notches had been cut, but most was cut away by scoring and adzing with adzes D2(2) and D3 before the surface was fluted with the same adzes. A gauge to check the depth of this hollowing was made from a straight stick with a thin shaving set in a split in its centre (Fig 9.20).

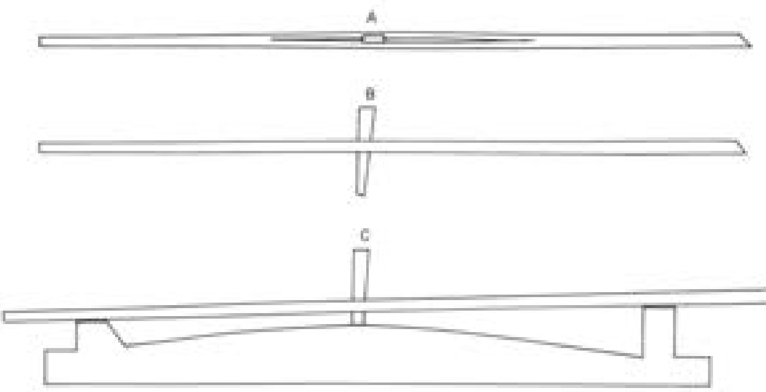


Figure 9.20 (below) Depth gauge used to check the deck height between the rails, made from elder wood with the gauge wedged in a central split. A: view from above. B: view from side. C: the gauge in use on one of the bottom planks.

Figure 9.21 (bottom) Shaping one of the cleats on a bottom plank.

Shaping the cleats

The cleats were marked out by hand and shaped with axes and adzes. It was very easy to finish the cleats with a smoother surface than that found on the originals (Fig 9.21), despite the fact that the team had been working with the bronze tools for only eighteen days (the implications of this are discussed in Chapter 8).

The cleat holes were difficult to cut because the holes in the cleats had to be lower than the rails in order for the transverse timber to go through the rails. These rails made it extremely difficult to swing the axes. The hafting of axe C1 was modified by reducing the size of its elbow to enable it to be used in the confined space. Axes, adzes and chisels were used to complete these holes, including the long-handled chisel F2.

In hewing the surface of one cleat, a smooth surface was produced by thirty-four rapid short blows, made in fifteen seconds (with axe D1), followed by fifteen seconds' rest. This pattern – a burst of rapid activity followed by a pause – is typical of much hewing. The majority of the cutting was done in bursts of between thirty and forty-five seconds, interspersed with pauses of a similar length during which the work was observed more closely, considered and cleaned.

Stage 5: shaping the rails and lath seats and cutting wedge slots and stitch holes in the bottom planks

The rails and lath seats were shaped by scoring and cutting the sides of the rails with axes and then cutting the horizontal faces of the seats with adzes. The wedge slots and stitch holes were cut with chisels and gouges after being marked out on the rail sides and ile seat.

Shaping the rails

After the waste had been removed from around and between the cleats, the outer 0.15m was flattened to the level of the upper surfaces of the rails (marked on the sides). The position of the rails could then be marked in with string line, and the wood both outside and inside the rails could be removed. On our central section, all the lines marked were straight, whereas in the original boat length the seam rail had to curve at the end of the boat and may have had to be drawn in free-hand in those areas. One of our notches had been cut slightly too deep and left a shallow notch on the finished rail as evidence of our roughing-out technique. No similar evidence for the roughing-out techniques survives on the original bottom planks, although it does on the ile planks (Chapter 8).

The lath seat outside the rail was cut out mainly with axes, by hewing down the outside of the rail with A2 and D1, but the horizontal surface itself was adzed out with C3. The ile seat outside the seam rail was taken down in a similar manner. When cutting rail sides and rebates, only one person could work on the plank at a time, because the weight of an extra person caused the wood to 'bounce' on its round-wood supports, making accurate work very difficult.

Cutting the wedge slots

The wedge slots were marked on the rails, allowing space for the laths to run underneath them, then cut out (Fig 9.22). The wedge slots on the bottom planks were cut with a chisel and mallet. Once the technique had been mastered, each hole took less than fifteen minutes to cut with chisel F1. The top of the wedge slots were left curved, so that the wedges would bear only on a small area. The stitch holes under the seam rail were more difficult to cut, as they were much longer, having to be chased into the ile seat first, then cut under the rail which (because it is chamfered on its inner face) is almost 100mm wide. This hole was at the limit of the length of hole that could be cut with the socketed bronze gouges G and H (Fig 9.23). The handles broke off in the gouges a number of times, and the gouges also got stuck in the holes.

Making the wedges and laths

The wedges, transverse timbers and laths were split and shaped with adzes and axes from the offcuts of the logs. These were a mixture of radial and transverse sections, as found in the original.

Figure 9.22 (above)
Cutting a wedge slot through the central rail of one of the bottom planks; great care had to be taken not to split off the rail by accident.

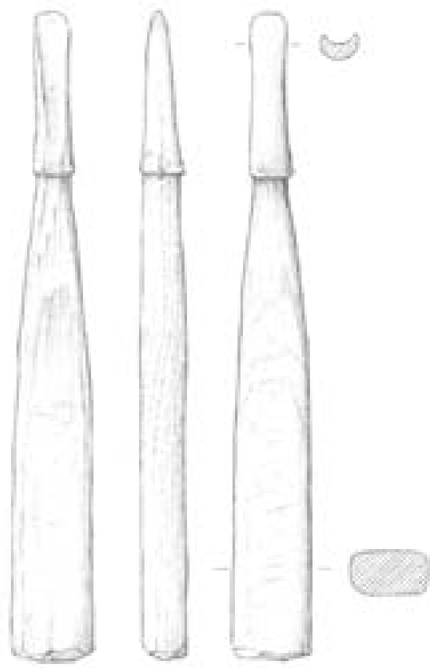


Figure 9.23 (left)
A replica gouge used in the reconstruction experiment (type G).

Stage 6: shaping the ile planks

The edges of the ile planks were shaped by splitting off a radial section from each half log (ie one-sixth of the original tree), marking the cross section of the ile on the ends of each log (*see* Fig 9.24a), together with a flat along the top and bottom edges of the ile, then notching and splitting down to this flat with wedges. This flat surface was smoothed off with adzes, the edges of the ile were marked, and the notches cut down to the outer line (*see* Fig 9.24b).

The outer surface of the ile was shaped by notching and splitting with axes to produce two faces at right angles (Fig 9.24b); then, after the inner surface was finished, the outer surface was hewn away – with axes near the edges and with adzes in the middle – to finish.

The inner surface of the ile was shaped by marking out the cleat, and then notching around it, removing wood from the centre of the tree by notching and splitting with wedges down to the line between the two internal corners of the ile (Fig 9.24b). Then, using shallow notches, followed by splitting out with adzes, wood was removed from the inner curve of the ile (Figs 9.24c; 9.25), finishing by fluting with adzes. The cleat was shaped with axes and adzes and the stitch-hole positions marked and cut out with gouges.

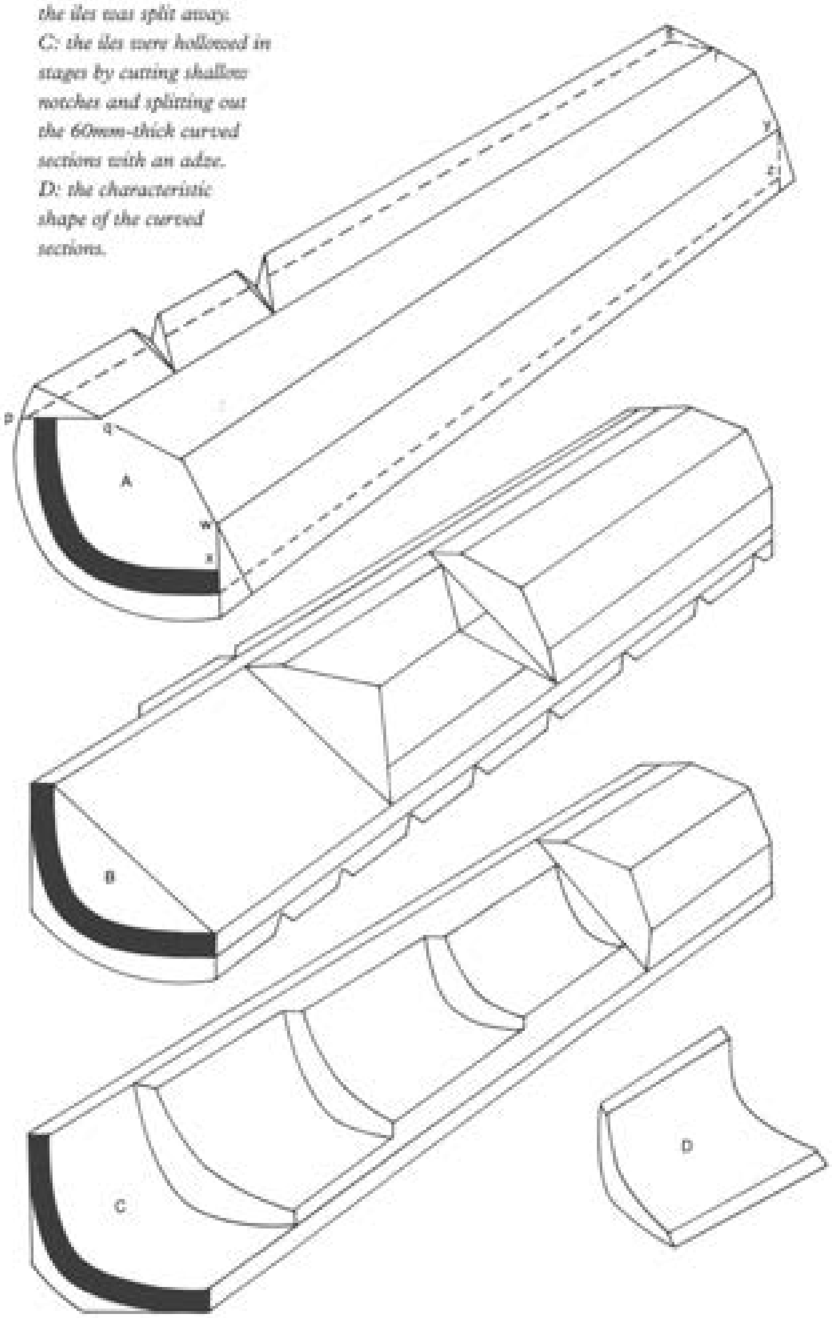


Figure 9.24
Shaping the iles. A: the halved ile trunk was split down into a 120-degree sector; two flats (pqrs and wxyz) were cut at right angles so that the side of the ile could be marked on. B: vertical faces were notched and hewn outside these lines, starting the shaping of the outer face of the ile. The central part of the tree above the line of the iles was split away. C: the iles were hollowed in stages by cutting shallow notches and splitting out the 60mm-thick curved sections with an adze. D: the characteristic shape of the curved sections.

The ile planks were marked out by placing a template at each end, and a plumb line was used to check that they were correctly aligned. In the reconstruction, we had an advantage over the original builders in that we had only a straight section of ile to build. We were able to mark the profile of this ile on the sawn surface at each end and work from these profiles. The complete ile would have been a more complex shape and not so easily marked out.

Before the ile planks could be marked out, further timber was split off so that the log section was approximately one third of the tree, rather than half a tree. Two surfaces were cut at right angles on which the top and bottom edge of the ile could be marked (Fig 9.24). These edges were marked with string lines and the wood on the outside of the ile planks was notched and split away, then hewn. The first stage of this hewing was to cut a vertical face from the horizontal surface with the top edge marked on. The timber was then turned and a vertical face cut from the line marking the outside of the bottom edge of the ile. The curved part of the outside of the ile was left unshaped until the inside of the ile had been shaped. The tree used to build the ile planks was much easier to work than that used for the bottom planks; it was straight-grained and less hard.

The first stage in hollowing the ile was to split away the triangular section of wood. Above the marking lines this was notched and split away tangentially. Thereafter, work was within the curve of the ile and care had to be taken not to split the ile itself. Most of this splitting was neither radial nor tangential, but followed the line of the annual rings; indeed some splits were made exactly along the annual-ring lines, following the weaker spring vessels. Cleaving along the concave surfaces of the annual rings was very effective.

Notches 50mm deep were cut across the grain every 0.25m, and the pieces were split out. Although these pieces could be split out with wedges, it was found to be best to weaken them first with a series of powerful adze blows along the line of the intended split, then to tap in a wedge, separating the

Figure 9.25
Shaping one of the ile planks using an adze.

waste section of wood. The final surface was fluted with adzes.

There was a special problem with the cleats on the ile planks, as these were much more delicate than the bottom cleats. Because of the curve of the ile, the holes through these cleats can be cut only from above, using axes or adzes. When the inside of the cleats was completed they were turned over and the outside curve hewn. The hollowed quarter-round shape is not stable and had to be held in position between two pairs of stakes.

The stitch holes in the ile planks were easier to cut, as they were a straight through hole. At the end of the twenty-five days of work, only fourteen ile stitch holes and one rebate remained to be completed; these were finished in less than one person day.

Stage 7: assembling the boat

The final stage in the reconstruction of the boat was the assembly of the various parts, beginning with the two bottom planks being slid together. The transverse timbers were fitted through the cleats and slots in the central rails, together with the wedges in the central rails. Then the ile planks were placed so that they rested on the step outside the seam rail, and they were then stitched into place (Figs 9.26; 9.27). (See below for a discussion of the joints.)

Estimates of time

The timing of each stage of the reconstruction was studied to enable tentative suggestions to be made about the number of person hours that would have been required for the construction of the original boat. This was a major aim of this element of the analysis programme.

A log was kept of the work carried out on the reconstruction, and analysis of this gives the times taken on the various key tasks during the reconstruction (*see* Table 9.3).

Recording the work on the reconstruction

The log was very detailed; over the twenty-five days worked, 1,652 timed activities were recorded. This detail was made possible only by having a full-time project recorder. On days when he was absent, and the participants recorded their own activities, detail in the record dropped dramatically. The recorder recorded the total time activities took, whereas the individual recorded the actual time the activity took. The distinction can be explained by example. A worker who cut a notch recorded the time taken as three minutes, whereas the recorder recorded the time for the same task as five minutes. This is because the total time was five minutes – measured from the start of cutting one notch to the start of start of cutting the next and including preparation and rest time. This gives a truer picture of the time needed for the job. An independent recorder is needed to log the real times taken during different phases of a reconstruction (*see* Table 9.4).

Figure 9.26
Assembling the boat: the two bottom planks offered up to each other.

Table 9.3 Time taken for the various phases of work on the reconstruction

reconstruction phase	*plank number*				*total time*
	I	*II*	*III*	*IIII*	
splitting log 1	10	–	–	–	10
flattening underside of bottom plank	31	21	–	–	52
shaping sides of bottom plank	4	7	–	–	11
roughing out top of bottom plank	31	27	–	–	58
shaping cleats on bottom plank	9	7	–	–	16
cleaning deck between rails	11	22	–	–	33
cutting holes in bottom cleats	8	2	–	–	10
splitting log 2	–	–	4	–	4
shaping inside the ile	–	–	5	12	17
shaping outside the ile	–	–	14	21	35
cutting wedge slots	9	11	–	–	20
cutting stitch holes	1	5	–	12	18
making tool handles	–	–	–	–	25
sharpening tools	–	–	–	–	23
relashing tool handles	–	–	–	–	14
laths, transverse timbers, wedges	–	–	–	–	7
making splitting wedges	–	–	–	–	15
assembly	–	–	–	–	1
oiling timbers	–	–	–	–	6
other	–	–	–	–	26
total time taken (hours)	–	–	–	–	401
total hours recorded	–	–	–	–	527

The time taken for the reconstruction was a total of 103 person days worked between 22 July and 18 August 1996. Close examination of these data reveals that the main jobs account for only just over four hours per day of those 103 person days, and the total logged hours account for only five hours per day. There were five days when filming disrupted the rate of work and four days when training courses reduced the effective rate of work. If we take these into account, then the time spent solely on building the boat is eighty-five person days.

Figure 9.27
Assembling the boat: one of the ile planks in position.

This is a record of the times taken by a group of 20th-century woodworkers, familiar with the concepts of working wood without using power tools, but not with building a Bronze Age boat. It is the time taken by a group of people acquiring skills and often using bronze tools for the first time.

A group of Bronze Age boatbuilders working as a team, perhaps having already made a similar boat, would be working in a very different way. They would each know exactly what to do and would be familiar with the limitations of specific tools and handle shapes. For example, we began adzing with a bronze adze (A6) set in a right-angled haft. This combination of handle and head was awkward to use and

Table 9.4 Extract from log on day 9 (31 July 1996), recorded by Geoff Haliwell

time	*comment*
0945	Richard Darrah continuing fluting bottom plank I with adze D2.
	Trevor Marsden continuing notching bottom plank II with axe D1 (84 blows/min).
	Damian Goodburn re-sharpens axe B2 for 1 min.
0946	Damian Goodburn begins notching south end of bottom plank II (82 blows/min). (Note the sapwood has dried out – if it were wetter it would be much easier to work.)
1015	Richard Darrah still working on bottom plank I adzing with and without weakening (scoring) 8–10 blows then removes waste by hand.
	Trevor Marsden 60 blows/min on notching bottom plank II with axe D1.
1020	All stopped for discussion on tree rings and growth.
1030	All restarted. Richard Darrah still weakening and adzing bottom plank I.
	Trevor Marsden and Damian Goodburn still notching bottom plank II. Damian Goodburn making notch with axe B2 used vertically then removing the central area by axing laterally and removing small chips sideways.
1035	Trevor Marsden notch now finished and second started; therefore, since yesterday, 70 minutes + 50 minutes = 2 hours.

1040	Damian Goodburn stopped scoring with axe B2; now hafting adze C3.
	Trevor Marsden sharpening D1.
1050	Richard Darrah still weakening and scoring bottom plank I.
1050	Trevor Marsden stopped sharpening, starts notching again.
1105	Damian Goodburn sharpening axe B2 for 10 minutes.
1115	Damian Goodburn still hafting adze C3.
1120	Trevor Marsden using adze A5 to remove central area of notch.
1125	Richard Darrah still weakening and fluting waste on bottom plank I.
1125	Trevor Marsden changed to axe D1 to remove central area of notch.
1133	Trevor Marsden off site to make tea.
1135	Damian Goodburn sharpening adze C3.
1135	Richard Darrah noted that the edge of D2 was bent probably from a knot.
1145	Trevor Marsden on site.
1200	Richard Darrah continued adzing groove on bottom plank I (37 blows in 30 seconds).
1205	Damian Goodburn adze C3 and axe D3 – notching on bottom plank II – completing notch to true levels.
1210	Trevor Marsden started (continued) notching on bottom plank II.
1215	Stopped fluting bottom plank I to discuss axes.
1220	Damian Goodburn continuing notching bottom plank II.
1220	Trevor Marsden resting from notching for 2 minutes.
1226	Trevor Marsden stopped notching and sharpening adze A5.
1230	Trevor Marsden continued notching on end notch.
1240	Trevor Marsden sharpening D1 (ie resting from notching).
1245	Damian Goodburn still notching.
1249	Trevor Marsden stopped.

was never used again (as soon as another had been hafted). But the handle was reused with a different adze head (type C), which turned out to be excellent for splitting out waste on the ile planks, and cutting holes in the cleats. The original builders would not have had to find this out, or spend time persevering with the wrong tool.

So, although the reconstruction team took eighty-five person days to build a 3m length, the original builders would have been able to work more efficiently and faster, but with a larger project.

A comparison of work rates with bronze and steel hand tools

It is interesting to compare the relative efficiency of the bronze axes against modern heavy-steel felling axes. Two equal lengths of side on timber I were marked out, and then notched, so that the pieces between the notches could be slabbed off. Three notches were cut in three minutes with the steel axe, each notch taking thirty blows in thirty seconds to produce. The other side was cut with a bronze axe, and had to have four notches cut (as the pieces to be split off with the bronze axe had to be smaller). These four notches took eleven minutes to make, each notch taking between 140 and 200 blows. The rate of delivering the blows was almost one-and-a-half times as fast with the bronze as with the steel axe. The pieces between the notches (the slabs) were then split off. The steel axe took six minutes to remove the slabs, the bronze axe ten minutes. Overall time for the job was nine minutes with the steel axe, twenty-one minutes with the bronze axe.

A further comparison was made between the bronze axe D1 and a steel axe in cutting the large notches, (0.75 × 0.25m), in roughing-out the upper surfaces of plank I. The bronze axe took ninety minutes; the steel axe only nineteen minutes.

The comparison with modern steel tools indicates that the steel tools are more efficient. Our experience suggests that the efficiency of the tools is more to do with the weight of the tools than the metal they were made from. In the reconstruction the bronze adzes with the heaviest handles were found to be much more effective at removing wood with less effort. The D-type adze with a total weight of 1.5kg was much more effective than another D-type adze weighing 1.0kg (of which the blades weighed 0.475kg). In bronze tools, much of the weight of the handle is directly over the head and therefore contributes to the effective weight of the head. As the advantage of the steel axes was in their weight, the Iron Age axes that followed these bronze axes would be more effective only if they were heavier.

Whereas the steel axes were more efficient than bronze axes, comparison of steel and bronze adzes showed little difference in efficiency when working along the grain to achieve the fluting effect, even producing similar-shaped waste.

Bottom plank II and ile plank IV were shaped entirely with bronze tools. To speed up the shaping of the second bottom plank and second ile (and to provide comparative data), steel tools were used in place of bronze tools for seven hours of notching and slabbing. This probably saved three person days.

Estimates of the time taken to build the original boat

From the times recorded throughout the shaping of the boat sections, estimates have been compiled for how much time would have been needed for each piece of the original boat to be shaped. Given that all sourcing, harvesting and preparation of materials was complete, a reasonable estimate may be that a team of ten Bronze Age boatbuilders would have taken twenty-five working days (about a month) to shape all the timbers and assemble the 12m-long boat (Table 9.5). It is likely that felling, movement of the timber and assembly of the materials (the yew withies, moss, beeswax and spare tool handles) would have taken far longer than would the shaping and assembly of the boat. Two-hundred-and-fifty person days is a minimum estimate of the time taken, but this assumes everything went perfectly; that the wood was easy to work (unlike the timber we used for the bottom plank), that the timbers were marked out accurately and cut to shape with skill, and that the offering up and fine adjustments were done quickly.

This estimate should be treated with caution, as there are a number of unknown factors. We do not know the length of the working day. We do not know how easy the oaks were to work (one of our oak logs was twice as difficult as the other). We were building for the first time (and consequently faced a steep learning curve) and our agenda was very different, involving filming and public open days.

It is also a low estimate; the boat may have taken several times as long to build (Chapter 8). Apart from the practicalities of assembling the raw materials, there may have been social or ritual activities perceived as an equally important part of the process.

Felling of a large oak tree (of 1.1m diameter at breast height) is likely to have taken two people one day of work. This estimate is based on the time taken to cut the notches in the upper surface of timber II, approximately ninety minutes per 0.25m deep notch with bronze axes.

There are many finishing operations where only one person can work on a log at one time because of movement of the log (although this may vary with the length of log being worked). However, with a variety of potential jobs and boat sections (upper side planks, end pieces, transverse timbers, laths and wedges) there is no reason why a team of ten people should not all have been fully employed throughout the construction. No time was wasted by the original

Table 9.5 Estimate of time needed to build a complete boat from reconstruction data[1, 2]

description	*bottom plank*	*ile plank*
hours to make each 3m plank length	104	45
hours to make 12m plank lengths (×4)	416	180
estimate of hours to make upper side plank as the same number of hours as the ile	–	180
estimate of hours to make each end as half the number of hours as the ile	–	90
associated jobs for 3m excluding making tool handles as, unlike us, they already had these	–	92

number of hours to shape each boat part

task[9]	*hours*
splitting trees[3]	10
making 2 bottom planks (12m)[4, 7, 8]	832
making 2 iles[6, 7, 8]	360
making 2 upper side planks[6]	360
making end planks	180
assembling waterproofing and stitching	368
total number of hours[5, 10]	2 210

[1] The above figures are to build a boat approximately 12m in length, with thwarts and one upper side plank.

[2] The following have not been included in these estimates: sourcing, felling, moving or collecting materials.

[3] I have not used the time taken to split the tree from log 1 as I have split a 10m trunk length with a basal diameter of over 1m in less than 5 hours.

[4] No allowance had been made for the hardness of the wood of the trunk used to make the bottom planks. If this log had been straighter grained and easier to work it might have taken less than half the time to rough out a bottom plank.

[5] No allowance had been made for the under-recording of work, but this will be cancelled out by 4 and 7.

[6] The times for shaping the first ile have been used in these estimates; the times for shaping the second ile are under-recorded as shaping went on throughout the last day. However, the second ile was probably shaped in half the time required for the first ile (a steep learning curve), therefore the ile times are over estimated.

[7] No allowance has been made for the time taken to learn skills.

[8] No allowance has been made for the time taken to shape the more complicated ends of the boat, except that the bottom-plank lengths have been over-estimated, so 10% of the plank-shaping time would be spare for shaping the more complicated ends.

[9] These estimates are based on actual figures (except the time of assembly, which is a guess) and give the time in which the boat could have been built – if everything went perfectly – as 250 eight- to nine-hour days for ten skilled experienced men. It is the possible time for building a boat. Having given this base-line figure, there is no margin for error. If I were a Bronze Age shipping entrepreneur putting in my annual order for ten such vessels for my cross-Channel slave trade, I would expect them each to take up to three months to build.

[10] No allowance has been made for weather, available light, acts of gods or civil commotion.

boatbuilders on smoothing or polishing the surfaces of the original boat, and most moving and turning operations could be carried out by the reconstruction team.

Throughout the process of shaping the boat timbers the wood was green and wet. If exposed to hot sunlight, visible splits began to appear. To avoid this splitting, the reconstruction was done in the shade, and the wood was covered with linseed oil every evening for further protection. Because of filming and publicity, we had to make our reconstruction at the time of the year that is worst for shaping timber (July and August). Working in the winter makes the wood less likely to split, allowing it to harden less slowly and lessening worker's fatigue (particularly with the shorter winter days).

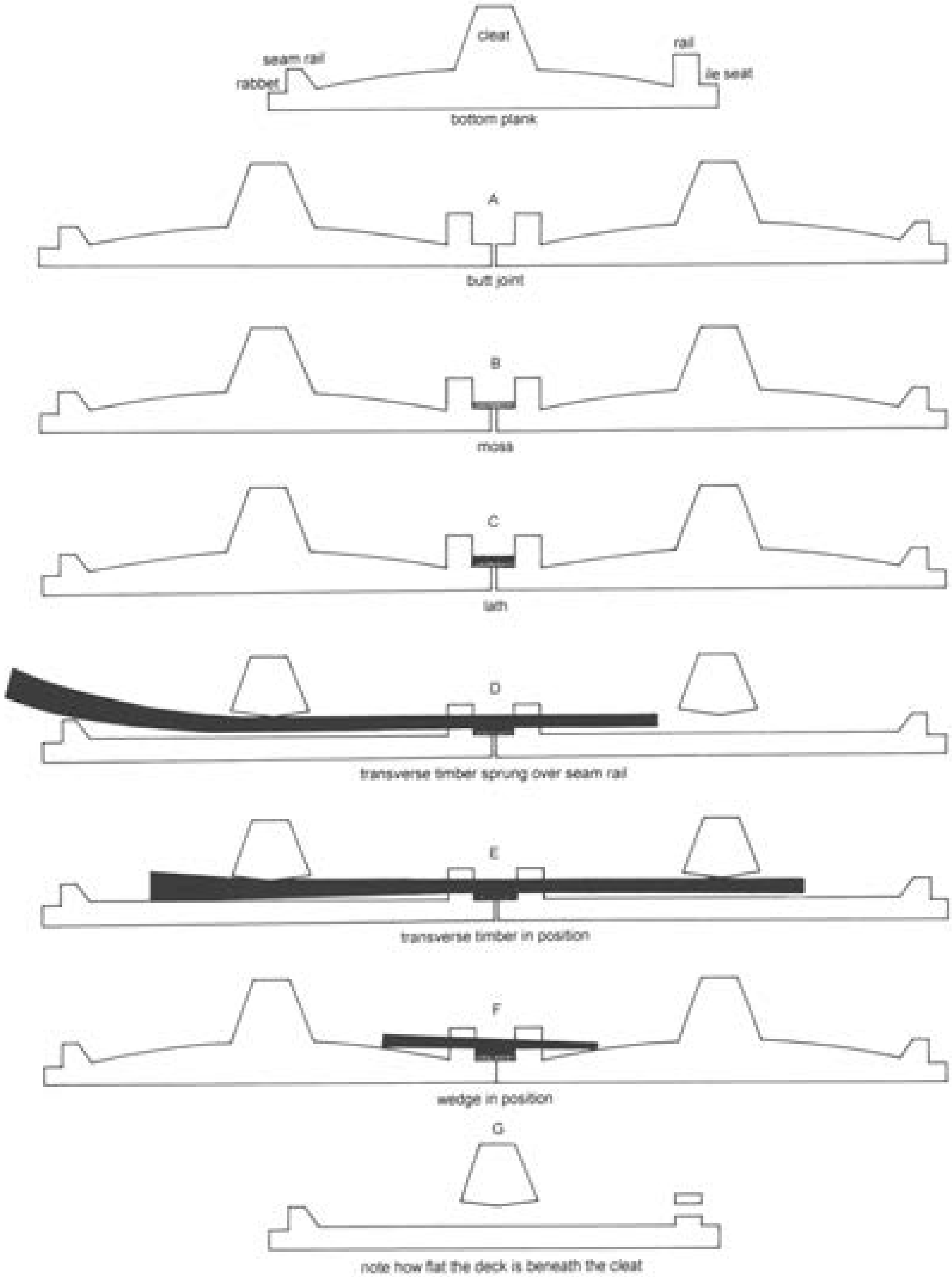


Figure 9.28
Cross sections showing how the bottom planks were joined together.

Joints and waterproofing

One of the main aims of the reconstruction was to study the joints in the boat, how they were made, how they worked and how they were waterproofed. The jointing techniques establish the order of assembly of the main boat parts.

There are two distinct methods used to join the boat timbers together and both are represented in the reconstruction. The central seam is a butt joint held together with wedges and transverse timbers (Fig 9.28). The ile seams are rabbeted joints held together with stitches (Fig 9.29).

The reconstruction

Central seam

This section discusses the assembly of the joint between the two bottom planks (Fig 9.28). The stages of assembly and waterproofing of the central joint cannot be separated, as the wedges and transverse timbers that hold the joint together also hold the waterproofing in place.

In the reconstruction, the two bottom planks rested on round bearers in order that they could easily be slid together by one person as they were oiled. The first stage of assembly was to confirm that the fit was satisfactory, both between the two planks and between the planks and each wedge (which were made to fit individual slots). The shaped timbers were placed side-by-side, with packing pieces placed under them to align them horizontally. Any high points were marked and hewn away. The final gap between the planks at the butt joint was less than 5mm.

Moss was placed on the horizontal steps between the rails, and the laths were laid on top of the moss. The transverse timbers were driven over the seam rail, through the hole in the cleat, through the slot in the central rail, over the lath, through the slot in the second central rail and through the second cleat. The timbers had to be flexible enough to bend as they went over the seam rail, or they would have forced the top off the cleat; they were bent by human weight (*see* Fig 9.30). The central lath in the central joint had to be held down as the transverse timbers were inserted, so that the transverse timber rode over the lath and fitted into its hole in the second central rail.

Because the transverse timbers had to be hammered in over the seam rails (as the heads of the timbers were too big to fit through the cleat holes), they had to be fitted before the ile planks were fitted (there was no room to fit them with the ile planks in place). The first stage of assembly must be the joining of the two bottom planks.

As the transverse timbers are 125mm wide and held at two points on each plank, they give the two bottom planks (and hence the two boat halves) complete lateral stability. As they are less than 30mm thick they will bend slightly, allowing the central joint to be slightly raised (*see* Fig 9.31).

The transverse timbers were fitted from alternate sides of the boat, as they would have been in the original boat (*see* Fig 9.32). The timbers are most supple at their thin ends, but, as they alternate, this will

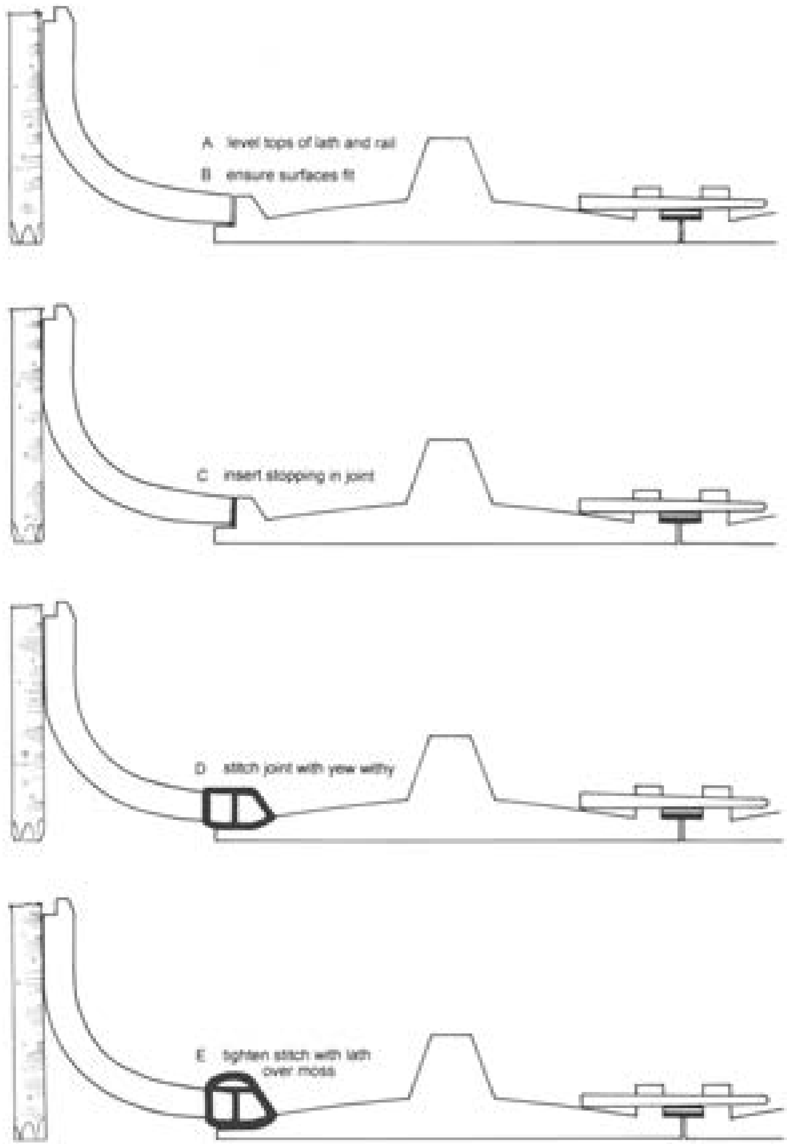


Figure 9.29
Cross sections showing how the ile planks were attached.

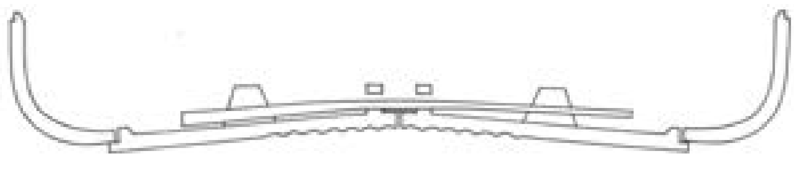


Figure 9.30
Bending of the transverse timbers. Fluting that survived near the centre of the plank indicated that this area did not wear when the boat was beached, suggesting that the central seam was permanently bent up, probably because of bending of the transverse timbers. Note how the ends of the transverse timbers bear against the tops of the cleats.

reduce the amount of bending that may occur. If these timbers were too stiff they would be more likely to split off the cleats, as the boat would have flexed in moderate seas. The trenching in the inboard face into which the transverse timbers are let gives a clue to how curved the central inboard face section was originally, and how low down these timbers have to be fitted in order to go through the rails. Indeed, it was found that providing a slight slope to the transverse-timber holes through the central rails eased the insertion of the timbers, a feature that was seen on the original boat when it was re-examined.

Next, the wedges were fitted through the two parallel central rails. These oak wedges are similar in size, and taper to splitting wedges; they would have split the top of the rail if hammered home hard, so care had to be taken that they didn't press on both the top and bottom of the wedge hole. The tops of the holes in the central rails were curved, which reduced the chances of splitting off the rail top. The wedge does not bear on the bottom surface of the hole, but on the lath that presses on the moss. The function of these wedges is to compress the moss and make the seam watertight. They are a firm fit across the boat and have to be hammered out as well as in. This means that they will tend to hold the boat halves together and stop the central seam from spreading.

Ile seams

The ile joint that we reconstructed was that between the outside of the seam rail of the bottom plank, and the square bottom edge of the ile (*see* Fig 9.29). A second joint existed in the original boat along the top edge of the ile, which was rabbeted and had stitch holes with stitches *in situ*, but this was not reconstructed completely.

The ile plank sits on the step outside the seam rail, so two surfaces at right angles are in contact. The two timbers were held in the correct position and high points marked. The timbers were then

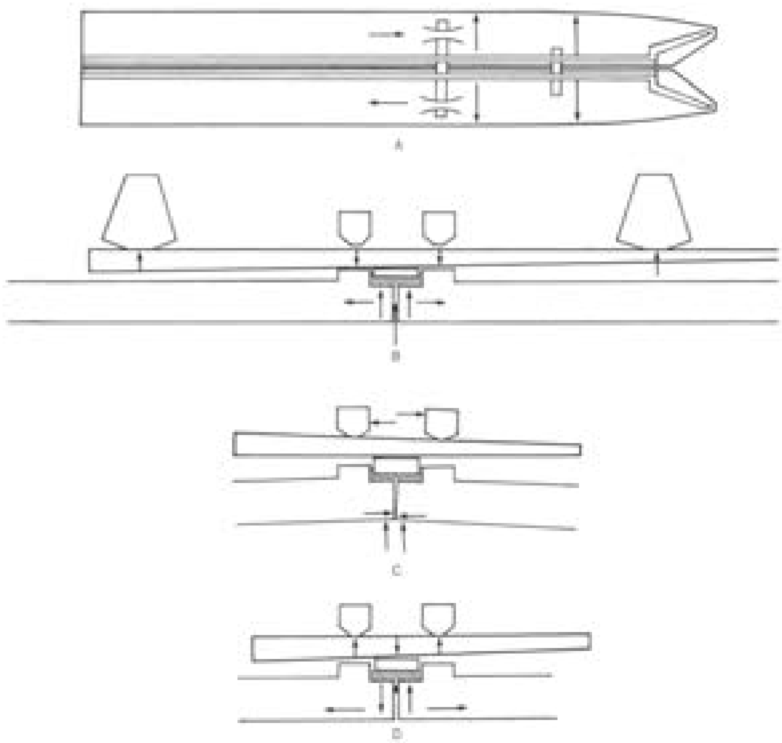


Figure 9.31
Forces on the boat timbers.
A: the transverse timbers stop the two bottom planks from moving independently of each other, both holding them together and stopping them moving longitudinally independently of each other. The wedges stop the timbers moving apart only.
B: the points where the transverse timbers bear on the bottom planks. Note how the transverse timbers take the upward pressure off the cleat rails and hold it at the cleats.
C: problems arise if the transverse timbers bend too much when the bottom corners of the two bottom planks bear against each other. This could force the seam to open but would be resisted by cargo.
D: the points where the wedges bear on the bottom planks. The wedges press on the lath, which compresses the moss luting.

separated and the high points removed, so that they were a good fit in both planes. Because of their curved shape, the ile planks were not as easy to handle as the bottom planks (although they were much lighter). They tended to rotate and so had to be held very steadily while the high points were being noted and marked. Here, using a lubricant was a disadvantage, as it made the ile difficult to support with packing wedges.

When the fit of the rabbet was satisfactory, the tops of the rail and inner face of the ile were hewn so that they were level and the moss and lath would fit well.

The seam was closed, and a stopping pressed along the joint; the seam was then stitched with twisted yew withies. This was not easy work, as one person had to lie under the boat and feed the withy through to a second person on top, who fed it back through the paired hole until the withy had gone round three or four times. The withies were much easier to use if they had been soaked overnight (when a stitch took between five and ten minutes to complete). The thick end of each withy was left unbent, jamming the hole, with its end sticking out on the outside. In the original Dover boat the thin end is some times held by being wrapping around one of the other turns; this was not a technique used in the reconstruction and did not seem to be needed (Chapter 8).

After four or five stitches were completed, a lath with moss under it was driven under all the stitches, helping to tighten the stitches and the joint (Fig 9.33). The moss was attached to the lath with lard and slid along the seam with the lath. If the moss was placed on the seam first it was pushed out by the lath. We later found that the moss was best fed under the lath during driving home. Only after the lath had been driven under all the stitches was the next group of stitches completed. The stitches had to be fitted in groups matching the lath lengths, as it was impossible to drive in the laths with moss on them if they had to ride over stitches rather than slide along the top of the seam rail. The laths were made with a thickened end for hammering; this was removed with an adze after fitting, and the tapered end of next lath was driven over the end of the previous one (Chapter 8).

While assembling this joint, it was noted that the perfect place for waterproofing appeared to be within the seating (where the ile presses against the rail) and not laid as a layer on top of the rails (where the moss was actually found). This led to a later re-examination of the original boat, where a stopping of unknown composition was found pressed into the ile seam, underlying the moss and clearly inserted after the ile plank had been offered up.

Figure 9.32
Inserting transverse timbers over the seam rail and beneath the bottom cleats and central rails.

Figure 9.33
Fitting the seam laths. Large quantities of moss were needed even for this short section of the reconstructed boat.

How do the joints and waterproofing work?

The central seam

The moss (25mm thick before compression) in this joint is the waterproofing element. It is compressed between the lath seat and the laths, which are between 90mm and 120mm wide, forced down onto the moss by the wedges. Thus the role of the laths and the wedges is also to waterproof the boat.

The wedges also work to hold the two halves of the boat together by friction. The upper faces of the wedges press against the curved top of the wedge slots, while the lower faces of the wedges press against the top of the lath (above the moss). Figure 9.31 shows how the wedges oppose the forces pulling the two halves of the boat apart. The curved top of the wedge slot allows the wedge to be tightened without splitting the top of the rail off; the small area of wood in contact can compress as the wedge tightens, allowing controlled tightening of the wedge.

Owain Roberts has suggested that it is the angling of the wedges across the central joint (so they are not parallel to the transverse timbers) that stops the boat halves from parting (Chapter 10).

The transverse timbers (100mm wide) work to hold the two halves of the boat together and also prevent longitudinal slippage of the bottom planks. They have a minor role in compressing the laths and aiding waterproofing of the boat. The transverse timbers also contain the upwards flexion of the central joint by moving the stresses well away from the weak rail top at the centre of the boat to the stronger cleats. Allowing a degree of upward flexion in this joint further compacts the waterproofing moss layer. This has to be limited, however, as the joint will be levered open if the bottom edges of the two bottom planks are in contact. The transverse timbers accomplish this delicate dual role.

Evidence of this bending – with the central joint being slightly raised – is seen in the lack of wear to the tool marks of the original Dover boat on the central part of the underside of the bottom planks. This suggests that this bending of the bottom planks was present even when the boat was beached.

The technique of water tightening with moss and laths seems to have been good, but not perfect. In the original boat, some stopping was found along the edge of the lath between two wedges, but respecting the wedges (that is, it did not run underneath the wedges). This is likely to have been a running repair and suggests that the joint worked fairly well as a moss-only joint, and that sufficient pressure could be applied to the lath to make the moss joint watertight under most circumstances. Roberts has suggested that in a boat of this type there may have been two crew members bailing out continuously to keep water levels down, implying that the joints may have been expected to allow some seepage.

The ile seams

The yew stitching passed under the rail, through a groove in the ile seat and through a stitch hole in the ile. Its role was to stop the ile from falling down or out from the bottom plank, although it does not stop it so effectively from rising up and in.

The lath tightens the stitches, pulling the seam tight, compressing the stopping and making the bottom plank and ile into a rigid piece. The combination of the lath and the stitches is very powerful, helping to prevent the ile from rising up and into the boat.

The role of the moss here may be partially as a secondary waterproofing, but, as a single long lath was hammered under several yew stitches, the amount of compression of the moss varied from stitch to stitch and the even compression seen in the central joint is not achieved. This may have made the waterproofing less effective.

The stopping would have worked as a more effective waterproofing as it is compressed within the wooden joint. The moss may have worked to prevent the stopping from being squeezed out of the top of the joint. This may be the reason that long laths were used to run under several stitches (rather than one lath per stitch) as the laths also serve to hold a continuous layer of moss, acting to keep in the stopping and perhaps aiding the waterproofing.

There is no consistent evidence that the stitch holes were wedged, although a wooden plug survives in one of them in the original boat. This may have been used to hold in the end of the withy stitch, but in the reconstruction (on dry land) friction was enough to prevent the stitch loosening. Friction, to hold the stitch tight, was increased by the sharp angle on the chamfered side of the seam rail.

In the original boat, the D-shaped laths were hammered under four or more stitches at a time, working from the south end, each lath fitting over the top of the previous one for a short distance to keep up the pressure on the layer of moss beneath. Thus the boat was stitched (four stitches) then the lath hammered in (under those four stitches) towards the south end.

The yew withies became workable after being soaked overnight in water, but were even more flexible after being boiled for five minutes (D Sanders, pers comm). These yew stitches are very strong, and, when new, are stronger than the stitch hole through the oak. The life of these stitches may be limited, however, as the thinner yew stitches on the Poole dugout have begun to break up after six years of use at sea (J Keen, pers comm).

The reconstruction studied the joints within the middle section of the boat, but another element is introduced to the working of the rabbeted joints when the curved ends of the boat are also considered. The rabbeted joint is a straight joint in the reconstruction, but, nearer the ends of the original boat, the bottom and ile planks would have had to be bent in towards each other to create the prow shape. The yew stitches appear to be strong enough to hold the flexed planks in place.

The ile planks would have to be added after the scow end/punt end in the original Dover boat. This is because the wedges holding the end of the boat onto the two bottom planks cannot be hammered in with the ile planks in position (this may be why these wedges were cut rather than knocked out when the end was removed).

Tool marks and tools

Several tool edges were damaged in use, and left prominent tool signatures on the wood surfaces. Most of this damage happened during bark removal and roughing-out of the boat parts. As we used the same tools for this work as for the finishing exercises, we left tool signatures on the finished boat. Although blade marks were visible on the original boat, no tool signatures were present. This suggests that the original boatbuilders' blade edges were in better condition than some of ours. If damage to blade edges is bound to occur (through grit and sand in the bark), they may have used different tools for work where they were likely to damage the blade edges.

Figure 9.34
The completed reconstruction. This reconstructed midsection is now on display at Dover Museum alongside the original boat.

The tool handles were chosen to come from trees where there is a branch leaving the trunk at an appropriate angle. Forks were not used, as here the wood grain linking the two branches is not continuous, and so weaker. Only one palstave handle broke during the reconstruction, indicating that these angled handles can withstand many hours of sustained heavy work. Probably the best test for tool handles is to allow inexperienced users to use them. The palstaves, which are heavier than the socketed axes, weigh less than 0.5kg and were found to be most effective when the wooden haft had a lot of weight behind the head.

The tools were used for several weeks on the reconstruction, too short a time to consider that we became experts with them. However, even over that short time, preferences were established. The D-type palstave, either hafted as an adze or an axe, was the most frequently used. The narrow C-type palstave, with its deeply grooved blade, was found to be especially effective for splitting off waste (as an experienced toolsmith had predicted before seeing it used). The narrow B-type axes were liked for hewing, possibly because of their high weight/blade-width ratio.

The evidence of the notches and splits we made in roughing-out the boat occasionally survived on our reconstruction. There were few similar marks left on the bottom planks of the original boat as incuts, and the trace of a notch on one ile. This suggests that the original workers were extremely competent. The lack of tool signatures on their blade edges indicates well-maintained blades.

In several areas, the reconstruction had a better finish than the original (Fig 9.34).

These areas were the stitch holes, the curved faces of the cleats and the trenching in the inboard face of the bottom plank for the transverse timbers. This may have been because the original boatbuilders were under pressure near the completion of the boat, or because of later repairs. As these were areas of the boat that may have been left until last, time pressure would seem to be a likely explanation; reworking of the stitch holes seems less likely, even if the stitching were replaced.

The original boat was beautifully shaped and moderately well finished, suggesting the boatbuilders were very familiar with their work, were skilled workers, and had probably built several boats of this type before.

Conclusions

Many valuable lessons were learnt during the reconstruction experiment that helped inform the suggested sequence of construction of the original boat (Chapter 8). To summarise:

- The bronze tools worked effectively in shaping the green oak, their main drawback being their lack of weight.
- With wooden wedges and bronze tools, weighing less than 1kg, 2.5 tonnes of wood were removed and the timbers shaped in eighty-five person days.
- A sequence of marking out and shaping processes were demonstrated, which would have allowed the original boatbuilders to control the shape of their boat.
- On the cleats and stitch holes, a better finish was produced – and with ease – than that found on the original boat, suggesting that the original boatbuilders were not trying to produce a high-quality finish but that this was a functional boat.
- The time taken to axe notches in the timber suggested that the time taken to fell a 1.1m diameter tree would be two person days.
- A series of offcuts and shavings were produced that should help archaeologists identify hewn waste from Bronze Age sites.
- To shape and assemble the complete 12.5m boat, it is estimated that a team of ten skilled and experienced workers would have been needed, each working eight hours per day for twenty-five days. The finding and collection of the raw materials would have taken more time than the building of the boat, although that need not have been done by the boatbuilders themselves.
- The reconstruction confirmed that the transverse timbers stop the longitudinal movement of the two boat halves.
- The flexibility of the transverse timbers meant that they did not resist the upward movement of the central joint completely; this bending was contained by the transverse timbers bearing against the top of the cleat holes and not the rails.
- The friction joint created by the wedges was sufficient to hold the boat halves together, assisted by the transverse timbers.
- The competence of the original boatbuilders suggests they were very skilled and this is unlikely to be the first of this type of boat that they had built.

10
Reconstruction and performance

by Owain Roberts

The ultimate reference point for all subsequent interpretation is the extensive archaeological record made available to the writer, supported by the detailed interpretation of both the growth patterns and extensive distortion located within the recovered timber by Richard Darrah. The author's own photographic record proved a useful source of supporting information. The environmental report had considerable influence on the eventual reconstruction. In drawing the craft, a process of reconstructing the edges, curves, sections and fixtures leads to a smoother, rationalised impression, containing few of the rugged features and inconsistencies that result from construction using hand tools. The resultant drawing is what might have been the vision of perfection held within the original boatbuilder's mind, upon which were superimposed the technical limitations of the period as revealed by the archaeological evidence.

Design and technology

The technology used in the construction shows a conscious application of certain mechanical and structural engineering concepts. For example, the use of tensioned fastenings, the use of rails as flanges to stiffen flexible areas of planking, and use of transverse linking members set at opposing angles through the rails to solve the problems of parallel movement and separation of the two bottom planks.

Joining technology seems not to extend to dowels, treenails or metal spikes but is confined to wedges and stitches. This could be owing to an inability to produce small-diameter, deep holes with the precision needed for treenails or spikes.

Stitches as fastenings

The only fastenings found in the craft have been stitches, which were used exclusively to retain side-plank edges in contact. The mechanical advantage of using three loops of a single withy enabled great tension to be applied. Three loops around the two parts to be drawn together have a similar mechanical advantage to that obtained from a tackle having two triple-sheaved blocks, that is a power of six times the pull applied, if friction losses are ignored. In the case of a withy these would be noticeable but would still permit considerable stitch tension to be applied. It has been suggested that, when such stitches are secured, the friction against them within the holes and against the surface of the planking would increase by perhaps twelve-fold when resisting load applied to them through hull-flexing, (Coates 1985). Tightly held seams not only stiffen the craft but contribute to water-tightness. The technology enabled moss to be placed over the seam but beneath a batten, which was held down very tightly by the stitches.

Flanged planking

The bottom planking consists of two boards, generally 0.06m thick, 0.85m wide and perhaps 10m in length. In any boat, hull-flexing destroys seam fastenings, watertightness and structural integrity. The inclusion of deep flanges close to each long edge of the two bottom planks causes them to stiffen like girders, so making them better able to resist bending. That each of the flanges – or rails, as they have been named – has another purpose too, is just good engineering. From the structural drawings, the side rail is seen to become part of the ile or chine girder's lower-edge support, prior to stitching.

The centre rails are noticeably larger than the side rails, which suggests an awareness of the need for more stiffness at the centre line. Might these be the first stirrings towards the concept of a single keel as an engineered item within a boat? As with the side rail, the rails at the centre are needed to perform another function in conjunction with the isolated cleats standing proud of the surface – that is, to be part of the centre-line joining method.

No continuous system of framing across from one sheer line to the other has been used. The thickness of the planking helps each plank to retain its shape virtually unsupported. The width of the plank edges provides a stable base between adjacent planks. Movement across the adjacent plank edges is resisted by simple edge jointing, except at the centre line. Stitches made over battens fitted along the seams complete the stabilising and, more importantly, the linking of each plank seam. Again, a different method is used at the centre line.

Framing in the hull bottom is restricted to a few straight transverse timbers across the centre line. This is discussed below. Archaeological evidence shows that a few part frames were in place each side, inserted through the large cleats on the vertical faces of the iles or chine girders, and in corresponding cleats on the side planks. Part frames appear to be placed where no curvature was present on the surfaces against which they were fitted, emphasising the structural importance of the iles or chine girders in joining the sides to the bottom.

Joining at the centre line

What is most noticeable about the centre-line join is that no method of pinning, stitching or jointing is used to prevent separation of the two bottom planks. In the structural drawings (Figs 10.1; 10.2) it can be seen that the centre seam is padded with moss, held in place by a long, flat batten. The batten is pressed down by the insertion of short, slightly tapering wedges through slots cut in both centre rails. Also passing through the centre rails are several long, transverse timbers that fit into opposing pairs of isolated cleats. Effectively, these timbers perform the function of floors, or bottom frames, that are found in almost all wooden-boat constructions of a later date. They reduce the opposing, independent, vertical movement, or wracking, of the bottom planks that would occur somewhat in spite of the deep flange-form of the centre rails, whenever the boat was at sea.

Friction within the slots in the rail is confined to the slots' vertical surfaces, as otherwise the bursting power of a tightly driven wedge, if applied to the slots' horizontal surfaces, would split the rails. This is owing to the orientation of the medullary rays within the bottom planks (Chapter 7). The tightly fitted short wedges are not in themselves holding the two halves of the boat together. The dynamics of the joining method used by the ancient boatbuilder is further evidence of good engineering. On examining the structural plan-view drawing (Fig 10.1), one notices that no transverse timber or wedge crosses the centre line at a right-angle. This is believed not to be carelessness but a deliberate technique. Note also that most of the wedges lie at one similar angle to the centre line, while the transverse timbers are aligned generally in another. To misalign the matching slots for just some of the transverse timbers and wedges would be careless. Deliberate intention is indicated by the straightness of the common centre line passing through each pair of slots. By driving in transverse timbers and wedges at diverging angles along the length of the centre rails, any athwartship force trying to separate the two bottom planks locks the transverse timbers and wedges tighter, but at their sides only (Fig 10.1). As noted earlier, this avoids bursting the rails and the bottom cleats. Such a method would also reduce any tendency for the two bottom planks to move in opposing directions longitudinally. To rely on the iles or chine girders to hold together the two halves of the boat, however, does not take account of the reaction of the bottom planks to hull movement over even slight waves. By being linked only across the ends of the boat via the transoms, the iles or chine girders would not prevent the bottom planks opening and closing in response to hogging and sagging strains. Effectively, the iles or chine girders could act as though hinged at their ends – in the manner of a helmet's visor – if not prevented from doing so by the locking action of the wedges and the transverse timbers.

The structural drawings

All drawings have been constructed with the boat's dimensions assumed to be symmetrical about the relevant centre line as, probably, would have been the original boatbuilder's aim. However, all structural detail has been drawn in the position discovered. There is no conflict between these two actions. Where sections were missing these were rebuilt drawing on the evidence available from the archaeological remains and from contemporary nautical evidence, or with due reference to structural or hydrostatic requirements.

Length

The bottom planks' outer edges taper only towards the southern end, being parallel-sided for most of their northern half to the straight centre line, as is to be seen in the lines plan (*see* Fig 10.4). This form is found in prehistoric craft based on simple log-boat building, and reflects the taper of the trunk. It indicates the root end and, invariably, that is the after end of such craft, probably because it makes steering easier, as the weight distribution would cause the end with the larger girth to trim down slightly deeper. That same reason could decide that the Dover boat's diverging, yoke-like end is its fore-end.

There is no indication given by the archaeological remains that the two ends of the boat were similar to one another – although this option is considered later. It is possible that very little of the bottom planking remains in the ground. An early assessment of the structural strength of the boat as recovered showed that it could be marginal in rough water because of the shallow depth-to-length proportions suggested in the height reconstruction of the sides, based on the archaeological evidence. The hull probably was shallow and trough-like with a useful range of stability. Lengthening the bottom planking much beyond that recovered was considered as another option for a reconstruction of the Dover boat. These problems are examined later and show that indeed the boat seemed to have been built close to the limits of the strength of its materials as disposed within the structure.

The most likely indicator of original length found within the remains is the pitching of the bottom-plank cleats and the chine-girder side cleats. That five sets of bottom cleats and their respective floors had been used is known from the archaeological record. Their pitch or spacing is regular. Close to and above the forward set was located the most forward side cleats. Another set of side cleats was located close above the third set of bottom cleats at what could be regarded as amidships. If, as seems likely, the side cleats supported a method of stiffening the sides of the hull, then a third pair of side cleats would have been necessary above the fifth set of bottom cleats, although none was recovered. However, if this is close to the after end of the hull then transverse support could have been supplied by the insertion of a transom, dispensing with the need for a third pair of side cleats. This is one likely solution to closing the end and provenance for a similar method is to be seen in the Brigg and Hasholme boats, (McGrail 1978; McGrail and Millet 1987). In the drawings, the distance of the transom from the fifth set of bottom cleats is made the same as that from the 'V' of the diverging stem to the first set. The method of retaining the transom uses the same deep-rail and wedging technology that is found elsewhere in the Dover boat. By this means, the length of the bottom planking was defined for the purposes of this reconstruction.

Careful consideration was given to completing the missing end by adding a sloping transom similar to that found at the recovered end, and this was drawn out as a lines plan. It lengthened the boat by about 3m. A similar version, extended to 18m, was also considered – a length based on the maximum length of oak bottom plank likely to have been available (*see* Fig 10.5). Because of the general shallowness of the hull, and the distribution of the structural features, it was established that the extra length renders both proposed reconstructions as being too weak to operate on the sea on a number of accounts. This is discussed in detail later.

The fore-end and its assembly

No remains of the timber that closed the fore-end to make a scow-form bows transom were recovered. The intersection of the centre-line sealing batten and a short cross-batten was almost undisturbed. Combined with two side wadding laths, various under-cutting slots, and the hacked remains of locking wedges, it was evident that a lot of thought had produced a fairly complicated watertight end. There are slight similarities with the later Hasholme log boat, (McGrail and Millet 1987), but nothing in the latter prepares one for this level of ingenuity. Figure 10.3 suggests the assembly components.

The large, shaped board shown to fit precisely must, necessarily, be an interpretation. At its bottom end it would need matching rails to locate the locking wedges driven through the yoke rails. At its edges, higher up, it would require seam rails to accept the tapering ends of the chine girders (ile planks) and the probable sheer strakes. It has been given slight curvature in profile to meet the sides more easily. A vertical bow transom above the level of the chine-girder ends had been considered, but the method of linking it to a shorter, angled scow-form transom would have differed from the technology contained in this end of the boat.

Ile or chine girder

The iles or chine girders had both lost some of their original shape, so due reference was made to Richard Darrah's report (Chapter 6). Recovering the original shape was necessary in order to fit the bottom-plank edge, especially where the latter showed some slight rocker towards the fore-end. For all of its length, the ile or chine girder has a curving cross section fixed by a constant arc and radius. From a point past the middle-side cleat it was noted that, although the arc and radius did not change, the length of the arc or curvature decreased towards the end of the ile. The reduction in cross section through to the end could be defined almost entirely as a reduction in the chord distance measured across the section's curve, or arc, from the top to the bottom edge, and not as a change in curvature along the edges of the ile or chine girder. The top edge remained a straight line, which was also horizontal and therefore parallel to the datum line when the chine girder was drawn in its position on the bottom plank (*see* Fig 10.2).

The side cleats shown in the archaeological sections suggest from their angles to the inner surface that they have drooped, especially if the iles or chine girders were thought to be carved from quarter logs. However, a quarter-log orientation of the sections precludes a fit to the bottom planks. The chine girders must be set up with more flare; that is, they must lean out a little more. The slight flare then causes the top surfaces of the side cleats to become nearly horizontal. This is considered to be their correct position and might answer questions of their orientation within the log from which they were carved.

The side cleats could have had a temporary function during the assembly and stitching of the iles or chine girders. A rope tensioned between opposite pairs would draw in and hold up to position the chine girders ready for fitting and stitching.

Sheer strake

Stitch holes, and the remains of a lap-joint rabbet along the upper edges of the iles, confirm that a further, slightly thinner strake was fitted. It was decided that it should have a width equal to the height of the assembled ile or chine girder. There being no evidence of a comprehensive upper supporting framing system, the width was limited. It was decided – similarly, because of the lack of structural evidence – that no other planks could be justified above the one for which there were indications. It is fortuitous that the depth of hull resulting from this decision suits the ergonomic needs of a paddler, while leading to a hull section of good stability. As the hull was almost parallel-sided and flat-bottomed, there was no inducement from its geometrical form to cause the sheer to do other than lie in a horizontal line. The single plank or sheer strake would have posed problems of support, as there is very little curvature in it to create stiffness and, hence, it would have been floppy owing to its length. Coupled with a shallow hull, which would benefit from any athwartship structure, the interpretation has used the following construction based on evidence gathered from the boat's remains.

Perhaps on the inner face of each sheer strake was carved a side cleat above the one carved on the chine girder. A tightly fitting, rounded timber is inserted vertically to link each sheer strake side cleat with the ile or chine girder's side cleat below it. This might be the reason for the latter's being carved to have a nearly horizontal upper surface. Perhaps across the tops of these round timbers were fitted two beams, as in the Hjortspring boat (Landström 1961) lashed to prevent their jumping off. The lower ile or chine girder cleats could be tensioned across the lower hull by rope trusses looped around the vertical timbers and wound tightly. An alternative method would be to cross the trusses diagonally from the ile one side to the top of the round timber on the other. The orientation of the medullary rays within these cleats allows such tension without their being pulled off (Chapter 7).

The beams help to resist the hogging and sagging of the hull. The iles or chine girders are likely to experience strains that constantly force them outwards, so a system of rope trusses – as suggested, tensioned athwartships and low in the hull or crossing diagonally – is a means of resisting this. The ends of the iles or chine girders and the sheer strakes are supported further by their attachment to the sloping scow bow and to the transom aft.

There is no indication in the archaeological record of there having been any more complicated forms of structure across the hull. The estimated dimensions of the hull after minimal reconstruction are presented in Table 10.1.

Table 10.1 Hull dimensions after minimal reconstruction

length	11.7 m
beam	2.26 m
height from datum	0.80 m
inside hull depth	0.74 m
length : beam ratio	5.2:1
length : depth ratio	14.6:1
beam : depth ratio	2.8:1
dry weight of hull	2.3 tonnes

Specific gravity of part-seasoned oak taken as 0.9 (Desmond 1919). Volume of hull envelope calculated as averaging 0.06 m thick.

Hull lines

The hull-lines drawings (Fig 10.4) were originally made to a scale of 1:20 for the sheer plan and the half-breadths plan. The body plan was drawn to a scale of 1:10, as in the structural drawings. As well as creating the shape of the boat accurately in three dimensions, hull lines enable a mathematical analysis to be performed that defines the parameters of performance and stability in ways that allow comparison with other, similar craft. The calculations might be made after direct measurements from the hull lines.

This process takes time and, as results over a wide range of uncertain conditions were desirable, it was expedient to enter the hull lines into a computerised hull-design programme. Three versions of the hull lines were entered to be explored:

1 a boat barely longer than the recovered remains;
2 a boat having a stern similar to the bow, so longer than in version 1;
3 a boat as in version 2, but having a length based on a 15m one-length bottom planking, thought to be the maximum size possible.

The first (Dover 1) was based on the 1:20 scale plans drawn by hand. The second (Dover 2) was developed from Dover 1 by the addition of a sloping stern transom similar to the scow bow. The third (Dover 3) was developed from Dover 2 by increasing the bottom-plank length, resulting in a maximum length of 18m (Fig 10.5).

Results of computerised hull design

The design programme employed is Hullform Professional (v.5). The hull lines produced manually were measured at each section for a number of lateral and vertical measurements that were entered directly into the Hullform programme to replicate the lines on screen. From these it was possible to perform all calculations described below, either within the design programme or by planimeter, calculator and standard formulae.

Structural problems of the Dover boat versions

All three versions of the Dover boat that have been proposed in the light of the missing portion, probably the stern, show hulls that are shallow for their length (Fig 10.5).

Increasing the length should exacerbate the problem of hull stiffness. This, in its turn, would demand more from the strength imparted by the structure and increase the loading on the stitches, as the other dimensions, of hull width and hull depth, are decided by the archaeological remains. As a means of gauging how much length was missing, a standard analysis of the three possibilities was undertaken. As a hull is a form of girder, its strength, and the forces acting on it, might be calculated as such.

Longitudinal bending

Dover is located far along the coast from any extensive inland waterway, having a river that is likely never to have been any more than a minor feature, only navigable at its small estuary. One must consider that the Dover boat had been used for making coastal voyages. Whatever its length, the boat would be subjected regularly to waves that would cause the hull to bend and twist in response. To assess the capability of the structure to withstand this, the forces were resolved by investigating the reactions to longitudinal bending in three states – that is, in calm water and when hogging and sagging

Table 10.2 Extract from the Beaufort Wind Scale*

Beaufort number height (m)	*mean wind speed (knots)*	*open-sea criterion*	*probable wave height (m)*	*probable maximum height (m)*
force 2	4–6 light breeze	small wavelets, still short but more pronounced; crests have glassy appearance but do not break	0.15	0.3
force 3	7–10 gentle breeze	large wavelets; crests begin to break; foam of glassy appearance; possibly scattered white horses	0.6	1.0
force 4	11–16 moderate breeze	small waves becoming longer; becoming longer; fairly frequent white horses	1.0	1.5

* from Reed's *Nautical Almanac* 1981, 811

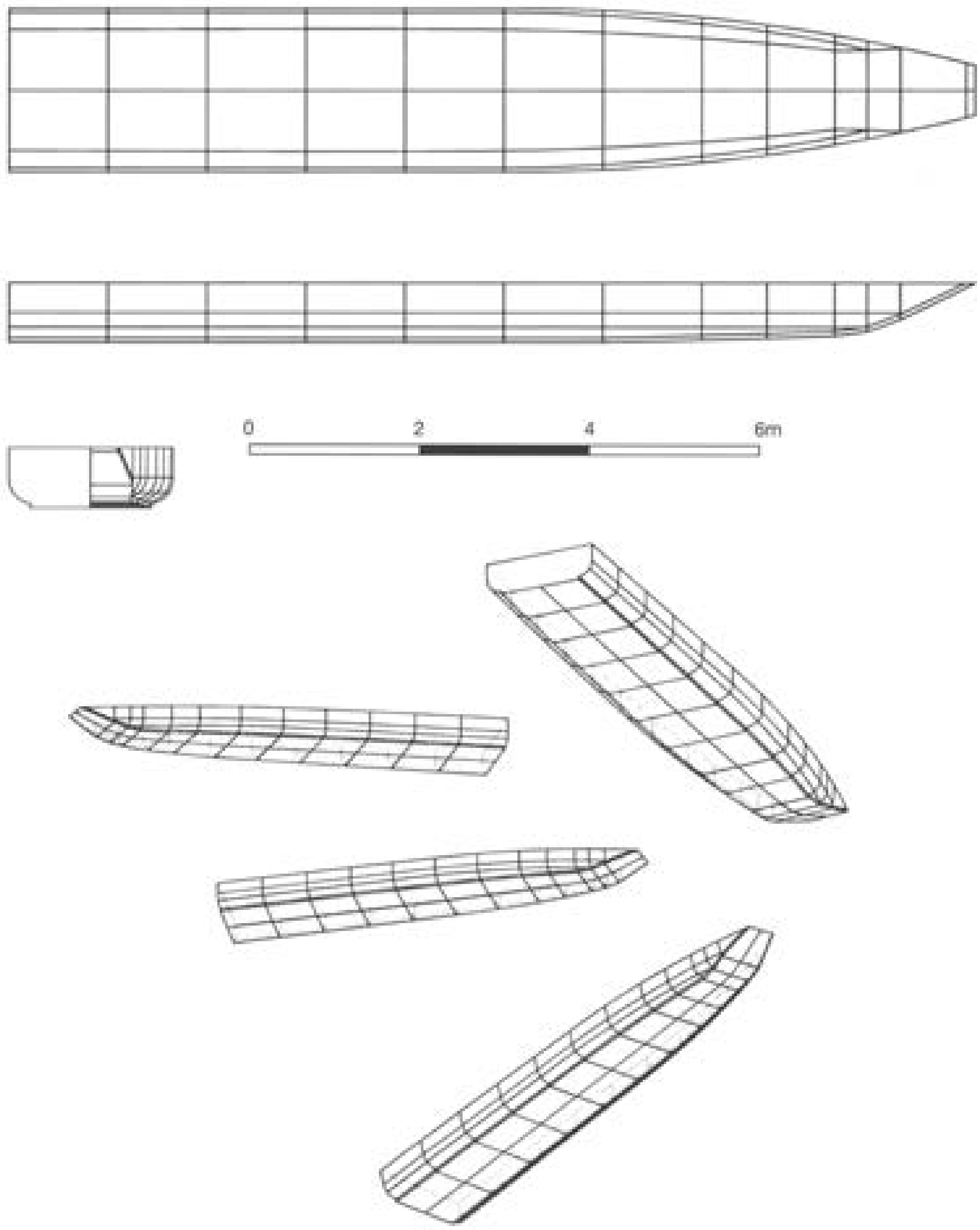


Figure 10.4
Hull lines. (Note: scale bar refers to main views only, not to the perspective views.)

in waves – for all three versions. The boat would be in a hogging condition when supported by one wave crest at its middle and in a sagging condition when supported by two crests, one each end of the hull. The size of such a wave – known as the standard wave – is equal to that of the boat and having a depth one-twentieth of the distance between crests or troughs. For the Dover 1, the wave's height would be about 0.6m.

The height of the standard wave has relevance to the frequency of certain sea conditions that induce the stresses calculated for hogging and sagging (Figs 10.6; 10.7).

Any version of the Dover boat would meet its standard wave frequently during those conditions most suitable for passage-making (Table 10.2), and could expect to dip its bows into the occasional head sea or be slamming the odd wave in beam-sea conditions, so shipping heavy spray.

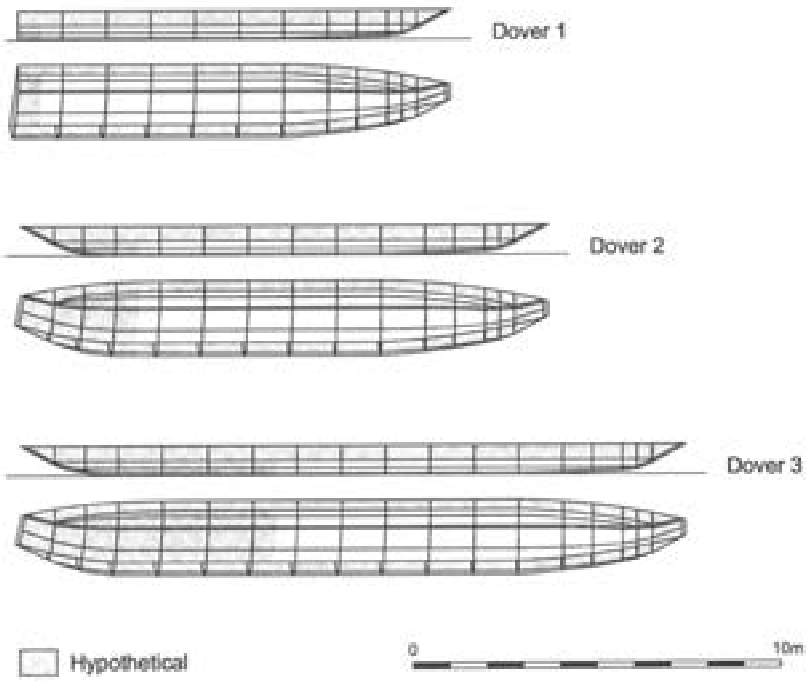


Figure 10.5
Three hypothetical reconstructions of the Dover boat.

Determining the forces involved in longitudinal bending

The shortest version of the three reconstructions was assessed first in a light condition, then with twenty men distributed mainly in pairs. To the Dover 1 was added two tonnes of a notional cargo, evenly distributed about the middle half, which brought it to a draft of 0.3m. Freeboard is then 0.5m in still water.

The weight line in the strength-curves graphs for the Dover 1 indicates this distribution (Figs 10.6; 10.7). This resulted in a displacement of 5.5 tonnes. Since total weight must equal total buoyancy the position of the standard wave has to be established by trial and error until a match is made and it might be struck in on the profile of the hull. Area measurements by planimeter for each section are integrated to produce a volume that supports the hull and is illustrated by the buoyancy curve. The difference between that and the weight curve gives the ordinates for the load curve. The ordinates of the shearing-forces curve are obtained by integrating the areas of each station of the load curve. Further integration of the ordinates of the newly drawn shearing-forces curve gives values for the bending-moments curve.

This process was undertaken for five load conditions of Dover 1. The strength curves for Dover 1 in both hogging and sagging states, 0.3m draft, 5.5 tonnes displacement are shown (Figs 10.6; 10.7). Table 10.3 lists both bending moments (BM) and shearing forces (SF) for the five conditions of loading and three sea states.

Table 10.3 Maximum bending moments (BM) and shearing forces (SF)

Dover version	*loading*	*displacement (tonnes)*	*sea state*	*max BM (tm)*	*max SF (t/m)*	*calculation method*
Dover 1	light	2.3	calm	0.14	0.05	integrated
Dover 1	20 crew	3.5	calm	0.14	0.06	integrated
Dover 1	20 crew and cargo	5.5	calm	1.2	0.5	integrated
Dover 1	20 crew and cargo	5.5	hogging std wave	1.8	0.55	integrated
Dover 1	20 crew and cargo	5.5	sagging std wave	3.9	1.4	integrated
Dover 2	20 crew and cargo	6.4	hogging std wave	2.7	0.76	formula
Dover 2	20 crew and cargo	6.4	sagging std wave	5.4	1.8	formula
Dover 3	20 crew and cargo	8.7	hogging std wave	4.6	1.02	formula
Dover 3	20 crew and cargo	8.7	sagging std wave	9.2	2.04	formula

The standard approximation formula for maximum bending moments is (Barnaby 1954):

$$\text{BM} = \frac{\text{length} \times \text{displacement}}{\text{K}}$$

K is a factor based on design experience. For destroyers, hogging, it is 30, and John Coates uses this figure in his calculations on the stitch stresses in sewn boats, and in particular on those of the Ferriby boats (Coates 1985) because of general similarities in proportions. From the results of the calculations made for the loaded Dover 1 on the crest and in the trough of a standard wave, K figures of 34 for hogging and 17 for sagging were used in subsequent calculations on Dover 2 and Dover 3.

A similar formula for estimating maximum SF is available (Munro-Smith 1977) where 4 is proposed as the value for a coefficient C, based on previous design experience. From the BM and SF already calculated for a loaded Dover 1 in a hogging and sagging state, a coefficient of 4 is still appropriate. The formula is:

$$\text{maximum SF} = \frac{\text{C} \times \text{maximum BM}}{\text{length}}$$

The calculated values for all three versions of the Dover boat under consideration are given in Table 10.3. These figures indicate that all versions resist bending better when hogging than when sagging. The sides retain their shape better when the boat is on a single-wave crest but would seem to buckle easily when the hull ends try to rise while the rest of the hull is in a trough. The BM for a sagging, loaded Dover 1 exceeds the BM for a hogging, loaded Dover 2.

The results of calculations for Dover 1 to determine BM and SF (so that the hull stresses could be found) are presented in Figs 10.6 and 10.7. The distribution of weight (hull, crew and cargo) is blocked in. The support from the wave, whether hogging or sagging, is indicated by the buoyancy and the load curves. From those curves are obtained the BM and SF values. In the first graph (*see* Fig 10.6) the topsides are in tension and the hull bottom is in compression. In the second strength-curve graph (*see* Fig 10.7), the reversal of the buoyancy and load curves show how the middle of the hull must sag, thus putting the topsides into compression and the hull bottom in tension.

Equivalent girder

To perform the calculations for moment of inertia (I), and the height of the neutral axis (NA) the main cross section of the Dover boat was redrawn as an equivalent girder having the same cross-sectional area and height as that of the boat (Fig 10.8).

Calculations based on the equivalent girder (Table 10.4)

Reduction of the hull to an equivalent girder is a recognised practice and is applicable to a boat of this shape. Only one side is measured here, although this is allowed for in the equations and in the calculations that follow.

No allowance is made in these calculations for the flexibility of the seams, which in any case, is destructive both to the stitches

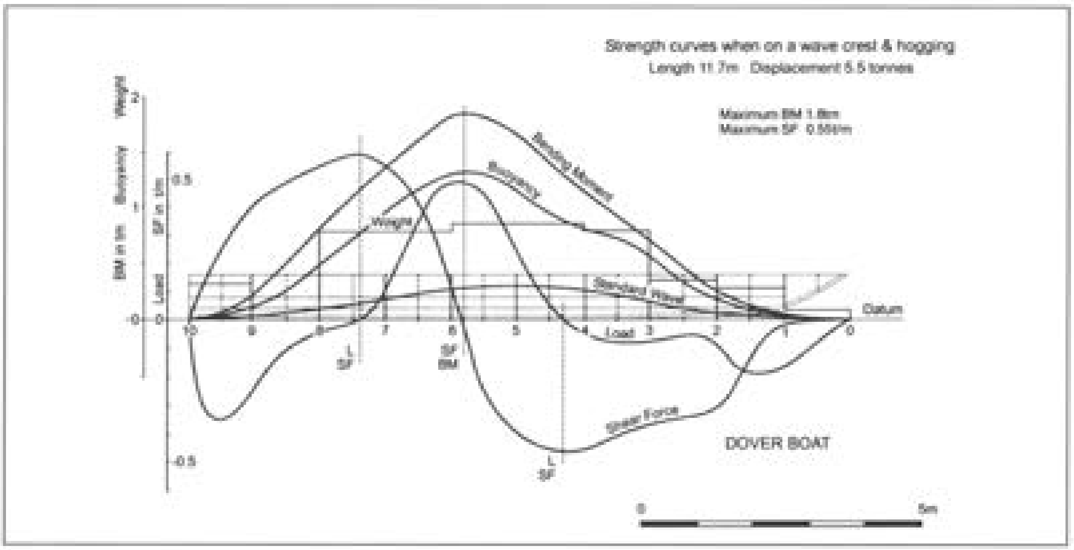


Figure 10.6
Graph showing strength curves when on a wave crest and hogging.

and to the luting. These figures must therefore reflect the best possible case rather than the lesser situation, which would be the norm. Flexibility would need to be controlled by tightening stitches or re-stitching at intervals throughout the boat's life.

The results of these calculations are required as values for use in later calculations.

In all three versions, the position of the neutral axis (NA) lies a little above the upper surface of the centre rails, owing to the concentration of material low in the boat's structure. Because of this, there is less resistance from the bottom planks to the flexing of the hull. The hull sides have insufficient support from beams or decking to resist their buckling, and this is a weakness that would be compounded by greater length. It should be noted that the lower seams are only a little lower than the NA, and later calculations show how these would be stressed

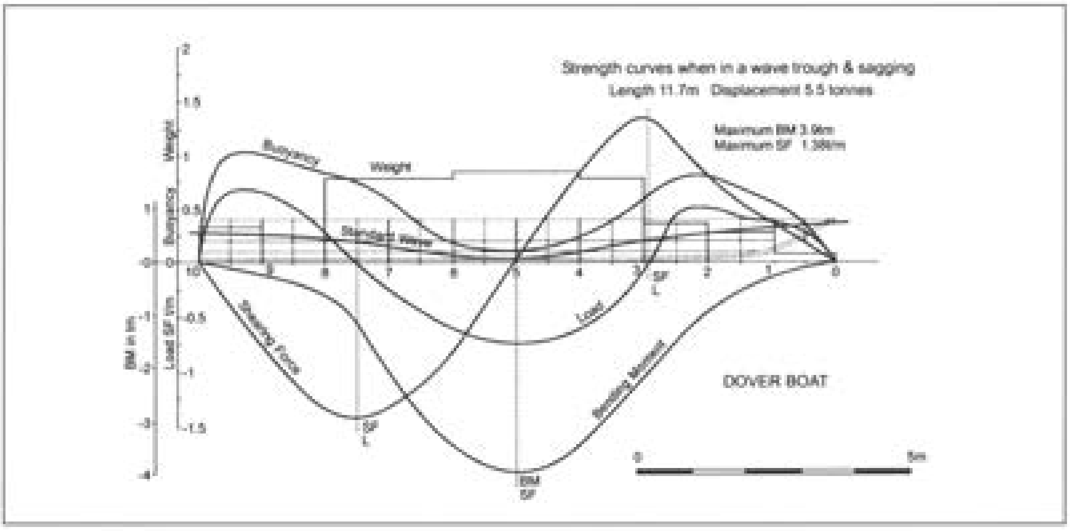


Figure 10.7
Graph showing strength curves when in a wave trough and sagging.

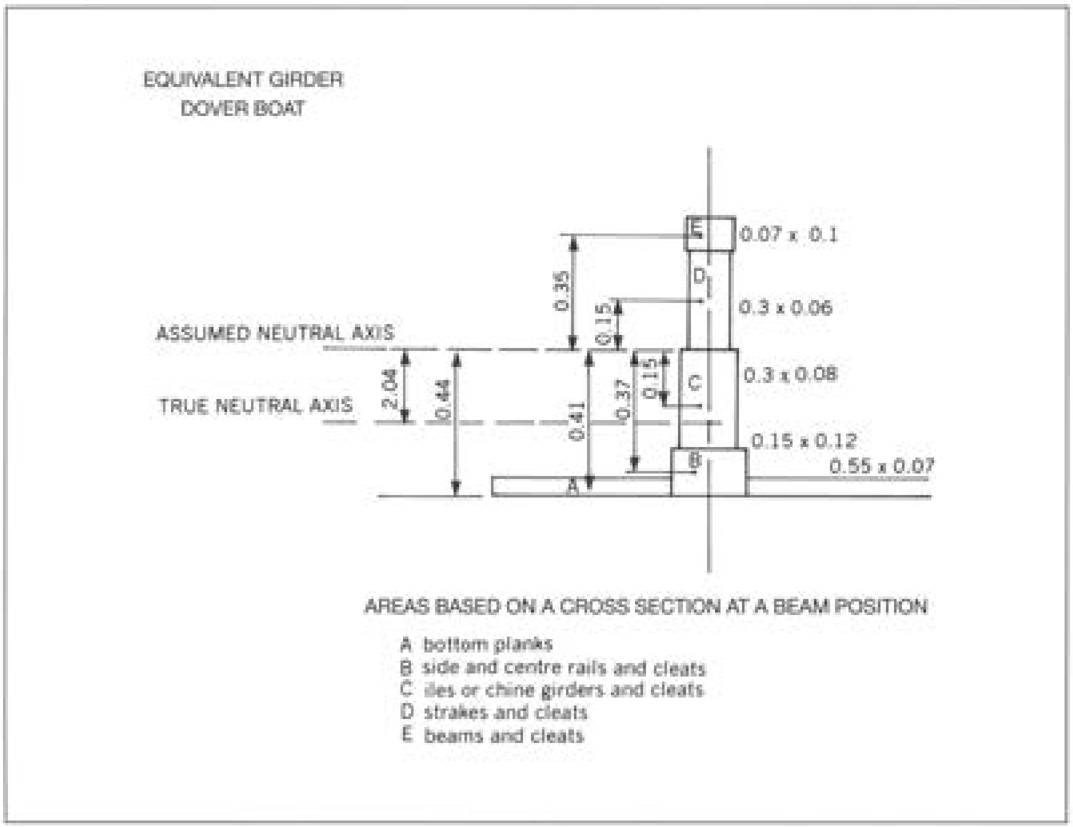


Figure 10.8
The main cross section of the Dover boat, redrawn as an equivalent girder.

Table 10.4 Calculations based on the equivalent girder

item	*dimensions (cm)*	*area (cm^2)*	*cg to assumed n a (m)*	*m'mnt about assumed n a (cm m)*	*(col4)^2 (m^2)*	*col 3 × col 6 (cm^2 m^2)*	*depth of item (m)*	*(col 8)^2 (m^2)*	*col 9 × col 3 (cm^2 m^2)*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
below assumed neutral axis									
A	55 × 7	= 385	× 0.41	= 158.0	0.17	65.5	0.07	0.005	1.93
B	15 × 12	= 180	× 0.37	= 67.0	0.14	25.2	0.15	0.023	4.14
C	30 × 8	= 240	× 0.15	= 36.0	0.02	4.8	0.30	0.090	21.60
				261.0					
above assumed neutral axis									
D	30 × 6	= 180	× 0.15	= 27.0	0.02	3.6	0.30	0.090	16.20
E	10 × 7	= 70	× 0.35	= 24.5	0.12	8.4	0.10	0.010	0.70
		1055		–51.5		107.5			44.57

true neutral axis $= \dfrac{\text{col. 5}}{\text{col. 3}} = \dfrac{261 - 51.5}{1055} =$ **0.2 m** below assumed neutral axis

moment of inertia $= 2([\text{col. 7}] + \dfrac{[\text{col. 10}]}{12} - [\text{col. } 3 \times 0.2^2]) =$ **138 cm²m² or 1380 000 cm⁴**

section modulus

at keel $= \dfrac{1\,380\,000}{44-20} =$ **57 500 cm³** or **5.7586 m cm²**

at sheer $= \dfrac{1\,380\,000}{44+20} =$ **21 563 cm³** or **2.1563 m cm²**

Hull-stress and shearing-force calculations
Information gained from the previous calculations is used to establish the tensile and compressive stresses due to hull distortion in both hogging and sagging situations. Some examples follow:

Dover 1 – sagging: the stresses placed on the gunwale or sheer line and at the bottom

$$\text{stress P} = \frac{M \times Y}{I}$$

where:
M = bending moment from strength curve
Y = distance from NA by equivalent girder
I = moment of inertia by equivalent girder

$$\text{At gunwale P} = \frac{3.90 \times 0.6}{138} = \frac{\text{tm} \times \text{m}}{\text{cm}^2 \times \text{m}^2}$$

Stress at gunwale = –1.7 MN/m² (compression)

$$\text{At bottom P} = \frac{3.90 \times 0.21}{138} = \frac{\text{tm} \times \text{m}}{\text{cm}^2 \times \text{m}^2}$$

Stress at bottom = + 0.23 MN/m² (tension)

Dover 2 – sagging: to calculate shear stress at NA

$$\text{shear stress q} = \frac{F\,A\,Y}{b\,I}$$

where:
q = in t/m² or MN/m²
F = SF from strength curve
A = area from equivalent girder
Y = from NA to centre of gravity of area from equivalent girder
b = width of material
I = moment of inertia from equivalent girder

$$\text{SS at NA} = \frac{1.8 \times 318 \times 1000}{24 \times 138} = \frac{\text{t} \times \text{cm}^2\text{m}}{\text{cm} \times \text{cm}^2\ \text{m}^2}$$

S.S. in t/m² = 173 t/m²
as 173 × 1000 = 173 000kg/m²

then $\dfrac{173000 \text{ kg/m}^2 \times 9.813}{10^6}$ so

Shearing stress in MN/m² = 1.698 MN/m² at the neutral axis.

Table 10.5 compares the stresses calculated, and shows values increasing with loading condition and length.

The third column of Table 10.5 might be used to consider whether the versions of the boat have sufficient structure in the

Table 10.5 Comparing stresses

version	*max bending moment tm*	*max shearing force (t/m) and MN/m*	*max gun'al stress MN/m² (in compression)*	*max bottom stress MN/m² (in tension)*	*max shearing stress at NA in MN/m²*
Dover 1 still water 3.5t	0.15	(0.06) 0.59	–0.06	0.02	0.023
Dover 1 still water 5.5t	1.2	(0.5) 4.9	–0.51	0.18	0.47
Dover 1 sagging	3.9	(1.4) 13.7	–1.7	0.23	1.32
Dover 2 sagging	5.4	(1.8) 17.6	–2.3	0.81	1.69
Dover 3 sagging	9.2	(2.04) 20	–3.9	1.37	1.92

Table 10.6 Cross-sectional area of oak at the gun'al required to withstand stresses for different versions of the hull lines

cross section at gun'al = 0.014m²	*max. gun'al stress MN/m² (in tension)*	*min. cross-section area needed in m²*
Dover 1 still water 3.5t	0.06	<0.005
Dover 1 still water 5.5t	0.51	0.005
Dover 1 sagging	1.7	0.018
Dover 2 sagging	2.3	0.025
Dover 3 sagging	3.9	0.042

gunwale area to withstand the forces that could be applied to them. Clearly, the forces increase as the length increases and the sea conditions worsen.

The bursting or rupturing point of the fibres of British oak has been found by experimentation to occur when stressed to 92 MN/m² or 9362 t/m² (Desmond 1919). To find what cross-sectional area of oak at the gunwale would be needed to withstand the force calculated for each line in the third column, the value was divided by 92 MN/m², to give a result as a fraction of a square metre. The results are listed in Table 10.5.

At the gunwale or sheer line, the thickness of the sheer strake and the material in the beams and the upper edges of the transoms were included in the drawing of the equivalent girder and show a cross-sectional area of 0.014 m², on which the gunwale stress would be acting. The values in the right-hand column of Table 10.6 show the least cross-sectional areas that would just withstand the forces calculated. From these calculations, one of the limits of the length of the original Dover boat can be determined.

The results suggest that the gunwale would be showing slight stress even on the shortest version (Dover 1) if it were carrying cargo in calm seas. However, the gunwale is a part of the sheer strake so that some support would be gained from it. The gunwale would not burst, but would show animated buckling if making a passage in the worst conditions, which is in waves comparable with its standard wave. Leaking at the seams would be of more concern to the crew, as they would have become inured to the flexibility of their craft. The versions Dover 2 and Dover 3 would need to operate in calm waters and lightly loaded at all times, because of the effects of severe seam distortion and consequent (possibly overwhelming) leakage via the seams and stitch holes.

Similar calculations for the bottom planks show that their dimensions exceed those necessary for resisting all compression and tension arising from flexing over waves.

The very excess of material in the bottom might be expected to help in resisting the natural flexing, except for its being in the form of a large slab, the depth of which is a very small portion of the total hull depth. The rails on its surface and the iles or chine girders comprise most of the vertically arranged material and so provide the greatest resistance to flexing. Splitting and repair stitching over battens was noted in the iles during examination of the archaeological remains and would seem consistent with such stressing.

The strength of the stitched seams

John Coates states that the breaking stress of withy-stitch material is about 100N/mm² and that the mean safe tensile stress (factor of safety) is about 1/40 or 0.025 of the breaking stress, which is about 2.5N/mm^2 (Coates 1985). By calculation, the minimum diameter of a single withy stitch might be found, with reference to the stresses placed on a boat. This was done as follows for the three versions of the boat and under different loadings.

Where:
T = tension
W = weight
L = length water line
P = length of lower seam at the approximate level of the NA
K = the factor discarded by substitution:

Then $T = \frac{WL}{28P}$ (after Coates 1985) but bending moment (BM) $= \frac{WL}{27}$ by the approximate formula so, after substitution, $T = \frac{BM}{P}$ was used.

The formula applied to Dover 1, displacing 5.5t, both hogged and sagged, is as follows:

With BM 3.9tm and with P at 10m then

$$T = \frac{3.9\text{tm}}{10\text{m}} = 0.39\text{t} \times 9.813 \text{ (for Newtons)}$$

Tension in stitch (sagging) = 3.8KN total of both sides of the stitch hole:

And for F of S

$$\frac{3.8\text{KN} \times 100}{100\text{N/mm}^2/40} = 1520\,\text{mm}^2 \text{ (twice cross-sectional area)}$$

per side of stitch hole = $760\,\text{mm}^2$ cross-sectional area of total material within hole.

Cross-sectional area of one strand of, say, three $= \frac{760\,\text{mm}^2}{3 \text{ strands}} = 253\,\text{mm}^2$ **(sagging)**

For hogging strength, the cross section of one strand is calculated as 115mm^2

Using Radius $= \sqrt{\frac{\text{Area}}{\Pi}}$ then stitch material

material radius is 8.97mm and 6mm.

So the diameter of withy stitch should be from 12mm to 18mm for Dover 1.

Note that the average withy-stitch diameter in the archaeological record is 14.6mm. Results for the three versions are listed in the Table 10.7.

Table 10.7 Average diameter of single withy for a three-strand stitch

version	*average diameter of single withy for 3 strand stitch (mm)*
Dover 1	12–18
Dover 2	14–21
Dover 3	20–28

From the calculations for the tension within a stitch, the safe load on each would be 1.52KN. If there are 34 stitches in the seam then all the stitches together could, in theory, withstand a bending moment of 5.3tm, which is in excess of the maximum BM of 3.9tm applied to this seam in Force 3 sea conditions. In a real situation, the strength of the stitches would be less, owing to factors such as inconsistency in their material, variable thickness, skill of the stitcher and the flexible nature of the boat's structure as a destructive agent.

Deflection of the ends while hogging

The continuous deflecting of the ends owing to the action of passing waves is an indication of the shearing stresses being placed on the structure, and especially on the stitching. The greater the amplitude of these waves, and the further the relative movement of the planking, the faster wadding will be destroyed at the seams and the slacker the stitches will become. The increase in deflection follows the rise of stresses in each hull version as length is increased within the constraints of a fixed beam and hull depth based on the archaeological evidence. The deflection of a hull might be assessed approximately as would that of a beam curving under load. No allowance is made for stretched stitches and the relative movements between planks, all of which would add significantly to the end deflections calculated for the hulls and the values shown in Table 10.8.

The calculations of the radius of hull curvature and of the end deflection for the Dover 1, displacing 3.5t in calm water, are as follows:

$$\text{When} \quad \frac{\text{stress}}{\text{distance to NA}} = \frac{\text{BM}}{\text{moment of inertia (I)}}$$

$$= \frac{\text{modulus of elasticity (M)}}{\text{radius of curvature (R)}}$$

then radius of curvature

$$= \frac{\text{M of elasticity}}{\text{moment of inertia}} \quad \text{or } R = \frac{E \times I}{M}$$

where:
E (for English. oak) = 104747kg/cm^2
I = 138 cm^{2}m^2
M (from strength curve) = 1.8tm

Radius of hull curvature =

$$\frac{104747\text{kg/cm}^2 \times 138 \text{ cm}^2\text{m}^2}{1800 \text{ kg m}} = 8030.603\text{m}$$

The deflection being small, the chord of the hull curvature and the length of the hull are almost the same. By Pythagoras' theorem, let the hull length be the base of a right-angle triangle, whose perpendicular side is 4239.759m. That is the calculated radius of hull curvature. The hypotenuse to the hull's end might then be calculated and its length compared with the radius of hull curvature. The difference is the total deflection.

When to find the hypotenuse 'a',

$$a^2 = b^2 + c^2$$

and b = radius and c = hull length

then $a^2 = 8030.603^2 + 11.67^2$
$a = 8030.612\text{m}$

subtract $8030.612 - 8030.603 = 0.009\text{m}$

Total deflection is therefore 9mm, so deflection at each end is 4.5mm downwards.

The increase in deflection follows that of hull length. The standard wave increases in height as with the length. The period of deflection and oscillations between hog and sag might be found by calculating the speed of each of the three version's standard wave (Table 10.9). These rates of deflection are for regular waves at the limit of suitable conditions.

One end of Dover 1 would bend up and down 22 times per minute over a range of at least 15mm, while Dover 2 would range more than 27mm at almost the same rate, doing far more damage to the stitching and hence its watertightness. Dover 3 would be so flexible that its shape would try noticeably to follow that of its standard wave. More benign weather – that is, shorter waves of less height providing a more general support along the hull – would not stress the seams in the same way except towards the ends. This would still be serious for the Dover 2 and Dover 3 versions.

Conclusions derived from the strength analyses

The recovery of the Dover boat from a site on the buried banks of a minor river, far from any large, quiet, estuarine waters seems to be a paradox, as the size of the remaining timbers indicate a craft of a type that is inappropriate for its final surroundings. Whichever of the three versions is considered, the boat seems either too long for the river itself in the shortest length,

Table 10.8 Calculated deflections at the ends of the hull

version	*hogging end deflection (mm)*	*sagging end deflection (mm)*
Dover 1 3.5t calm water	>1	>1
Dover 1 5.5t calm water	–3	>1
Dover 1 5.5t on standard wave	–5	+10
Dover 2 on standard wave	–10	+17
Dover 3 on standard wave	–25	+52

Table 10.9 Deflection rate on a standard wave

version	*period of standard wave*	*deflections per minute*
Dover 1 5.5t hogging and sagging	2.73 seconds	44
Dover 2 hogging and sagging	3.0 seconds	40
Dover 3 hogging and sagging	3.4 seconds	35

or too long in the longer sizes to withstand even the minor rigours of coastal passage to reach Dover.

The short version however, that is Dover 1, could have undertaken coastal passage-making with certainty, given fair weather up to Force 3 winds.

Problems with assessing suitability for sea conditions arise because of the beam and the estimated depth of the original boat. There being neither archaeological evidence of a comprehensive framing system nor of any extensive sheer-line structure of beams or thwarts, a hull having a beam about twice its depth was developed, having good stability for an unballasted model. Depth is an important dimension, as it makes a boat stiffer vertically, lengthways. Without appropriate stiffness, a hull flexes excessively, which damages fastenings, waterproofing materials in the seams and even the structure of the hull. Increasing a hull's length – as in Dover 2 and 3 – without making the hull deeper, encourages even greater flexibility. In quiet waters there would be little problem with flexibility after the first adjustment of the hull to its buoyancy. On the sea the flexibility would be in continuous evidence with each ripple and wavelet that disturbed the motion of the boat. Leaking would be a constant problem. The analysis of the three versions for strength and stiffness indicates that neither Dover 2 nor Dover 3 would have been suitable for coastal waters. Indeed Dover 3 might not have been a practical boat, even on inland waters.

Strength calculations have to be based on the standard wave suitable for the length of each version. As these waves occur in modest weather conditions, and so would not be infrequent, any version must be able to withstand the demands placed on it by the sea. It is evident that Dover 2 and Dover 3 would fail in this respect, almost entirely due to their flexibility. Although Dover 2 is barely 3m longer than the Dover 1 version, it still fails on this count. The reason is that Dover 1 is already reaching the limits of its strength and stitching, and perhaps even exceeding them slightly. As said earlier, these limits are a result mainly of the shallowness of the hull, even in the smallest version. Arising from this feature, the major obstacle to increasing the length, as in Dover 2 and Dover 3, is the flexibility of the hulls and the noted inability of the stitch fastenings to withstand this. The disposition of the timber in the hull structure, with its greatest mass towards the bottom, is not contributing to stiffness as much as one would expect.

Lengthening the reconstruction, as in the Dover 2 version, with a sloping transom creates a craft unable to cope with even modest sea conditions, mainly because no other dimensions are increased and the limitations of this method of seam stitching have been exceeded. The Dover 3 version, stretched to a length of 18m, must always remain a calm-waters craft for the same reasons but with greater emphasis and, even then, with doubt about its practicability owing to the high inherent stresses.

The recovered archaeological remains give no clue to the construction of a sloping-stern transom or even to further length in continuation of that cross section already recorded. The strength analyses oppose further length for a boat that, from the environmental evidence, must once have been involved in coastal passage-making. To meet such constraints it is necessary to finish the reconstructed hull abruptly, just beyond the side of the pit from which it emerged. A vertical transom fitted and fastened in a way commensurate with evidence in the hull, and with other contemporary archaeological evidence, is proposed as an acceptable method.

It is believed that the original boat, used on the sea, might have been similar in form to that developed for the Dover 1 version, because of the archaeological and analytical evidence available at this time. In this version, the Dover boat would have been capable of coastal voyaging whenever weather conditions were less stressful than the maximum its structure could withstand. The remainder of this report evaluates that version's performance.

Finding the dry weight of the hull

By 'sinking' the hull to its sheer line, a value for the 'wetted surface' was found, leading to the dry weight calculation:

surface area of hull envelope = 38.095m^2

hull envelope average thickness = 0.06m

specific gravity of part-seasoned oak, say: 0.9

volume of hull envelope is
38.095 × 0.06 = 2.285m^3

weight of hull envelope is
2.285 × 0.9 = 2057kg

add, say, 10 per cent for internal structure:
2057kg + 205.7kg = 2262.7kg

Dry weight or empty displacement afloat in fresh water is 2.26 tonnes.

Displacement to the same draft in salt water would be 2.31 tonnes, so a rounded figure of 2.3 tonnes was determined. All further calculations assumed major use of the boat on the sea because of the geographical nature of the site where the remains were found.

Displacement at various loadings

Crew weight in Table 10.10 assumes 60kg per man, as in the Brigg raft calculations (McGrail 1981; Roberts 1992), although this might be considered a little light by modern research.

Up to 6.5 tonnes loading, the freeboard is still sufficient to allow passages in winds of Force 3 (up to 10 knots) when waves up to 0.6m might occur. There is sufficient buoyancy in the scow bow to rise over rather than plunge through regular waves, when met head-on. Beam waves would cause the boat to heel as the weather side rose to accommodate movement of the centre of buoyancy on the slope of the wave. As can be seen in Figure 10.9, there is sufficient reserve stability to recover from the heel as the wave passes under. Reserve righting capability beyond the angle at which the sea would rush in over the lee side has been included because, as any open-boat sailor knows, a quick crew scrambling to windward could force the boat upright and avoid its being completely swamped. A passage along a coast in an offshore wind would allow voyages in stronger wind conditions. Rounding headlands would require slack water to avoid over-fall waves that tend to steepness and increased height irrespective of wind strength. This caution would be necessary whatever the loading.

Table 10.10 Displacement at various loadings

load	*displacement (tonnes)*	*draft (m)*	*freeboard (m)*
empty	2.3	0.14	0.660
5 men (300 kg)	2.6	0.158	0.644
20 men (1200 kg)	3.5	0.200	0.600
20 men and 1 tonne of cargo	4.5	0.246	0.554
20 men and 2 tonnes of cargo	5.5	0.300	0.500
20 men and 3 tonnes of cargo	6.5	0.354	0.446

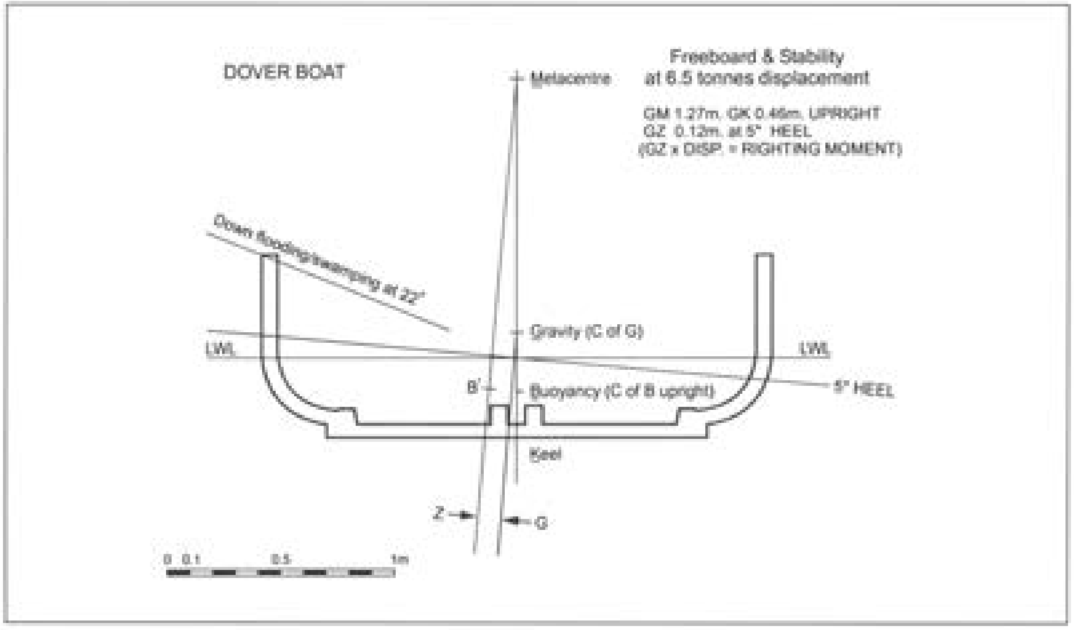
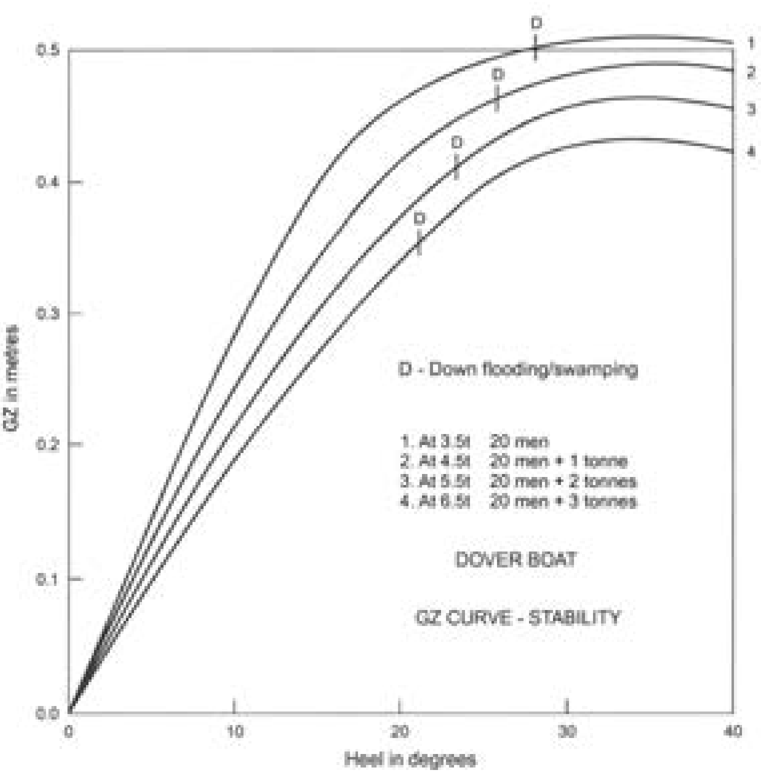


Figure 10.9 Transverse section through the boat showing freeboard and stability.

With a load of twenty persons – that is, one steering, a propulsive power of sixteen and three bailing continuously – the much better freeboard and much more buoyant hull would make short passages possible in Force 4 winds (up to 16 knots) and wave heights up to 1m in experienced hands. One has only to remember the use of similar-sized – though far better built – Cornish gig boats, which faced stronger, fresh breeze conditions in their daily work as pilot boats and hobblers during the last century. The predominant restriction on passage making in the Dover boat in choppy conditions would be the efficiency with which water could be returned to the sea. Worsening conditions would cause greater flexing, leading to a faster ingress of the sea. Bailers would be essential on every voyage.

The reduction in stability likely from the ever-present, free-surface bilge water might be limited by the bottom structure of the boat. The water would be contained within bailing areas because of the longitudinal and transverse barriers to bilge water movement. Surging bilge water, owing to wave action, might become a problem if bailing were not thorough. From Figure 10.9, the righting lever, at 5-degree heel and 6.5 tonnes displacement, is 0.12m, so that the righting moment might be about 780kg, sufficient to overcome the effect of some free-surface bilge water.

Figure 10.10
Graph showing freeboard and stability at various loadings.



Stability at various loaded displacements

Figure 10.10 shows change in the length of the righting lever GZ against angle of heel for four levels of loading. The point marked downflooding indicates the angle of heel attained before the water pours in over the side. It should be noted that some stability is still retained and that a recovery is possible even from this angle – for example, after being heeled unexpectedly in rough water – which is why values above that angle are shown. As freeboard decreases, so does the downflooding angle. The lightest loading allows the quickest increase in GZ value and the greatest heel, but to a point where the increase in righting-lever length has peaked. The heaviest loading has a more than useful range of stability for sea going in settled weather.

Hydrostatic curves

This is a convenient way to assemble the hydrostatic information available on the Dover boat as one graph (Fig 10.11), and enables comparisons to be made with other boats. An explanation of the information displayed is given as follows:

- Displacement is shown against increasing draft.
- GM: the distance between the centre of gravity (of the hull and its cargo) and transverse metacentre (*see* Fig 10.9) is shown to be decreasing as draft increases. GM is a measure of stability.
- KMt: from the underside of the keel to the transverse metacentre. It decreases as the metacentric height is reduced with increasing draft.
- Metacentre is the point in the middle plane of a boat through which the buoyancy force passes when the boat is heeled by a small angle.
- KB: from the underside of the keel to the centre of buoyancy. It increases in relation to the draft.
- MCT: the moment to change the trim per cm at the fore or after end.
- TPC: tonnes per cm immersion.
- LCB: longitudinal centre of buoyancy that, in the Dover boat, is aft of amidships

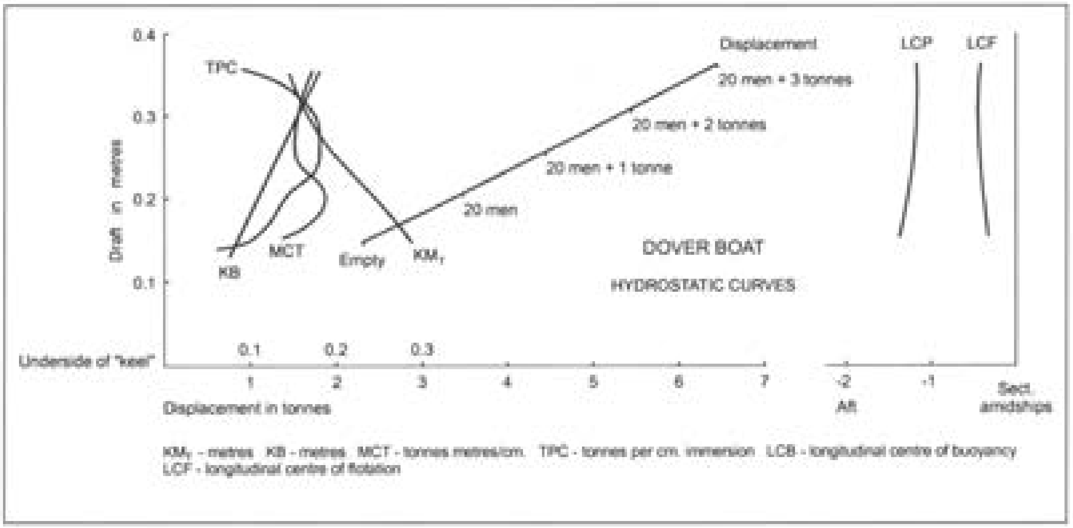


Figure 10.11
Hydrostatic curves.

because of the full after end. This might cause a trim by the bows slightly except for the extra weight of the structure aft and, if needed, stowage of cargo a little aft of centre.

- LCF: longitudinal centre of flotation is the centre of the water-line plane or the plan of the water line. Because of the Dover boat's slightly wedge-shaped plan form its centre will be aft of amidships.

Power, speed and displacement

At various loads and displacements, the possible speeds were plotted against the increasing resistance of the hull. From these were calculated the power input required from a reduced crew of five, then for sixteen paddlers and the individual output per man (Table 10.11).

Figure 10.12 shows how resistance increases rapidly with speed, in this case at a displacement of 3.5 tonnes with twenty men. At 5 knots, the individual effective power output would be about 65 watts. Similar power output is sufficient at the other increased loads to maintain that same speed. The graph shows the resistance rapidly increasing above about 5.5 knots until it is very steep at the theoretical maximum speed. This could not be attained

Table 10.11 Propulsive power for various speeds and loadings

knots	*m/sec*	*resistance (kg)*	*four paddlers (watts)*	*watts/paddler*	*Dover boat 1*
3	1.56	2.0	30	7.5	disp. 2.6 tonnes
4	2.10	13.0	268	67.0*	5 men aboard
5	2.58	35.0	886	222.0	
6	3.10	94.0	2 859	715.0	
3	1.56	9.0	138	8.6	disp. 3.5 tonnes
4	2.10	14.0	288	18.0	20 men aboard
5	2.58	41.0	1 038	64.8*	
6	3.10	105.0	3 193	200.0	
3	1.56	17.0	260	16.3	disp. 4.5 tonnes
4	2.10	21.0	433	27.0	20 men aboard
5	2.58	41.3	1 047	65.4	+ 1 tonne cargo
6	3.10	124.0	3 770	236.0	
3	1.56	18.0	275	17.0	disp. 5.6 tonnes
4	2.10	22.0	453	28.0	20 men aboard
5	2.58	43.0	1088	68.0*	+ 2 tonnes cargo
6	3.10	130.0	3953	247.0	

* 60–70 watts effective output is a comfortable rate for a paddler.

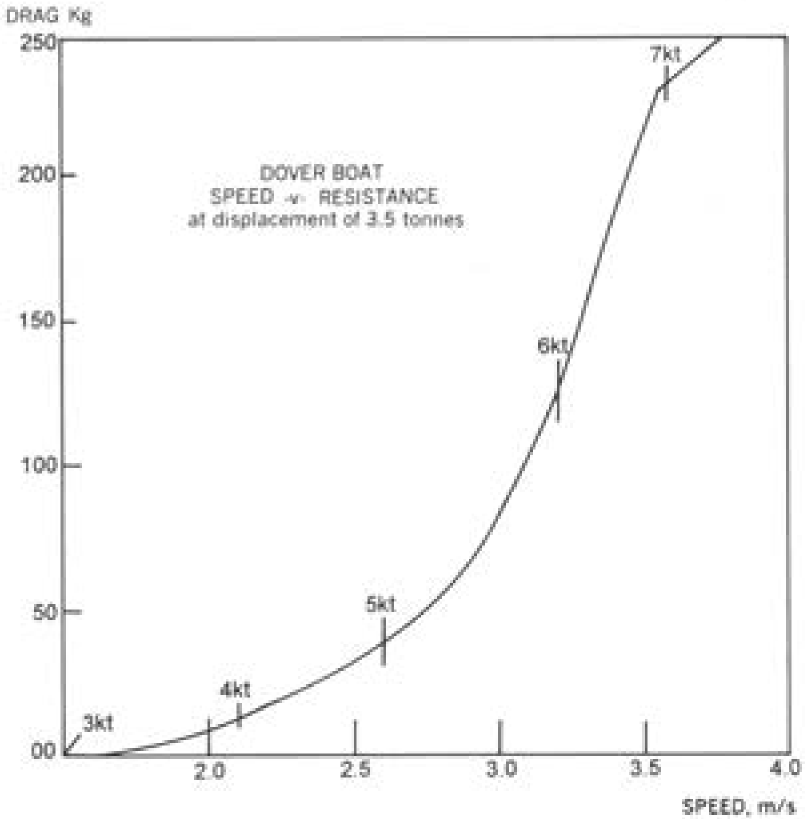


Figure 10.12
Graph showing how resistance increases rapidly with speed at various loads.

by a paddling crew as an impossible individual effective power output of over 500 watts would be required. At about 65 watts, effective power output the paddler would hardly be exerting himself propelling the boat at 5 knots, but then resistance increases so quickly that to attain 5.5 knots he would be working at a rate that could not be maintained for any useful period (Coates 1990).

Rising to about five knots, the major source of resistance is owing to the rough surface of the hull – the skin friction. That resistance is limited by the area of the hull available and soon reaches its peak. While it is slowly increasing, the resistance owing to the shape of the hull is developing and overtaking the amount from skin friction very rapidly indeed. At these speeds, it quickly multiplies beyond the power available to overcome its resistance. This form resistance is a block on useful speed above 5 knots in the Dover boat, but that speed is so comfortably achieved and maintained that it could be relied upon for most voyaging in good conditions.

A column was tabulated for performance with only four men to propel the boat. The speed that they could comfortably maintain is 4 knots. It suggests that for a crew of fewer than the 16 paddlers postulated above, an effective speed of about 4 knots could be expected with similar or larger loads. Such speeds are more than fast enough to make progress against Force 3 winds. Foul or contrary tides could be worked against for short periods if necessary.

Comparison by coefficients

Table 10.12 lists boats recovered in northern Europe dated to the 1st and 2nd millennia BC. Information on the meaning of the

Table 10.12 Comparison of coefficients that indicate levels of performance[1]

boat	*lwl (m)*	*bwl (m)*	*draft metres*	*displacement volume(m³)*	*volume coefficient*[2]	*block coefficient*[3]	*prismatic coefficient*[4]	*slenderness coefficient*[5]	*calibrated date (at 95% confidence)*	*references*
Dover 1	10.74	2.23	0.3	5.4	4.3×10^{-3}	0.74	0.83	4.8	1575–1520 Cal BC	
Ferriby 1	14.0	2.5	0.4	10.5	3.8×10^{-3}	0.75	0.94	5.6	1880–1680 Cal BC	Wright *et al* 2001
Brigg Craft	12.9	1.7	0.3	2.74	1.3×10^{-3}	0.37	0.53	7.0	820–780 Cal BC	Roberts 1992
Brigg Raft	12.3	2.3	0.46	12.5	6.7×10^{-3}	0.96	0.97	5.3	820–780 Cal BC	Switsur and Wright 1989
Hjortspring	14.7	1.5	0.31	2.64	0.83×10^{-3}	0.36	0.69	9.8	350–300 Cal BC	
Hasholme Logboat	12.0	1.4	0.75	5.8	5.5×10^{-3}	0.78	0.88	8.6	322–277 BC[6]	McGrail 1987

(1) based on table compiled by Sean McGrail (1987)
(2) Boats with values less than 2×10^{-3} are very easily driven and usually fast.
(3) Boats with values less than 0.85 may have a good speed potential.
(4) Boats with values less than 0.6 usually have a fine form.
(5) High values suggest good speed potential.
(6) dendrochronological date

coefficients and the method of their calculation is included below the table. The Dover boat sits within the range of coefficients derived for similarly shaped Bronze Age boats – that is, the Ferriby 1 and the Brigg raft (McGrail 1987) – where it is clear that increased beam has been recognised as an important factor in the improving of stability and load-carrying capability. These are not fast boats, as they are not suitable in form for hard driving by strenuous paddling.

The Brigg craft (Roberts 1992) and the Hjortspring boat are of a lightweight and slender form responsive to good paddling. However, their block and volume coefficients indicate that, besides being fast, they are not large-load carriers. This is the difference between a fine-lined naval destroyer and a bulky cargo ship of the same length. The coefficients of the Hasholme log boat are interesting in that they suggest it can do everything, yet it probably fails to excel in any one area of performance. The coefficients indicate it should be able to carry good loads but tries to do so with a slender-form coefficient, the result of the high beam-to-length ratio and the beam being almost equal to hull depth. Consequently, it is limited to small dense loads in order to control the position of its centre of gravity. Its ability to reach fast speeds is severely limited by its form, as shown by the first three columns of coefficients. It has all the log boat's limited range of performance that encouraged the development of greater beam for its advantages.

The Dover boat's coefficients indicate it was a very good load carrier but not a boat capable of fast speeds, yet still with a useful operating speed.

Methods of propulsion and steering

No evidence exists to indicate how the boat was propelled. By consideration of certain hull dimensions, and comparing these with the practical limits of wind power and the ergonomic requirements of the human body, it is possible to suggest likely propulsive methods.

Sail

Slight evidence exists in northern Europe for the use of sail during the Bronze Age. It is found on bronze razors that have been engraved with boats apparently setting a sail, and on rock carvings (Johnstone 1988). Having a length-to-beam ratio of 5.2:1 the Dover boat is not unduly narrow for a sailing boat. Sufficient stability and freeboard make it feasible. However, draft is shallow for sailing with the wind on the beam without a means of increasing lateral resistance. At its simplest, this would require a somewhat sophisticated side-rudder steering method to be successful, of which there is no evidence from the site, and whose earliest application is unknown in northern Europe (Roberts 1984).

With wind from astern and perhaps over the quarters, say up to 45 degrees either side, the Dover boat would respond to the setting of sail even if arrangements were not of a permanent form. For safety, and to help downwind steering, the mast would be in the first third of the boat and no permanent mast step would be necessary in this case. In its simplest rectangular form it would need a yard, but could be loose-footed. It could be hoisted with the raising of the mast without the need for a halyard. No braces would be fitted without the need to brace up for windward sailing (Roberts 1984). A sail no wider than twice the hull's beam would be one dimensional limit, to prevent excessive bellying of the loose foot. If the height were the same as the width, then an area of about 20m² would suit its occasional use and the need to be able to stow it within the boat. The fore-and-aft stability of the Dover boat would be high, but the need to be able to withstand an unexpected side wind, as in a sudden down draught, while following a coastal route, requires that the sail area be calculated for that risk.

Righting moments equal heeling moments, so, at a steady angle of heel, the sail area for a particular heel angle, displacement and wind speed can be calculated using the following formula.

$$GZ \times \Delta = H \times P \times A \times \cos^2\theta$$

where:
GZ = righting lever in metres
Δ = displacement in tonnes
H = centre of effort of sail in metres
A = sail area in square metres
θ = angle of heel
P = sail pressure in kg/m²

In a wind of 10mph, at a displacement of 3.5 tonnes, with a GZ of 0.286m and the sail's centre of effort at a height of, say, 4m, the pressure that could cause a 10-degree heel when setting a sail of $20m^2$ is:

$$3500kg \times 0.286m = 4m \times Pkg/m^2 \times 20m^2 \times Cos^2 10^o$$
$$\text{Pressure } P = 12.89kg/m^2$$

which is equivalent to 26mph wind speed, or Force 5.

A gust of Force 5 is not unusual, even when Force 3 is the general wind force, especially off high coasts. If a sail were ever set, then, for downwind sailing, an area 4m high by 5m wide would be about the maximum that would be carried sensibly.

In a wind of 10mph, with the sail producing its drive by being square on to the wind, then the favourable drag would be $20 \times 1.42kg = 28.4kg$ from the sail. Add to that the useful wind drag from the mast, crew and hull topsides, and the total could be 30kg force driving the boat downwind. Figure 10.12 shows that this is nearly the amount needed to overcome the hull drag at between 4.5 and 5 knots. Steering would be possible with a sweep or steering oar over the stern on this point of sailing.

Paddling

Sufficient evidence exists in northern Europe of the widespread use of paddles during the Bronze Age (McGrail 1987). Calculations for the Dover boat have assumed twenty men being aboard – that is, sixteen paddlers, based on the available length of sheer line with an allowance of 1m room per paddler, the remaining four being the skipper, bailers and a spare hand. As paddlers can manage without specialised seats, little archaeological evidence for such seating in northern Europe is available, apart from those of the Hjortspring boat and a few paddles found in association with certain ancient boat discoveries. It has been proposed that the Brigg craft had seating for paddlers in one of its reconstructions (Roberts 1992).

The structural drawings of the reconstructed Dover boat propose no paddler seating apart from the two sheer-level beams or thwarts. Freeboard, as reconstructed, is suitable for paddlers to wield their paddles from a standing position or to be part-seated on the edge of the sheer strake.

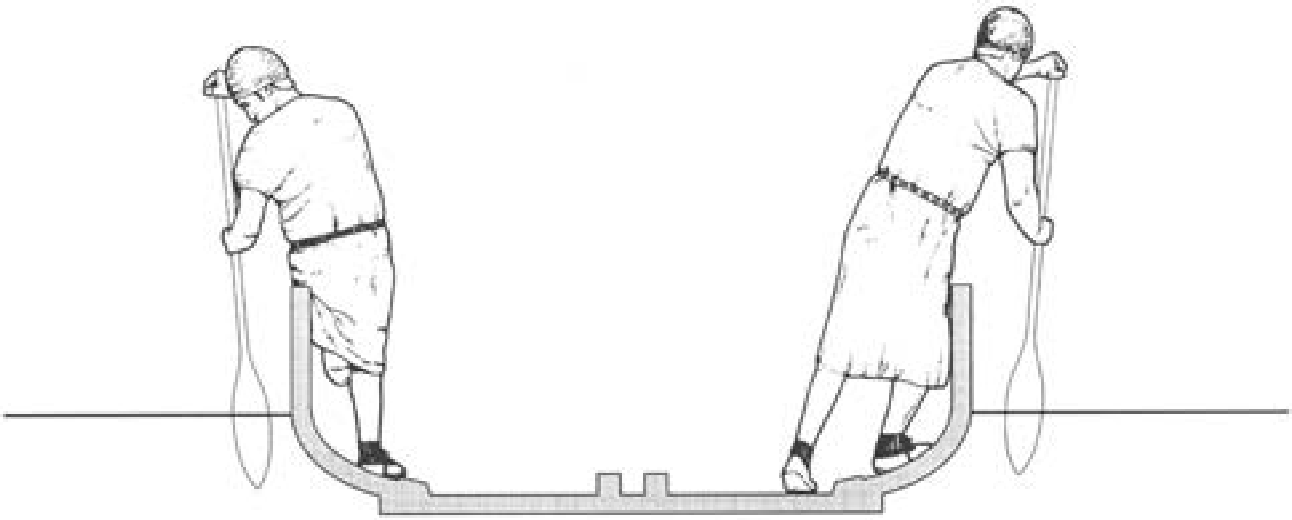
Paddlers drive a boat directly through their bodies so need to have a firm base against which to work. The drawings of the paddlers part-seated, show this to be possible without specialised seating (Fig 10.13), although probably with some padding. It is a style most often seen these days aboard inflatable 'white water' rafts. In both cases, a means of hooking one foot into or against a fixture and being able to brace the other would be desirable, especially if the boat were responding to waves. Having sixteen paddlers reduces the personal power output required of each man to an easily maintained level.

Rowing

There is no firm evidence for the use of oars during the Bronze Age in northern Europe until the 1st millennium BC. A boat engraved on a razor dated to the 9th century BC from Viemose, Zealand, shows evidence of rowlocks evenly spaced along the sheerline (Hale 1980, 122). Evidence from the upper strakes of Bronze Age boats has not been recovered and nor have their oars which, in any case, would float away or be passed on to other boats. Two later models have survived depicting oars. The gold Broighter Boat, *c* 100 Cal BC (*c* 2100 BP), discovered in Ireland (McGrail 1987), shows six oars, each side-pivoted in grommets threaded through holes in the top edge of the sheer strake. Rowers enjoy the luxury of thwarts. The model from Durrnberg, *c* 5th century Cal BC (McGrail 1987), again in gold, shows a hull similar in tapering plan-form to that of the Dover boat. In its starboard topside are cut two rowlocks to accept the two wide-bladed oars that have survived. The other side is damaged, so limiting the evidence.

In all the countries bordering the Mediterranean Sea there is evidence of the widespread use of oars from at least 2500 BC. Transmission of rowing technology northwards via the major rivers is not inconceivable, as the efficiency of that method of propulsion is its own best advertisement. The complexity of the Dover boat suggests sufficient home-grown inventiveness in Britain for rowing to be developed quite independently.

It would have been possible for the Dover boat to be propelled by oars, their pivots being withy grommets twined through holes cut near the upper edge of the sheer strake (Fig 10.13). The hull width would allow pairs of rowers, side-by-side, pulling oars 3m long. Freeboard allows the oars to clear the water well, on the recovery part of the stroke, which would be essential among waves. Rowing is quite natural from



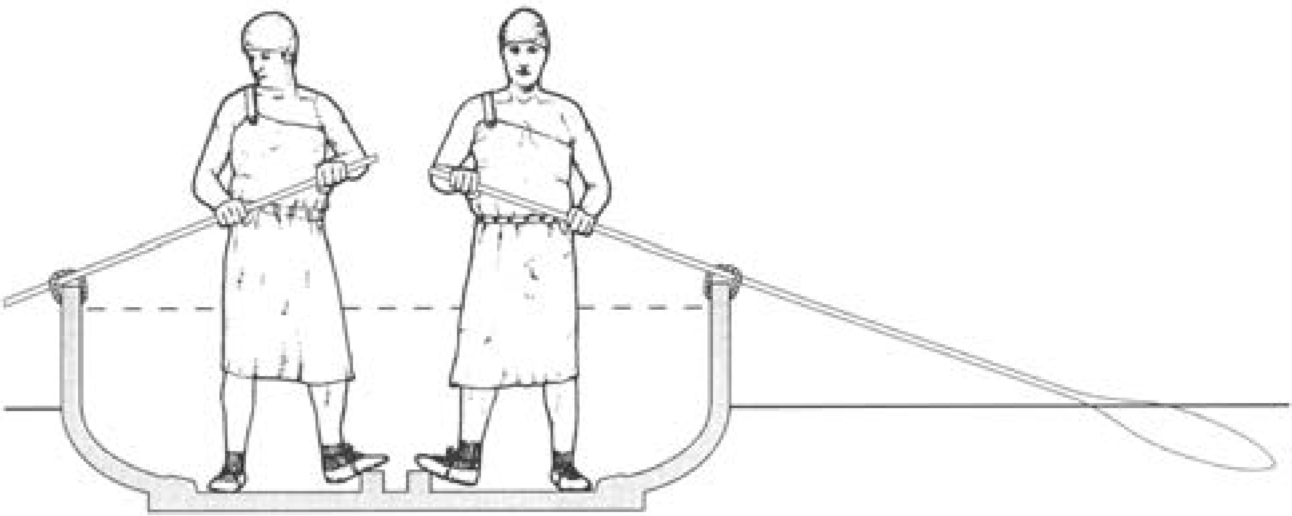


Figure 10.13
'By which she may be propelled'.

a standing, as well as from a sitting position, although the latter provides stability for the oarsman in rough water. The power calculations for four paddlers showed that four knots were attainable without exertion. It would be easier to move the boat with oars for the same power output. Oars have a longer power sweep and better gearing, owing to the use of a pivot on the hull. If only four men were pulling the oars then the projected beams would double as thwarts. Steering, for both paddlers and rowers, would be most effective by a long sweep (oar), angled over the stern transom located in a sculling notch or held by a grommet, as in the Broighter boat.

On balance, it is likely that, on the sea, the Dover boat was paddled, as there is no direct evidence to show that it was propelled by oar. In the shallow waters of a river it is likely that some form of quanting or poling was employed since few crew are required for that situation.

Some conclusions

The builders of the Dover boat were clearly familiar with complicated technical problem solving, although the boat was build entirely of organic materials. The design of the boat required a three-dimensional visualisation of the intended shape as a linked structure and the support of a group in the building and subsequent managing. The method of its joining – both stitching and wedging – shows the use of long-understood techniques. The proportions of the boat show an experience and understanding of the demands to be made on the hull when going to sea, those of strength, stability and speed. It is clear that the builders belonged to a society that relied on a technological culture to succeed.

There is little doubt about the ability to maintain good passage times at sea in the right conditions as the speed and power calculations show for this minimal reconstruction of the boat. There is a good range of stability that would meet the demands of seagoing. The cargo capacity indicates that the boat could have been involved in trade, especially with cargoes of a higher density, which would have helped with stability.

The calculated strength of the minimal reconstruction shows that it is capable of withstanding reasonable sea conditions produced by Force 3 winds, which would give a useful weather envelope for passage-making, coastwise.

On a good day, and with six hours of favourable tide, a distance of more than thirty nautical miles would have been a reasonable aim under continuous paddling, say from the River Dour to the River Rother or the River Stour.

Crossing the English Channel – although it is a shorter distance – would have presented a far greater challenge, owing to the risky commitment of an open-water voyage in a boat having, by modern expectations, such seriously limiting structural features. While coasting, it is often possible to suspend a voyage when weather or sea conditions become threatening, by turning towards the shore and finding a temporary landing place. Every mile that a vessel such as the Dover boat heads offshore reduces the chances of reaching a safe haven should weather conditions worsen. One should not sneer at the ancient crew's foolhardiness in going offshore, but pause in awe at the self-confidence in their competence that turned such journeys into successful ventures. Centuries and more of boatbuilding techniques preceding the Dover boat would have seen a parallel growth in that prime set of essential skills called seamanship, without which no venture on the sea will survive.

If cross-Channel voyages were undertaken periodically – say during the time of neap tides, when turbulence from them would be known to be least – then settled weather conditions would need to be forecast for a few days at a time. This would cause the concept of an acceptable risk to be developed, based on the likelihood that, while most voyages would be successful, some catastrophes could happen if untoward weather or hull failure should strike. Such an optimistic attitude must be as old as seafaring itself. It might have justified the extension of tenuous links across the English Channel by early Bronze Age seafarers and merchants in such a boat as that found at Dover, probably in continuation of those cross-Channel voyages undertaken by their Neolithic ancestors.

The Dover boat might be typical of those boats that existed on the coasts of the English Channel. In good weather, coasting and cross-Channel voyages could be undertaken to maintain contact with others. The boat's structure suggests it is the product of a society confident in its technology and organised in its planning.

11
Other artefacts from the site

by Paul Bown, Charlie Bristow, Jackie Burnett, Peter Clark, Alex Gibson, Nerina de Silva, David Williams, Tania Wilson and Jeremy Young

Introduction
by Peter Clark

The Dover boat did not contain any cargo, nor was there any sign of the portable objects that might have formed parts of the boat's original fittings; no paddles, bailing equipment, dunnage or ropes. The boat was not the victim of a dramatic accident on the high seas (a fate suggested for the vessel carrying the Langdon Bay hoard), rather, it was brought to a quite backwater, stripped of anything useful and even partially dismantled before being left to its slow burial under the silts of the River Dour.

However, inside the boat, and contained in the sediments surrounding it, were many objects of great antiquity; flint tools and debitage, sherds of pottery, a fragment of shale, a butchered animal bone, rough chalk blocks, reeds and other vegetation cut by a blade of some kind, many fragments of burnt flint, and a single, unused yew withy. Some of these objects might be associated with the boat directly, but most appear to represent refuse from a nearby settlement.

This refuse lay all around the boat, but seemed to concentrate underneath and to the west of the boat itself (*see* Table 11.7); it might be that this material was being dumped from the west, from the direction of the putative settlement on the western side of the valley (Chapter 15). The circumstances of the excavation in Cofferdam II allowed for more detailed recording of individual find spots (*see* Fig 3.11), and the position of the boat hull in Cofferdam I – hard against one corner – meant that less of the surrounding deposits were exposed for finds recovery. Nevertheless, no large chalk blocks were seen in Cofferdam I; these seem to concentrate around the southern end of the boat, and have been interpreted as 'stepping stones', perhaps placed to facilitate the partial dismantlement of the boat and, particularly, the retrieval of the end board. The boat seems to have come to rest on a slope, with its southern end slightly lower (*see* Fig 5.5); it might be that the ground was somewhat wetter here, or the water a little deeper.

The artefacts recovered from the excavation are described in detail below (the butchered animal bone is discussed in Chapter 12). Most items appear to derive from ordinary domestic rubbish, broadly contemporaneous with the boat itself. A few pieces, however, might have a more direct connection. A single, unworked fragment of shale, lying directly on the inboard surface of the boat, was found to come from Kimmeridge Bay, far to the west. Was this a fragment of the last cargo the boat carried? Study of the flint assemblage suggested that some knapping occurred *in situ*; perhaps the metal tools used in the dismantlement of the boat were complemented by simple flint tools made on the spot (possibly for cutting through the yew stitches?). The single, unused yew withy is also intriguing. Presumably this represents the raw material for a boat stitch, although the environmental evidence does not suggest the presence of either yew or large oak trees in the Dour valley at this time (Chapter 12). It would appear that the Dover boat was made elsewhere, so perhaps this withy was intended for repair or refurbishment. There seems little point in repairing a boat that was to be broken up and abandoned; were other vessels being brought upstream, closer to the settlement, so that splits could be patched, or damaged stitches replaced? Alternatively, might the objects associated with the boat be related to ceremonial activities carried out at the time of its abandonment (Chapter 16)?

We can do no more than speculate; very little of the surroundings of the boat was revealed at the bottom of the narrow shaft in which it was found. These finds offer a tantalising glimpse of a larger story, the evidence for which might still lie buried deep beneath the streets of Dover.

The pottery

by Alex Gibson, Jackie Burnett, David Williams and Jeremy Young

Three sherds of pottery were recovered from deposits associated with the boat. One (Sherd 1; Gibson 1994) was recovered during the excavation, and two others (Sherds 2 and 3; Gibson 2001) from soil samples processed several years later. All are small and worn, and are roughly contemporaneous with the boat, based on the radiocarbon analysis of the boat timbers (Chapter 13, p 254).

Sherd 1

This sherd (Fig 11.1) was recovered from the silts immediately adjacent to the boat, just 0.3m east of the eastern ile plank. The ceramic comprises a rim sherd in a hard, well-fired fabric with smooth surfaces and a 'soapy' texture. The outer surface is grey-brown, the inner grey, and the core grey to black. Both surfaces are smooth, although the outer is better finished than the inner. All the breaks are smooth and worn, with no fresh fractures visible. The fabric contains abundant grog inclusions, some of which break but lie flush with the surfaces. Traces of organic inclusions (probably grass) are also visible in some of the breaks, the outer surface and the internal rim bevel.

The rim is slightly everted, with a flattened top. It has a straight internal bevel 18mm wide. Possible traces of a join void in the fabric suggest that this internal bevel might have been applied. The outer profile below the rim is slightly concave, suggesting that the vessel comes either from a collared urn with concave collar or, more likely, from a biconical urn with a concave neck. The rim diameter is difficult to determine from such a small sherd, but is unlikely to have been in excess of 300mm.

The decoration on the outer surface comprises part of a chevron formed by two converging lines of overlapping fingernail (or pseudo-cord) impressions. The left-hand arm of the chevron is almost vertical and is well defined, while the right-hand arm is less clear and is at an angle of *c* 45 degrees. The lines cross slightly at the apex of the chevron, but both stop before the rim. A broken horizontal line of pseudo-cord decorates the top of the internal bevel and a second, similar line is present at the left-hand edge of the sherd. A possible diagonal line of faint pseudo-cord is visible on the extreme right of the surviving bevel. Still in this area, two diagonal fingernail nicks, possibly accidental, are present, 11mm apart, at the very top of the bevel. The top of the rim and the inner surface below the bevel are both undecorated, although the former is uneven, with finger-'straightening' depressions detectable.

Petrology

An examination of a fresh fracture of the sherd was made possible when a small slither was carefully detached as a sample for thin section analysis. Using a binocular microscope (× 20), frequent irregular-sized soft argillaceous inclusions could clearly be seen in the paste, mostly dark grey in colour, but with some lighter coloured material as well.

An examination of a thin section of the sherd under the petrological microscope confirms that these argillaceous inclusions can be identified as grog and that they occur in some numbers in what is a fairly calcareous clay matrix. Small, often rounded, pieces of limestone and tests of foraminifera (micro-fossils) are very common. Also present in the fabric are frequent well-sorted grains of quartz, normally below 0.20mm in size – probably occurring naturally in the clay rather than deliberately added – together with small strands of mica. Some thin, curved pieces of shell were noted, together with a little black iron oxide.

In a few examples, fragments of grog can be seen to contain other pieces of grog within them (Fig 11.2), showing that the crushed pottery that was used as grog-temper for the pot was itself grog-tempered. This demonstrates an early form of the

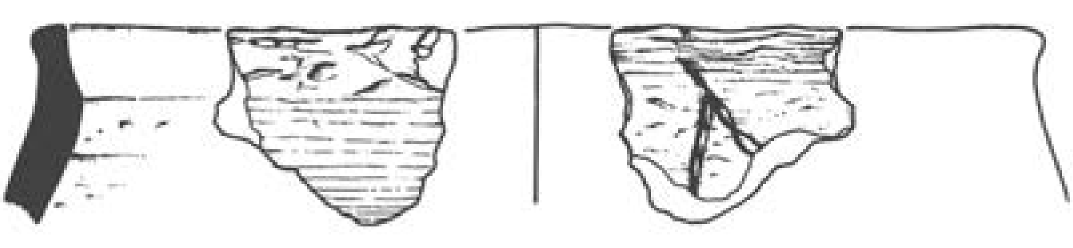


Figure 11.1 Pottery from the Dover boat excavations; sherd 1, a fragment of collared or biconical urn.

recycling of raw materials and the continuity of a pottery-making tradition in the making of the vessel (in this case involving two 'generations' of vessels within the clay of the sherd).

The texture and light brown colour of some pieces of grog appear identical to the clay matrix of the actual rim sherd itself, suggesting that they came originally from a vessel, or vessels, which used a similar clay to the one in which they are now incorporated. In contrast, other pieces of grog are dark brown in colour, contain no limestone, and have a slightly larger grain-size of quartz than occurs in the clay matrix of the Dover boat sherd, indicating that a different clay source was used.

The varied texture of the grog, and, to a lesser extent, the colour differences they exhibit, suggest that these fragments were acquired and crushed from a group of dissimilar sherds, some of which appear to have been made from a different clay to that used for the Dover boat sherd. This might mean that some of the pottery used as grog was not necessarily made at the same locality. Grog tempering of pottery was commonly practised during the Bronze Age.

Unfortunately, this type of fabric can prove difficult to source, as many grog-tempered vessels tend to lack inclusions of a more varied nature, such as distinctive rocks and minerals that have a fairly restricted outcrop. In the case of the Dover boat sherd, the high microfossil content of the clay matrix does make this a somewhat unusual fabric. However, as little thin-section work has been done to date on Bronze Age pottery from Kent, it is not known if similar fabrics occur locally.

Coccolith analysis

A study of the microfossils present in the clay was undertaken at the Natural History Museum to see if these could help identify the provenance of the sherd. Coccoliths are minute calcareous plates formed by unicellular planktonic algae. They are best known as the principal constituents of chalk, but have a wide geological distribution, occurring abundantly in marine sediments of Jurassic to Holocene age. Being extremely small (2–10 microns), they can be separated from very small rock samples (down to about $1mm^3$), so they are very widely used in the oil industry and in geological research for dating sediments (eg Young *et al* 1994). This information can also be of value for archaeological purposes (eg von Salis *et al* 1995). Typically, the information that can be provided is the geological age of the rock used in producing an artefact. This age might identify a particular geological formation, although, of course, individual formations might have wide geographic outcrops.

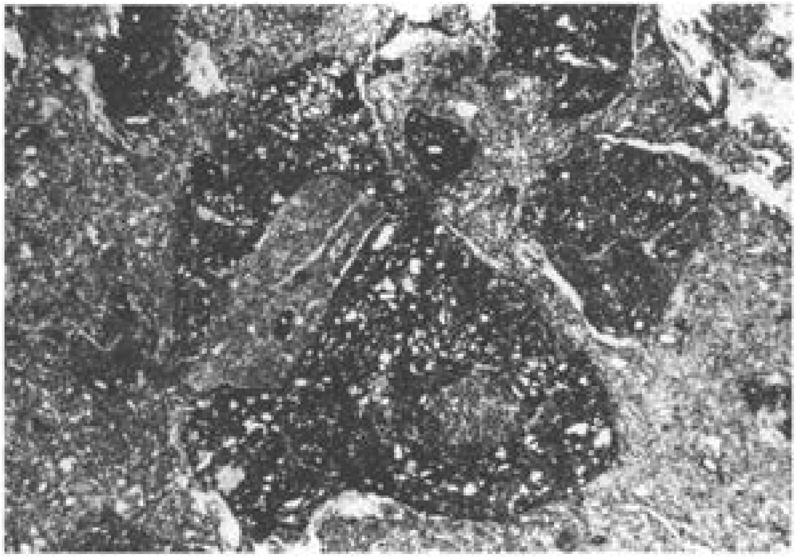


Figure 11.2
Photomicrograph of the Dover boat sherd; the large angular fragment of grog in the middle of the photomicrograph also contains smaller, lighter-coloured pieces of grog. This shows that the crushed pottery that was used as a grog-temper for the Dover boat pot was itself grog-tempered, demonstrating an early form of the recycling of raw materials and the continuity of pottery-making tradition in the manufacture of the vessel – in this case involving two 'generations' of vessels within the clay of the Dover boat sherd. The thin void around the large piece of grog is the result of the clay matrix shrinking away from the grog slightly when the vessel was drying out (Crossed Polars X40. Photo by N Bradford).

Methodology

Millimetre-sized fragments of the potsherd were picked off using a needle. Smear slides were prepared by crushing these fragments in a drop of distilled water on a microscope slide. These slides were then examined by light microscopy using cross-polarised light. Lord (1982) and Perch-Nielsen (1985) describe techniques in detail and provide documentation for the taxa mentioned including their stratigraphic ranges.

Results

Species identified included: *Biscutum ellipticum*, *Cribrosphaerella ehrenbergii*, *Cylindralithus nudus*, *Eprolithus floralis*, *Prediscosphaera cretacea*, *Retecapsa crenulata*, *Rhagodiscus achylostaurion*, *R. angustus*, *R. asper*, *Tranolithus orionatus*, *Watznaueria barnesae*, *Zeugrhabdotus diplogrammus*, *Z. erectus* and *Z. noeliae*. The co-occurrence of *Prediscosphaera cretacea*, *Tranolithus orionatus* and *Zeugrhabdotus diplogrammus* indicates an Albian age (nannofossil zone CC8), between 112 and 99 million years ago. This is supported by the absence of later marker species such as *Eiffelithus turriseifellii* and by the general composition of the assemblage, including, for instance, the common presence of *Rhagodiscus* spp. The Albian age, and the presence of abundant nannofossils, indicates the Gault clay formation. This formation underlies the chalk and forms the lowland belt around the base of the Downs escarpment, with coastal outcrops at Folkestone (Copt Point) and Eastbourne. A continuation of the Gault occurs in the Boulonnais of Northern France, with coastal outcrop at Wissant (between Boulogne and Calais). There are virtually no outcrops of Albian sediments around the North Sea.

The most likely source of the clay used in this potsherd is the Gault clay. Suitable Gault clays occur on both sides of the Channel, at Folkestone and on the opposite coast between Calais and Boulogne. The nearest outcrops are at Folkestone, however, so it seems likely that the pot was made locally, although a French origin cannot be ruled out. It seems unlikely that it was necessarily associated with the boat itself.

Sherd 2

This sherd (DS/T 92; 200; 5513/B; not illustrated), little more than 10mm square and 5mm thick, has a soft, shell-filled fabric. The surfaces are light grey-brown and the core is black. The shell is finely crushed and abundant, and the inclusions break both surfaces. The outer surface is quite smooth. The sherd is undecorated.

Sherd 3

This is a single rim sherd (DS/T 92, 204; not illustrated), in a dark grey fabric with finely crushed shell inclusions. The fabric measures 5mm thick and coil breaks can be seen in the section. The curvature of the rim suggests an original diameter of *c* 130mm, and the angle suggests that the rim led to a bulbous body. The sherd is undecorated, although horizontal wipe marks can be seen on the outer surface.

Discussion

Sherd 1 is part of a vessel that is clearly an early Bronze Age type, but it is difficult to be sure whether it comes from a collared urn or from an urn in the very varied biconical series. While grog inclusions are more common in the collared-urn tradition, they are also found within biconical urns and cannot be used, in themselves, to determine vessel class. If the vessel were a collared urn, then Sherd 1 might appear to have a markedly concave collar and would probably have come from an urn in Longworth's secondary series (Longworth 1984). The collar also appears to have been deep, the curvature suggesting that it might have had an angular profile. This would place the vessel late in Burgess's scheme (Burgess 1986). In this instance, at least (and with so little of the original surviving), both schemes agree, and a date of a century or so either side of 1500 Cal BC (*c* 3200 BP) might not be unexpected. The rim form, but not the decoration, is somewhat similar to the collared urn from Lord of the Manor, Site 3 (Perkins 1980), and to vessels in the grog-filled, collared-urn assemblage recovered from Castle Hill, Folkestone.

The rim form of Sherd 1 does not, however, bring to mind immediate parallels among Kentish collared urns, nor is the pseudo-cord decoration typical of the collared-urn series. Rather, the vessel is probably to be attributed to the biconical urns of Britain and Western Europe, where the rim form and the simple decorative motif are well paralleled (ApSimon 1972; Tomalin 1984; Glasbergen 1954; ten-Anscher 1990; Blanchet 1984; Blanchet and Lambot 1985).

The British parallels are clearly among the southern biconical urn series, the rim form and angle being almost exactly paralleled at Roke Down, Dorset (Calkin 1964, 36), and Lambourne, Berkshire (Smith 1921), to name but two examples. Tomalin (1984, 315–16) lists only ten biconical urns from Kent. Five from a barrow at Iffin's Wood, Nackington, survive only as undetailed engravings (Akerman 1844), but appear to have similar rim-forms to Sherd 1 and fingertip-impressed shoulder cordons similar to a more recent find from Ramsgate (Hawkes 1942). Two from Ringwould are handled variants, with horseshoe handles below the shoulder cordon (Woodruff 1874); both are decorated with twisted-cord chevrons on the upper portion, similar in motif to those on Sherd 1. Another handled biconical from Wouldham has horseshoe handles in the otherwise undecorated neck above the shoulder (Harrison 1982), resembling an earlier find from Capel-le-Ferne (Ashbee and Dunning 1960).

Radiocarbon dates for biconical urns are few, but they are generally accepted to be related to collared urns, cordoned urns and food vessel urns (Tomalin 1984). The estimated date for the construction of the boat (1575–1520 Cal BC at 95-per-cent confidence) might give a *terminus ante quem* for the sherds.

The sea-going capability of the Dover boat (Chapter 10), the Picardy pin associations with the Ramsgate biconical urn (Hawkes 1942) and the European occurrences of biconical urns raise the question of the European relationships of these vessels. On the Continent, Glasbergen has pointed out the similarity of some Dutch urn pottery – Hilversum and Drakenstein urns – to that from England (Glasbergen 1954). In the days of invasion hypotheses, he was the first to argue a British origin for the Dutch urns rather than the more usual Europe-to-Britain diffusion. Glasbergen refined his typology in 1969, in which article he stated that his early style, Hilversum urns are characterised by – among other things – their bevelled rims, cord or pseudo-cord ornament and gritty paste, as well as their markedly biconical shape. Glasbergen's scheme has been tested against a radiocarbon chronology by ten-Anscher (1990), who has demonstrated the contemporaneity of Hilversum and Drakenstein pottery, yet, nevertheless, the cord-ornamented material tends towards his HVS-1 phase, which he places around *c* 1800 Cal BC (*c* 3500 BP). This early date, however, relies on only two radiocarbon determinations from the settlement at Vogelenzang and tumulus 1B at Toterfout. A date obtained earlier for the Vogelenzang settlement of 1520–1210 Cal BC (GrN-2997; 3140 ± 70 BP) was dismissed as unreliable, although this author believes it to be acceptable. It would be difficult to place Sherd 1 quite as early as 1800 Cal BC, and it is worth noting that the Dutch dates are charcoal-derived with, perhaps, inherent difficulties pertaining (Kinnes *et al* 1991). Nevertheless, in both rim form and decoration, Sherd 1 finds close parallel with some of the pottery from the settlement of Vogelenzang (Groenman-van Waateringe 1966; ten-Anscher 1990).

Sherd 1 also finds close parallels among the 'urnes bitronconiques' from Le Fond Pernant, Compiègne (Blanchet and Lambot 1985, 106–10), where one urn in particular has been decorated with triangles of coarse, twisted-cord technique, similar to the Dover motif. Pseudo-cord can be recognised on a biconical from Remilly-Allicourt, Ardenne, (Blanchet 1984, fig 47) and fingertip-decorated cordons and handles resembling Ardleigh urns (Erith and Longworth 1960) or the biconicals from Nackington (Akerman 1844) are found in a domestic context at Cuiry-les-Chaudardes, Aisne (Blanchet 1984, 184–5).

Whether or not Sherd 1 carried horseshoe handles, like many of its insular and continental counterparts, is impossible to determine. Study of the coccoliths could not establish unequivocally if the sherd were a British export or a European import. Were its contents special, or was it the pot itself that might have been traded? Did it form part of a previous cargo, or was it brought to the site by other means?

The lack of decoration on Sherds 2 and 3 makes identification difficult. The shell-filled fabric and coloration of Sherd 2 suggests Beaker, and this would fit the recorded stratigraphy. Sherd 3 is more difficult to date and identify but, given its sealed context, it can be no later than the Middle Bronze Age. While the fabric is not altogether typical, the short, everted rim, leading to a bulbous body, might also suggest a Beaker, most likely of Clarke's (1970) East Anglian style.

The East Anglian Beaker is by far the most common Beaker type in Kent and one of the few of Clarke's groups to have a discrete distribution, being largely confined to the south-east of England. Other find-spots include Barham (Clarke 1970, figs 92 and 380), Bromley (Clarke 1970, fig 406), Cliffe (I Kinnes pers comm), Upper Deal (Clarke 1970, fig 391), Cottington Hill (Perkins 1992), Erith (Clarke 1970, figs 394 and 403), Folkestone (Clarke 1970, fig 336), Great Mongeham (Clarke 1970, fig 423), Ightham (Clarke 1970, fig 38), Preston (Clarke 1970, fig 389), Swalecliffe, Whitstable (N MacPherson-Grant pers comm), and Wye (Gibson and MacPherson-Grant 1992).

The only radiocarbon date associated with East Anglian Beakers is that from Cottington Hill, which has been dated to 3630±60 BP (BM-2725). When calibrated, the age ranges for this date fall between 2200 and 1770 Cal BC (at 2σ) with an 88.9-per-cent probability that the true date lies between 2150 and 1870 Cal BC. This date is perfectly in keeping with the dates from other Kentish Beakers and agrees with the stratigraphy at the Dover boat site.

The Shale

by Paul Bown, Charlie Bristow and Nerina de Silva

A small fragment of shale (Small Find 219, Context 4933; Fig 11.3) was found lying on the inboard surface of the boat (*see* Fig 3.11; de Silva 1996). It was roughly diamond shaped, *c* 73mm × 39mm, varying between *c* 1–10mm thick. The surfaces and edges were uneven and seemed to have a layered appearance. A few hairline cracks were visible. It was blackish-brown in colour, with minute white flecks and had acquired a polish in raised areas. It weighed 13.68 grams. It was studied by Scanning Electron Microscope, X-ray fluorescence and infrared analysis, prior to geological examination and nannofossil analysis in an attempt to identify its place of origin.

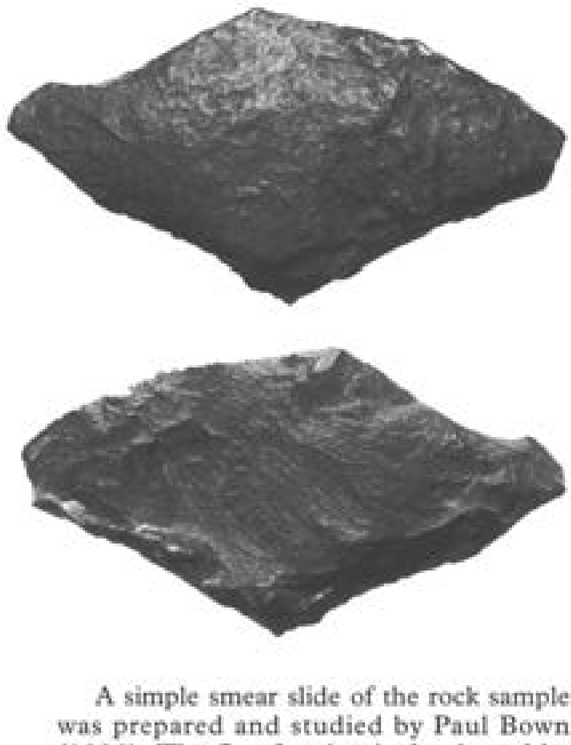


Figure 11.3 The shale object found at the northern end of the boat. A: dorsal view; B: ventral view (scale = 1:1).

A simple smear slide of the rock sample was prepared and studied by Paul Bown (1996). The fine fraction is dominated by amorphous organic matter and is low in carbonate. Most of the fine fraction carbonate is composed of calcareous nannofossils (specifically coccoliths). The coccolith assemblage is not well preserved and is virtually monospecific, consisting of *Watznaueria britannica*. Although *W. britannica* is a long-ranging species (dating from the Bajocian Age to the Albian Age, from 176 down to 99 million years ago), its occurrence in monospecific assemblages is very characteristic of the southern England Kimmeridge clay. Having examined the gross lithological characteristics together with the nannofossil content, it seems certain that the sample is of Kimmeridge clay formation (Kimmeridgian Age, from *c* 154 down to 151 million years old).

The most likely source of this material is somewhere near Kimmeridge Bay on the Dorset coast, about 160 miles (257km) west of Dover (Bristow 1996). There are rocks of a similar age in northern France, near Boulogne, but the lithologies there are quite different and the rock is unlikely to have come from France.

One outstanding feature of the rock sample is its low density, probably owing to a high organic content. The blackish colour, combined with the light weight, suggest that it was an organic-rich mud/clay stone with *c* 10-per-cent total organic carbon (TOC). Parts of the Kimmeridge clay are so organic rich that they will burn. In this case, it is possible that the rock could have been used as a fuel, although this seems unlikely. It is more probable that the sample is the protolith of a shale ring or bracelet, transported – interestingly – in a rough state and not as a finished product.

Wooden objects

by Peter Clark

Yew branch

Recovered from sediments adjacent to the boat was a fairly straight, yew branch (unnumbered), about 431mm long and 18mm in diameter, with several small knots (Fig 11.4). Its original position is unknown. A section 150mm long at one end has a smooth, concave facet 45mm long, the remaining 105mm being very rough, as though the branch was part cut and part torn from its parent tree. On the opposite side to this break is a small, shallow facet 45mm long. About halfway along the length of the branch is a section of apparently natural damage about 140mm long. This probably represents the scar of a branch torn off in antiquity. At the opposite end to the tool marks is a section 150mm long where the branch has been twisted, separating the wood fibres, in exactly the same way as the yew withy stitches in the boat had been twisted.

It is clear that this is not a fragment of stitch; it is unbent and could not have functioned as one of the boat fastenings. However, the treatment of the twisted end suggests that it had been intended as a withy, but was broken off and rejected, perhaps because of the area of damage. It has been suggested that perhaps withies were twisted when still attached to the parent tree (Chapter 8, p 139). Presumably, after twisting, they were cut or torn away, trimmed of side branches, foliage and bark, and trimmed to length before use. Maybe this piece represents an offcut from such a withy, although the twisted end showed no clear signs of having been cut. Perhaps withies were being harvested close by, or they were harvested untrimmed, the final preparation taking place at the site of use.

Why part of a withy was found associated with the boat is unclear. It is presumed that such yew withies were used for the repair or construction of boats, although this cannot be taken for granted. It seems unlikely that the Dover boat was to be repaired in any way; rather it was partially dismantled and abandoned. Perhaps this find represents evidence for repair of another boat at the same site?

Lath fragments

A number of lath fragments were retrieved from sediments adjacent to the boat, some probably deriving from the part of boat that had been accidentally destroyed by machine when it was discovered (Cofferdam I). Most were very small, although one section was 455mm long, 49mm wide and about 7mm thick, with a few fragments of moss adhering to one side. This seems somewhat narrower than the laths along the main seams of the boat (Chapter 5), most of which were of course *in situ*. Perhaps this represents a lath between one of the ile planks and a missing upper side plank, discarded when the boat was dismantled.

Other wood fragments

Apart from several fragments of boat timbers, presumably derived from the damaged section, there were also many other pieces of wood in the sediments around the boat, mostly unworked sticks and twigs, with occasional larger water-worn wood fragments. Few showed signs of tool marks, although a few reeds or sedges appeared to have been cut with a blade. These, sadly, did not survive the excavation. One piece, a smooth, curved branch, about 320mm long and 22mm in diameter, had been sharpened into a wedge shape about 45mm long by several blade cuts on opposite sides of the branch (165; *see* Fig 11.5). The other end, which had been twisted, also appeared to have been cut, but was quite badly damaged. It probably represents a yew withy end cut off during the dismantlement of the boat.

The lithic assemblage

by Tania Wilson

In total, 545 lithic artefacts were recovered during the excavation of the Dover boat. This assemblage consists of struck flints, large unmodified nodules and pebbles, and a substantial quantity of burnt flint. Table 11.1 shows the relative quantities and weights of these groups.

Table 11.1 Quantity and weight per artefact type

artefact type	*quantity*	*total weight (g)*
struck flint	211	14 813
unmodified nodules*	75	18 178
burnt flint	259	7 642

*excluding two nodules in excess of 2kg each

Figure 11.4
A fragment of an unused yew withy found in association with the boat.

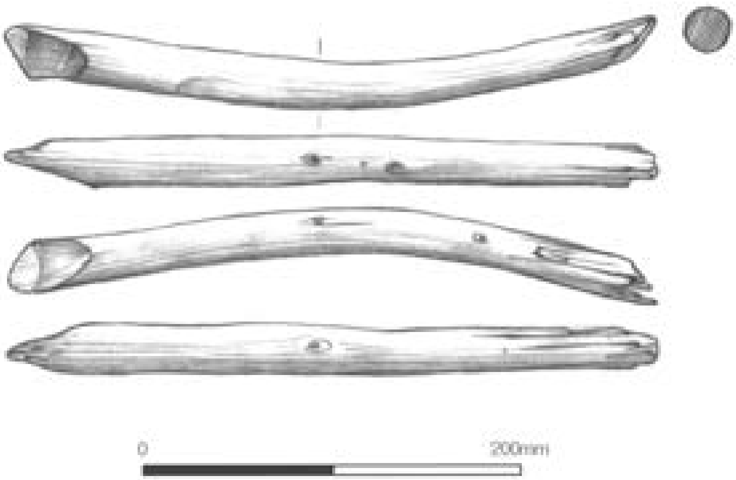


Figure 11.5 Timber 165 – probably part of a yew withy end cut off during the dismantlement of the boat.

Table 11.2 shows the quantities of lithics per context, excluding those that have no secure context. It can be seen that lithics of all groups were found in close association with the boat and are represented in deposits from above, on the floor of, within, outside and beneath the boat.

In addition to the flint artefacts, two examples of large unmodified pieces of chalk were recovered, both from context 5513, situated outside and to the east of the boat (*see* Figs 3.13; 12.1).

Methodology

All the artefacts – both struck and unmodified – have been fully recorded, and the catalogue is held with the site archive. The unmodified pieces, and those that are burnt, have been listed with their quantities and weights recorded. Each of the struck pieces has been recorded in greater detail, noting the class of artefact, its condition and completeness, the raw material used, the presence or absence of cortex and its dimensions. The method for recording dimensions follows Saville's recommendations (1980, 16), measuring the length perpendicular to the striking platform.

The cores have been categorised as follows: Class A (one platform), Class B (two platforms) and Class C (three or more platforms). In addition, there are a number of fragmentary cores that are recorded as such, and sparsely flaked nodules and pebbles that are classed here simply as having been struck. The dimensions of the cores and hammerstones, as quoted in this text, refer to the maximum dimension in each plane. Technological features, such as the type of striking platform and the presence of platform abrasion, have also been noted.

Raw material and condition

The raw material selected for knapping consists of three main types: a grey opaque flint with a buff, hard cortex; a black semi-translucent flint, including some examples with grey, quite cherty inclusions and a white, thick, hard cortex; and another flint with a similar black matrix but a grey, thin, hard cortex displaying

Table 11.2 Frequency of lithics per context

relationship to boat	*context number (fig 12.1)*	*struck flint*	*weight (g)*	*unmodified pieces*	*weight (g)*	*burnt pieces*	*weight*	*total number of artefacts*
above boat	4922	4	<1	–	–	–	–	4
above boat	4929	9	<1	–	–	–	–	9
above boat	5506	–	–	–	–	1	<1	1
floor of boat	201	15	2 337	22	6 405 + nodule >2 000	1	96	38
floor of boat	4933	7	368	–	–	–	–	7
deposit within boat	5530	4	1 279	1	232	1	36	6
deposit within boat	gravel in boat	4	<1	–	–	1	53	5
outside of boat to the east	5513	13	1 742	18	7 936 + nodule >2 000	16	510	47
outside of boat to the west	5515	57	2 620	26	2 565	162	5 051	245
outside of boat	5522	1	16	–	–	–	–	1
beneath the boat	4911	1	35	1	25	–	–	2
beneath the boat	4923	24	218	–	–	1	43	25
beneath the boat	4924	8	<1	–	–	5	56	13
beneath the boat	4961	51	5 616	6	853	63	1 688	120
beneath the boat	4962	1	12	–	–	–	–	1
beneath the boat	5510	1	65	–	–	3	32	4

'chatter' marks. Small quantities of other types are also represented; Table 11.3 shows the relative quantities of the raw material types.

Table 11.3 Relative frequencies of raw material types

raw material	*quantity*	*total weight (g)*
grey, opaque flint	19	3 043
black flint with white cortex	42	2 282
black flint with grey cortex	51	7 657
grey/brown flint	11	601
grey, semi-translucent flint	2	20

The different types of cortex show that the raw material was selected from a number of sources. The artefacts with a buff, hard cortex suggest that this raw material might have been surface collected from an area where nodules had been exposed for some time and had become weathered. The white thick cortex suggests a chalk source, perhaps from the nearby exposures at the sides of the valley. The raw material with 'chatter' marks present on the cortex is in the form of largish pebbles, suggesting a different source entirely – probably the beach. Working with these determinations, a comparison can be made between the quantities of chalk or surface material and those of pebble flint, and between those that have been struck and those that remain unmodified. Figure 11.6 presents the relative proportions of artefacts where the raw material could be determined.

Ninety-four percent of the struck-flint assemblage is in a fresh condition; the remainder consists of burnt (4.5 per cent) and rolled (1.5 per cent) pieces. A very small number have slight patination. The rolled pieces are in such insignificant quantities that they are considered to be merely 'background noise' and are probably not directly associated with bulk of the assemblage. With the exception of two pieces with slight irregular chipping, there is no evidence of any post-depositional damage.

Much of the struck assemblage and the unmodified pieces show slight staining. This staining, to a black colour, was observed within the main matrix of the flint and also on the cortex, and is particularly noticeable on some examples with a chalky cortex. It is likely that the staining results from the burial conditions within the sediments around the boat.

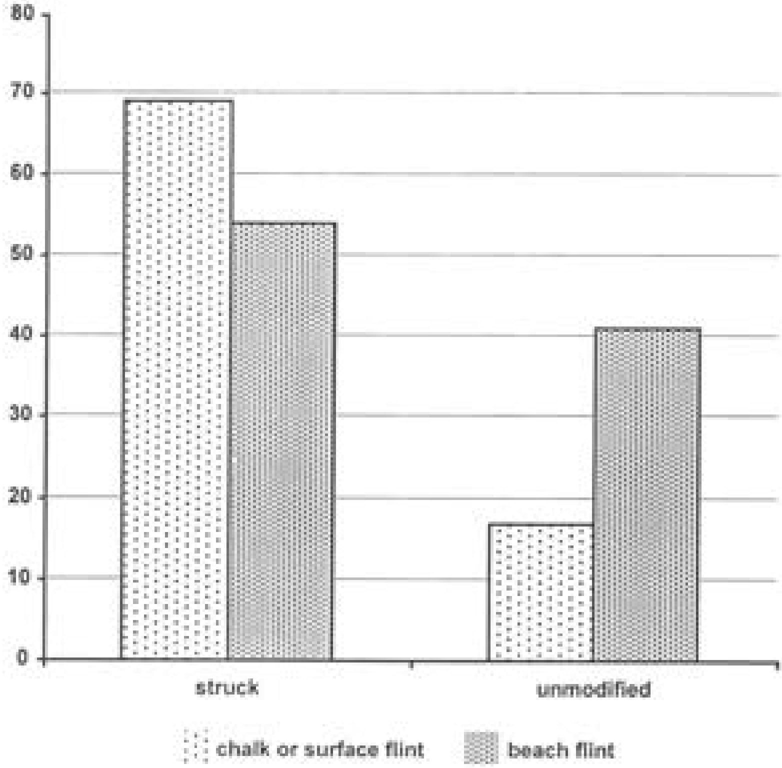


Figure 11.6 Frequency of raw material types in struck and unmodified artifacts.

The struck flints

In total, 211 struck flint artefacts were recovered; these have been placed into general artefact-type categories and are summarised in Table 11.4. The term 'chip' is used here to describe complete flakes of 15mm in length or less.

Table 11.4 Quantities by artefact type

artefact type	*total*
blades	2
chips	54
chunks	10
cores and struck lumps	23
flakes	103
hammer-stones	2
retouched pieces	17

In total, 157 flakes and chips were recovered, weighing 3,996g. Of these, 78 per cent of the flakes are complete and their dimensions are summarised in Table 11.5. Only two blades are present within this assemblage and both are incomplete. One of the blades (FN 123.12, *see* Fig 11.13) has traces of gloss in a small area on the left-hand side. ('FN' here refers to the find number allocated to individual pieces.)

Table 11.5 Dimensions of complete flakes

size (mm)	*length*	*breadth*	*thickness*
0–9	0%	0%	20%
10–19	2%	2%	44%
20–29	10%	10%	10%
30–39	11%	21%	2%
40–49	12%	16%	1%
50–59	15%	14%	0%
60–69	11%	6%	0%
70–79	8%	4%	0%
80–89	4%	2%	0%
90–99	2%	0%	0%
>100	2%	2%	0%

The scatter diagram (Fig 11.7) shows the distribution of the sizes of the complete flakes. It can be seen that the shapes and sizes of the flakes vary a great deal with no apparent clustering of breadth/length ratios, and there is a complete lack of flakes with a breadth/length ratio of 2:5 (ie blade-like in shape).

Analysis of the different proportions of primary, secondary and tertiary flakes shows that secondary flakes form the majority of the group (68 per cent), tertiary flakes 25 per cent, and primary flakes only 7 per cent. There is no variation in these proportions when comparing artefacts from different deposits.

Overall, where the striking platforms could be observed, those of both flakes and blades are almost exclusively plain. A small number have platforms with cortex remaining (7 per cent) or are dihedral/faceted (7 per cent); others make use of scars produced by natural shattering (3 per cent). The occasional prepared platforms, and a small number of pieces with slight evidence of platform abrasion, show evidence of a very limited amount of core preparation. There are no core trimming or rejuvenation flakes within the assemblage. Where visible, the bulbs of percussion are all fairly large, with pronounced cones characteristics of hard-hammer flaking. There are no pieces that suggest the use of a soft hammer.

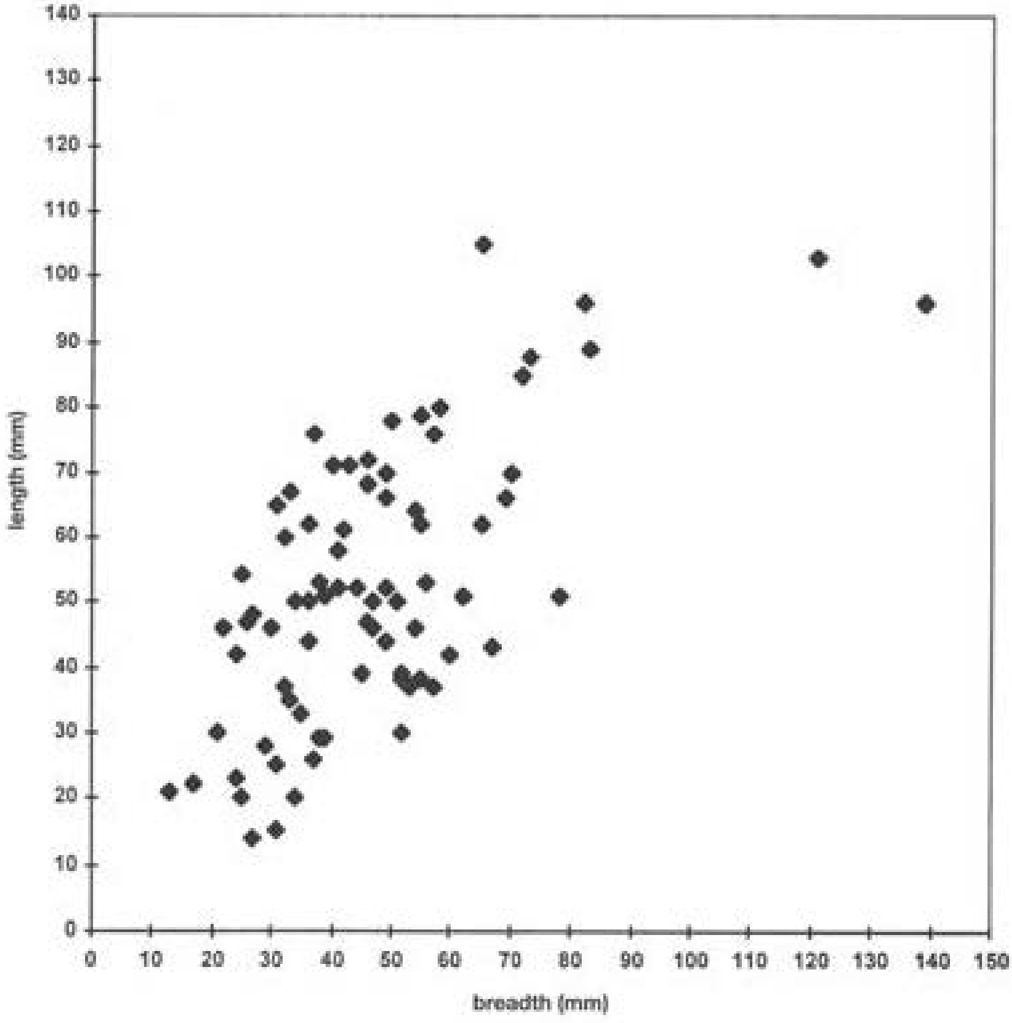


Figure 11.7
Diagram showing the sizes of the complete flakes.

Table 11.6 Quantities and weights of cores by class

class	*quantity*	*total weight (g)*	*average weight (g)*
A	7	3562	509
B	–	–	–
C	6	1993	332
fragments	2	202	101
struck nodule/pebble	8	2158	270

In total, twenty-three cores and struck lumps were retrieved; the quantities and weights of the different classes are summarised in Table 11.6.

The maximum measurement of the cores ranges from 40mm to 126mm, with an average of 90mm; the maximum of the struck nodules/pebbles is 26mm to 158mm, with an average of 66.5mm. Single-platform, multi-platform and simple struck pieces figure almost equally in quantity and, in general, all the cores and struck pieces bear the same characteristics, regardless of platform number. The majority of both the cores (80 per cent) and the other struck pieces (75 per cent) are of pebble flint. Both cores and struck nodules/pebbles were used exclusively for the production of flakes; most pieces have very few flakes removed (some examples resulting in stepping) and several have evidence of numerous mis-hits (FN 198, Fig 11.11). One exception (FN 134.21, Fig 11.11) is a small, single-platform core from which several parallel flakes have been successfully detached using a natural scar as a platform; a number of mis-hits are still evident, however.

Two hammerstones were also recovered (FN 145.1 and FN 128.1), measuring 88mm × 80mm × 70mm and 65mm × 52mm × 40mm, and weighing 679g and 135g respectively. The first (FN 145.1) has been flaked, and small chips detached from the scar of one of these flakes suggest that it was flaked prior to its use as a hammerstone. In the case of the second (FN 128.1), one flake was detached from one end of a small nodule and a small area of crushing through cortex is present at the opposite end. The hammerstone shattered during use and at least three further flakes were detached before the piece was abandoned.

Retouched pieces

In total, seventeen retouched pieces were collected during the excavation and the majority fall into a miscellaneous retouched category. These pieces generally have small areas of retouch, often located on one side of a flake, and are fairly random in style. One exception (FN 134.6) has an area of irregular retouch on a struck, naturally shattered lump. Another unusual piece (FN 202.13, *see* Fig 11.13) is triangular in shape with some bifacial working and semi-abrupt retouch at the distal end and along the left-hand side.

Two pieces within this assemblage have been tentatively classed as denticulates. The first (FN 128.3, *see* Fig 11.13) has three small notches situated at the distal end of the left-hand side, and the second (FN 346.11, *see* Fig 11.13) has continuous retouch on both sides, forming notches, on a now incomplete blade-like piece. The latter is, however, in a rolled condition and might be derived from elsewhere.

Two scrapers were also recovered. One (FN 134.5; *see* Fig 11.13) has a small area of abrupt retouch at the distal end; part of this end appears to be missing and it is likely that the area of retouch was once more extensive. The second scraper (FN 346.12, *see* Fig 11.13) has semi-abrupt retouch at the distal end. This piece stands apart from the entire assemblage in that it has slight blue patination and shows a greater degree of skill in manufacture than most of the other pieces.

Another retouched piece (FN 145, *see* Fig 11.12) has been tentatively classified as a knife. This is formed on a large blade-like flake with cortex remaining on the left-hand side; semi-abrupt retouch blunts the distal end and slight retouch extends around towards the right-hand side. Irregular chipping running along this side might be a result of use.

One flaked flake (FN 210, *see* Fig 11.12) was collected from the floor of the boat. A number of flakes have been detached from both the right- and left-hand sides of the ventral surface of this large flake.

The final piece worthy of note (FN 347, *see* Fig 11.12) is a large, triangular-shaped flake with irregular abrupt retouch on the left-hand side. This piece is of particular interest as it is wedge-shaped in profile and has an area of cortex on the dorsal surface that appears to be worn flat and very smooth. This piece might have been used as a wedge.

Relationship to the boat

Table 11.7 shows the distribution of the struck flints by type, in relation to the boat.

A small number of chips comprised the only struck artefacts collected from the deposits above the boat, and all of these were recovered from soil samples. A significant number of cores were recovered from the floor of the boat, together with two retouched pieces – the 'wedge' (FN 347) and the flaked flake (FN 210). The deposits outside and beneath the boat produced the majority of the assemblage, including both hammerstones, quantities of debitage, cores and retouched pieces. One scraper (FN 346.12) was recovered from context 5515, to the west of the boat, and both blades were recovered from beneath it.

Figure 11.8 shows the overall distribution of all the artefacts, including the burnt and unmodified pieces. It is clear that the majority of every artefact group was recovered from outside or beneath the boat, and burnt flint, in particular, is quite sparse in deposits above or within it. Interestingly, the comparison of the artefacts from the floor of the boat shows that the unmodified pieces are in almost equal proportions to the struck artefacts. The two very large unmodified nodules were recovered from the floor of the boat and outside the boat.

Conclusions

The discovery of the boat has provided a rare opportunity to study a well-stratified and dated lithic assemblage from Dover, where little is currently known about activity in the Bronze Age or, indeed, earlier. In addition to its context, the assemblage was situated at some depth below the present ground surface and, as such, has not been disturbed by post-depositional factors, which often damage artefacts and move them from their original place of deposition. The quantities of unmodified and burnt flint also found in association with the boat make this assemblage particularly interesting.

Two main questions arise when considering this assemblage, these being whether the assemblage is contemporary with the boat, and what activities are represented by the assemblage.

Is the assemblage contemporary with the boat?

As shown above, the lithic artefacts were recovered from around, beneath and within the boat. Table 11.2 shows that all classes of artefact – struck, burnt and unmodified – are present in each of these locations, and Table 11.7 shows that the distribution of the different classes of struck flint is fairly evenly spread. Comparison of the artefacts from each of these different locations shows that there is no difference in the condition of the material from each of the deposits and, furthermore, there are no apparent changes in the way in which the flint was being worked. These factors suggest that the deposition of the artefacts is contemporary with the

Table 11.7 Distribution of struck flint

artefact type	*above the boat*	*boat floor*	*other deposits within the boat*	*outside, to the east*	*outside, to the west*	*beneath the boat*
blades	0	0	0	0	0	2
chips	13	0	4	0	0	30
chunks	0	0	0	3	3	4
cores						
A	0	2	1	0	2	2
C	0	3	0	0	1	2
fragment	0	1	0	0	1	0
struck nodule/pebble	0	0	0	1	6	1
flakes	0	14	3	9	35	37
hammerstones	0	0	0	0	1	1
retouched pieces	0	2	0	0	8	7

abandonment of the boat. This is also suggested by the lack of artefacts recovered from the deposits that subsequently sealed the boat.

In addition to the proximity of the assemblage to the boat, consideration must also be given to the struck artefacts, the implication being that they are of a Middle Bronze Age date. None of the retouched pieces are diagnostic, and most – with the exception of one scraper (FN 346.12) – are fairly random in nature, with only small areas of retouch present on all manner of flake shapes and sizes. They cannot, therefore, be used in suggesting a date.

Technologically, the assemblage is marked by the sparsely and irregularly flaked cores and struck nodules/pebbles. Most of these pieces have been used for the removal of only small numbers of flakes, and evidence of stepping and mis-hits might suggest little skill or expertise. There are no signs of any attempt at core trimming and rejuvenation, and little evidence of core preparation; this probably demonstrates a lack of economy, reflecting relatively easy procurement of the raw material. Equally, none of the cores has been reduced beyond the point of usefulness. The apparent randomness of the assemblage suggests that the end product was not of a particular design or requirement, and this lack of consideration for the final product is also demonstrated by the choice of raw material. As can be seen in Figure 11.6, there is only a slight preference for the use of the better-quality chalk flint over pebble flint.

This group shows a number of features that are characteristic of lithic assemblages dating to the middle and later periods of the Bronze Age. The random nature, as demonstrated by the irregular flaking of the cores and struck lumps, and by the lack of more standard tool types, has been noted in a number of assemblages assigned to this period.

Flake shape is one feature that might be used to confirm the dating of this assemblage. Ford (1987) has demonstrated that the trend towards broader flakes from the Neolithic onwards continues on through the Bronze Age, and a glance at the scatter diagram (*see* Fig 11.7) shows the range of flake sizes. Fifty-eight percent of the complete flakes from this site have a breadth/length ratio of 4:5 or over, and none reaches blade-like proportions. Cortical flakes have also been shown to have a use as a chronological indicator, with a trend towards more flakes retaining cortex in the Bronze Age (Ford 1987, 75). This assemblage consists of 75-per-cent cortical flakes, although primary flakes are sparsely represented.

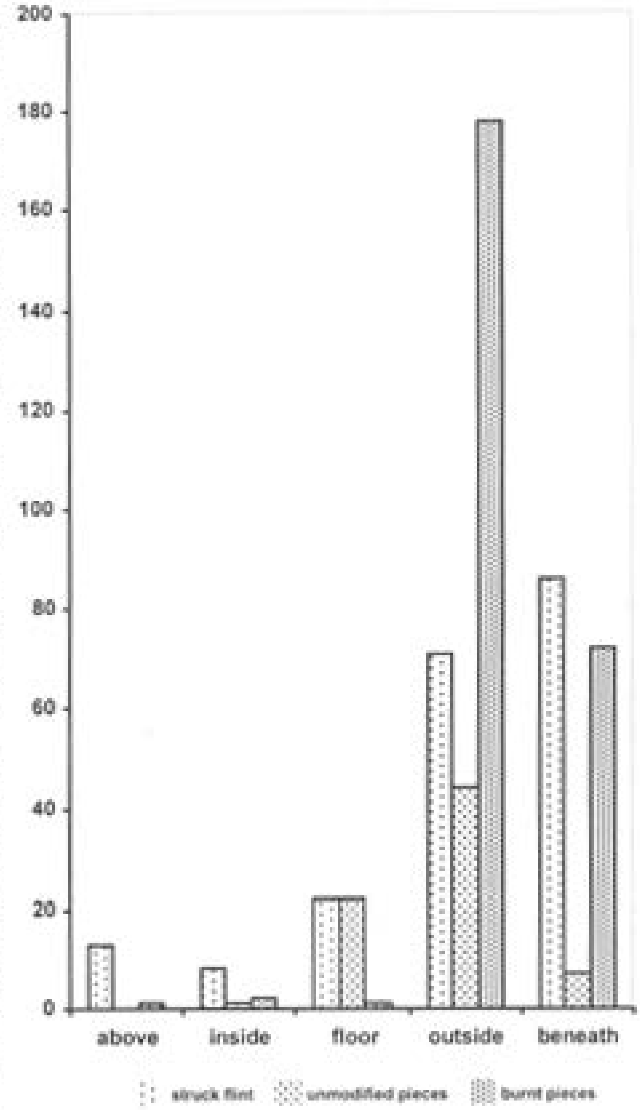


Figure 11.8
Frequencies of lithic artefacts in relation to the boat.

The Dover boat cores are almost equally split between those of Classes A, C and the struck lumps/nodules. The Middle-Bronze Age assemblage at Grimes Graves showed the main core class to be those with single platforms (Class A), with very few examples of three platforms or more (Saville 1981a, 19). However, one of the distinguishing factors of the Grimes Graves assemblage is the lack of platform preparation (Saville 1981a, 46). Similarly, the assemblage recovered from the North Ring at Mucking is also marked by these features

(Healey 1988, 24). The lack of prepared platforms is also evident on the cores of the Dover boat and, furthermore, only 7 per cent of the flakes have faceted/dihedral butts. Overall, the cores and struck lumps give the impression of a rather haphazard approach to flint working.

The paucity of formal tools is also in keeping with other assemblages of this date. At Grimes Graves, implements categorised as miscellaneous retouched forms constitute a considerable component of Middle Bronze Age tool types (Saville 1981a, 20), and Healey (1994) has also shown this to be

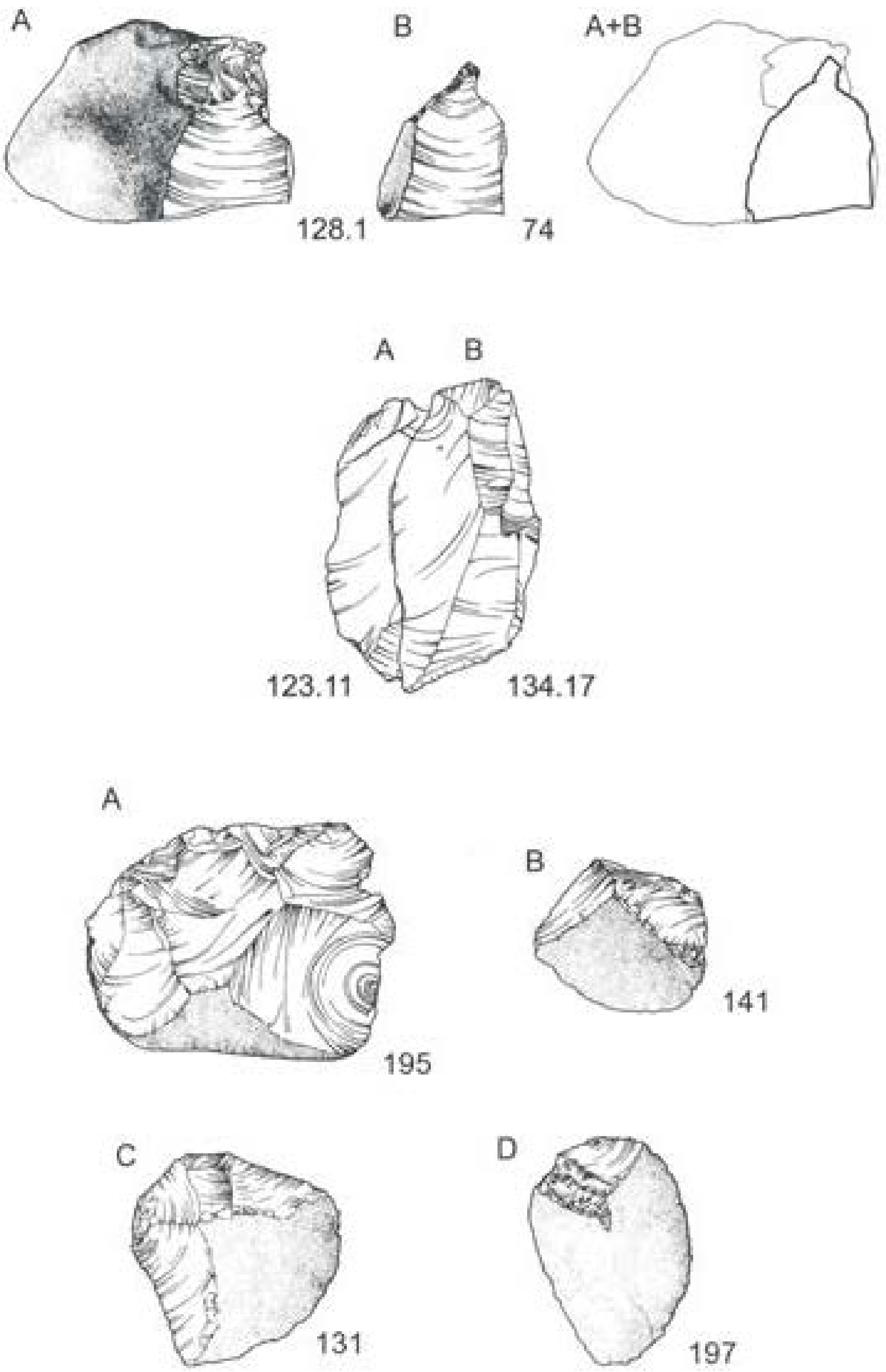


Figure 11.9
Refits. A core (195) with three re-fitting flakes (131, 141 and 197), with a hammer stone also used as a core with re-fitting flakes (128.1 and 74), with two re-fitting blade-like flakes (123.11 and 134.17) (scale = 2:3).

the case at Monkton Court Farm in east Kent, where the retouched pieces lack a standardised form.

What activities are represented by the assemblage?

The Dover boat assemblage is of particular interest given the quantities of unmodified and burnt material found to be associated with it. These pose the questions of not only how the material came to be there, but why.

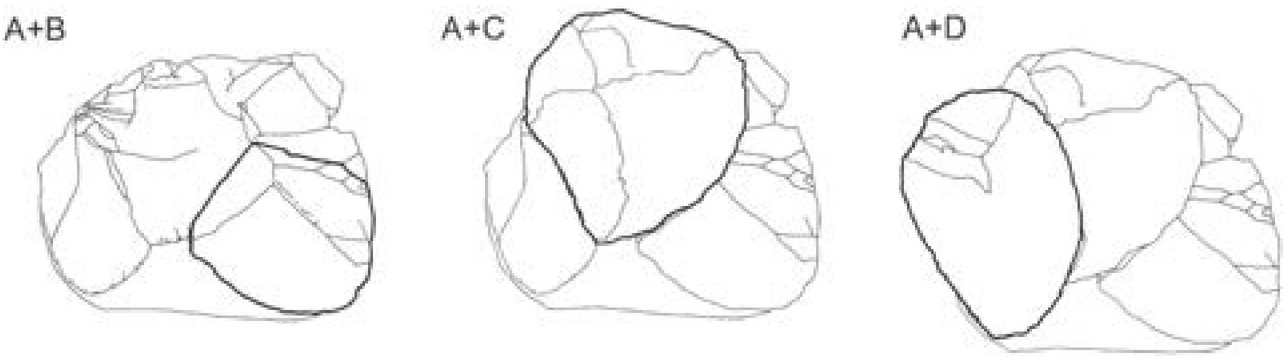
Both unmodified and burnt pieces were collected from most of the deposits relating to the boat, particularly those from outside and beneath it. As has been shown, pebble and chalk flint is present in the unmodified assemblage and it is clear from the analysis of the sediments that the assemblage cannot have been transported to the site by natural processes (Green 1998). Furthermore, the pebble flint is almost certainly derived from a beach context rather than a fluvial deposit, as the pebbles are quite large and only angular, flint gravels and tufa-pellet gravels are recorded from the Dour valley (Green 1998, 6–7). It is possible that the chalk- and surface-collected flint was gathered fairly locally, from outcrops at the side of the valley and material eroded out of the chalk. However, given the fact that the beach might have been, at that time, more than a kilometre from the site (Green 1998, 21; Chapter 12), the presence of the pebble flint is a little harder to explain. Nevertheless, it is clear both that these unmodified pieces were selected elsewhere and intentionally brought to the site, and that it is not possible for them to have reached this location by natural processes. The unmodified pieces might have been transported to the site for the purpose of flint working, but were never used.

The significant quantities of burnt flint are also of interest, most pieces being very burnt and friable. As has been shown at other sites, large quantities of burnt flint are not particularly out of place in a Middle Bronze Age context (Healey 1994; Saville 1981a). At Grimes Graves, burnt flint was associated with other cultural material in a dump of domestic waste (Saville 1981a, 4). The association of the burnt flint with the – albeit small – quantity of animal bone at the site of the Dover boat suggests that this might represent a similar type of deposit. This is further demonstrated by Stewart (1998), who has shown that some of the animal bone bears cut marks, implying it was a source of food.

It would not be out of place for the struck artefacts also to form part of this midden deposit, and it is likely that the majority do. There are considerably more flakes of chalk than could have been produced by the chalk-flint cores present, and many of the chalk-flint flakes are too large to have been detached from these cores, which might suggest that at least some of the assemblage was struck elsewhere and brought to the site. Additionally, the lack of primary flakes in this assemblage supports the supposition of some knapping of the material having taken place elsewhere.

An attempt at con-joins was made. Three flakes (FN 131, 141 and 197) were found to refit with a core (FN 195, Figs 11.9; 11.10); all of these were recovered from the floor of the boat. One blade (FN 123.11) and a blade-like flake (FN 134.17, *see* Fig 11.9), both from beneath the boat, also rejoined. Finally, one flake (FN 74) and a hammerstone (FN 128.1, Fig 11.9) were also found to refit; interestingly these two pieces were recovered from outside the boat, but separately, on either side.

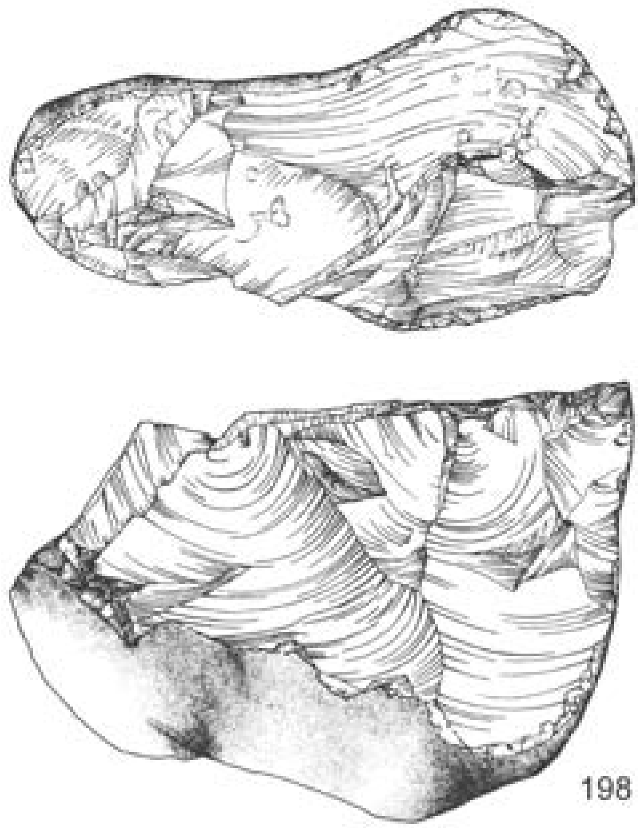
Figure 11.10 Refit sequence. The core 195 refitted with flakes 131, 141 and 197 (see Fig 11.9).



These refits, and the presence of the unmodified nodules/pebbles, might suggest that some *in situ* knapping was taking place, although this cannot be further substantiated.

Having established that some flint working might have been taking place at the site of the boat, we can attempt to make suggestions as to the use of the flints. One possibility is that the flints were used during the dismantling of the boat. The retouched pieces and the large unmodified flakes would have proved suitable tools for such a task. In particular, the possible 'wedge' is of note, as the worn area on the dorsal surface, which must indicate some form of abrasion and its shape would make it ideal for tasks such as separating timbers.

In summary, this assemblage is almost certainly contemporary with the Dover boat and appears to be directly associated with it. It appears to contain two main elements; episodes of the dumping of domestic debris, and the use of some of the struck flint in dismantling the boat itself.



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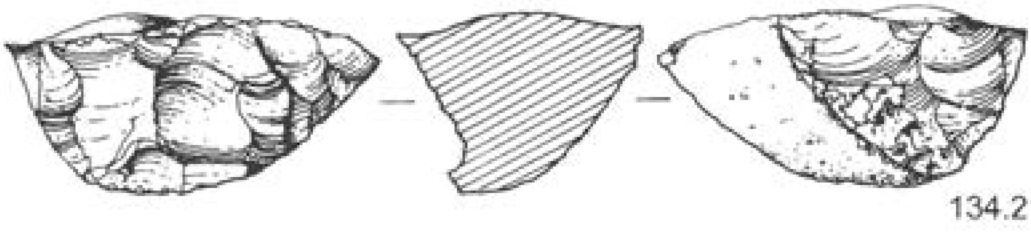


134.21

Figure 11.11
Cores. A small single platform example (134.21) and an example demonstrating numerous mis-hits on the striking platform (198) (scale = 2:3).

The discovery of the boat is clear evidence for Middle Bronze Age activity at Dover and it brings into perspective other discoveries from the area, such as a small assemblage from nearby York Street, probably of similar date (and, interestingly, using similar raw materials; Wilson 1996), and a substantial assemblage from Buckland (as yet unpublished), again, probably dating to the latter part of the Bronze Age. To date, very little of the discoveries of this period from the area have been published. The boat gives weight to the increasing body of lithic evidence demonstrating occupation in Dover and the Dour valley during the Middle Bronze Age and possibly earlier periods.

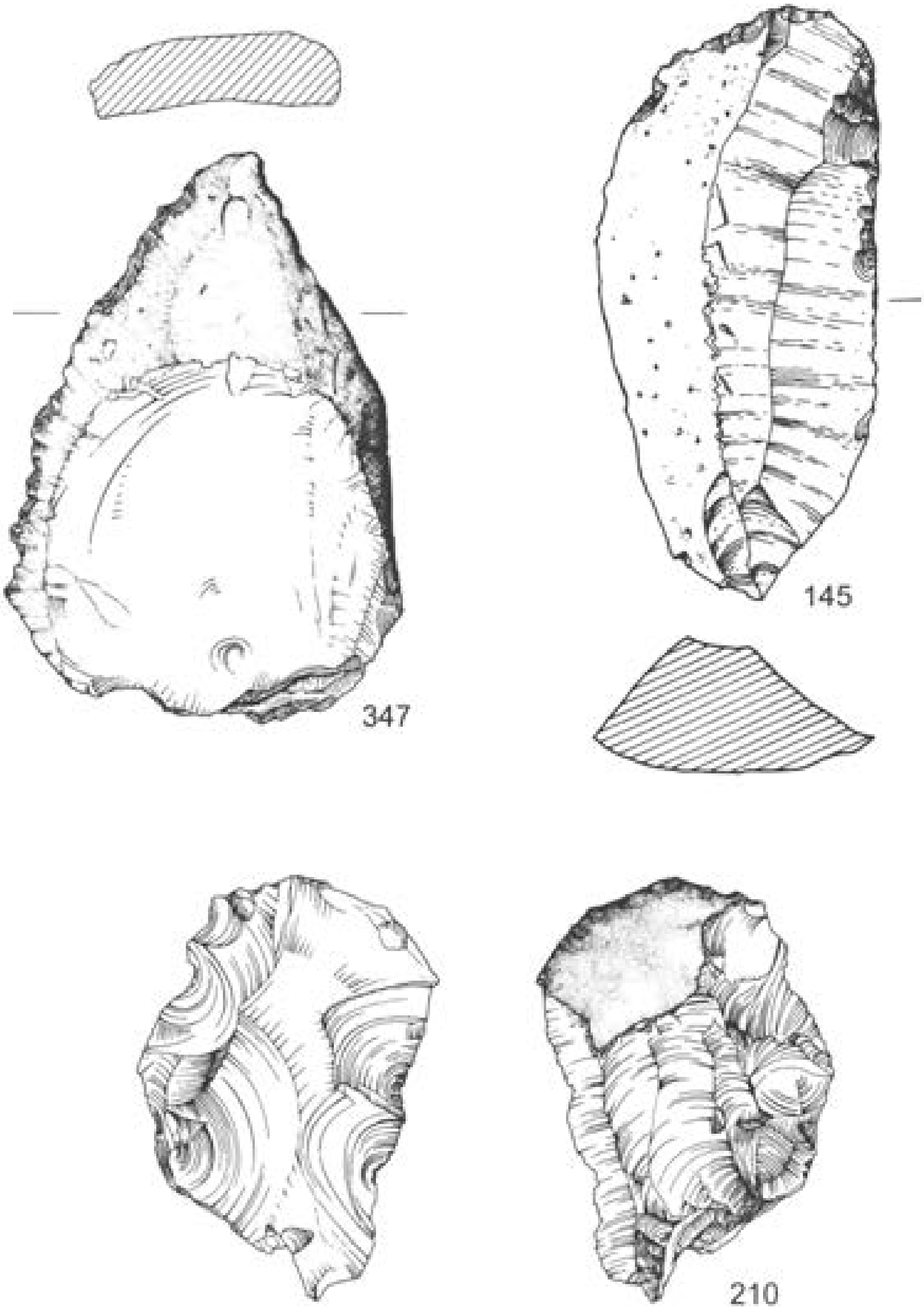
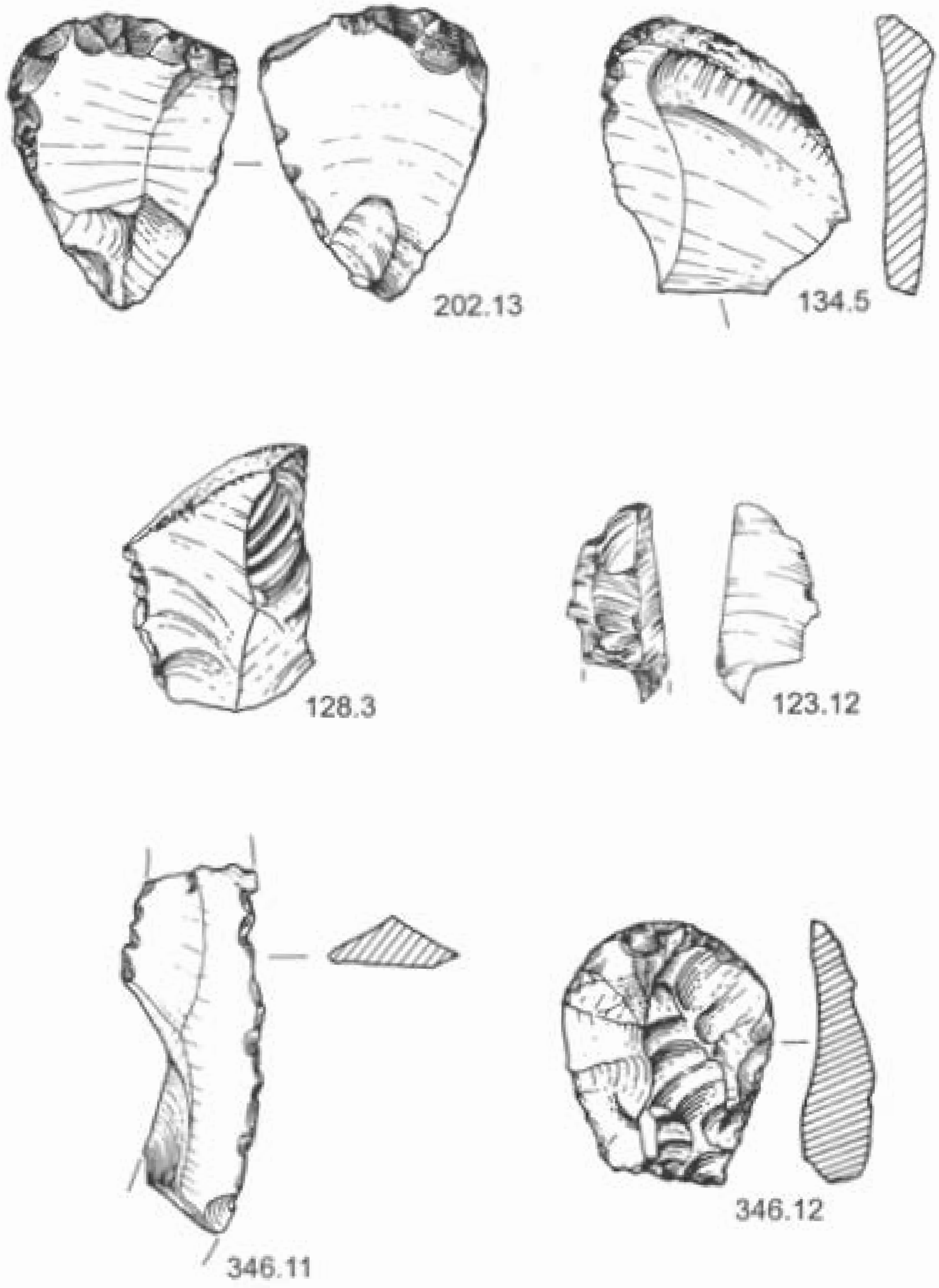


Figure 11.12
Retouched pieces. A large flaked flake (210), a knife (145) and a 'wedge' (347) (scale = 2:3).

Figure 11.13
Retouched pieces. A bifacially retouched triangular piece (202.13), two end-retouched scrapers (346.12 and 134.5), two denticulates (346.11 and 128.3) and a blade fragment with traces of gloss (123.12) (scale = 2:3).



12
The environmental evidence

by Helen Keeley, Enid Allison, Nicholas Branch, Nigel Cameron, Simon Dobinson, Isabel Ellis, Peter Ellison, Andrew Fairbairn, Chris Green, Robin Hunter, Jerry Lee, Alison Locker, John Lowe, Adrian Palmer, Eric Robinson, John Stewart and Keith Wilkinson.

To set the Dover boat within its Bronze Age landscape, a number of environmental investigations have been carried out, focusing on the study of a range of sediments and biological remains that were found associated with the abandoned boat timbers. The specialists looked for evidence of where and how the boat was used; in the sea or in the lower reaches of the River Dour? What was it used for? Why was it abandoned where it was and how did it reach its final resting place? How far away was the sea at the time? Where was the dry land and how wide was the river channel? Were the people who might have used the boat living nearby at the time? What farming systems were in place and were suitable raw materials for boatbuilding or repair available locally? What was the significance of the boat to these Bronze Age people? And, finally, what factors led to the exceptional preservation of the boat?

Pollen, diatoms, molluscs, ostracods, insect and macroscopic plant remains, animal bones and the sediments themselves have been examined, with a view to addressing these questions. The stratigraphy was recorded in separate sections (Bates and Williamson 1996), rather than by single-context planning, and the samples were collected as columns or in bulk from individual sections. Cores were taken from deposits below the boat that were too deep to be exposed in the sections. Consequently, it was difficult to link deposits in one section to those in another in order to produce a site matrix, although this was attempted (Fig 12.1) and, ultimately, the attempt proved to be extremely useful for selecting samples for analysis and for interpretation of the results.

The individual specialist reports have been used as the basis for writing this chapter. All of these reports are available separately, in full, as archives held at Dover Museum.

The Dour valley at the time the boat was abandoned

Geology and geomorphology

The whole of the Dour catchment is situated on an outcrop of Cretaceous Chalk. Today, the active course of the river is only some 5–6km in length, and much of the valley network within the catchment comprises dry valleys occupying the dip slope of the Chalk, which here forms the eastern extremity of the North Downs. The plateau surface is largely covered with Clay-with-Flints. Intermittent overland water-flow during periods of high run-off occurs locally, producing streams known as 'winterbournes' (Barham and Bates 1990). Most of the dry valley network is aligned from south-west to north-east, parallel with the dip of the Chalk, but the lower course of the river cuts across this regional trend and is aligned from north-west to south-east. The down-valley gradient of the Dour in the 5–6km of the active course, averages about 7.5m/km. The valley sides in the immediate vicinity of where the boat was found rise steeply from the edge of the valley floor, reaching levels of over 70m OD within 0.5km of the site. The mouth of the Dour valley is flanked by chalk cliffs that rise to a level of over 100m OD. Soils in the area have been mapped by the Soil Survey of England and Wales as the Andover 1 Association and the Batcombe Association (Jarvis *et al* 1984).

Extensive tufa deposits (carbonate springs and algal growths) along the western side of the valley have often been found associated with peat (sometimes containing well-preserved wood and other plant macrofossils) and archaeological material (Bates and Barham 1993a). The remains of the boat lay at *c* 0m OD between the centre and western edge of the valley, about 30m from the course of the modern River Dour and about 150m from the modern sea front, at a point at which the

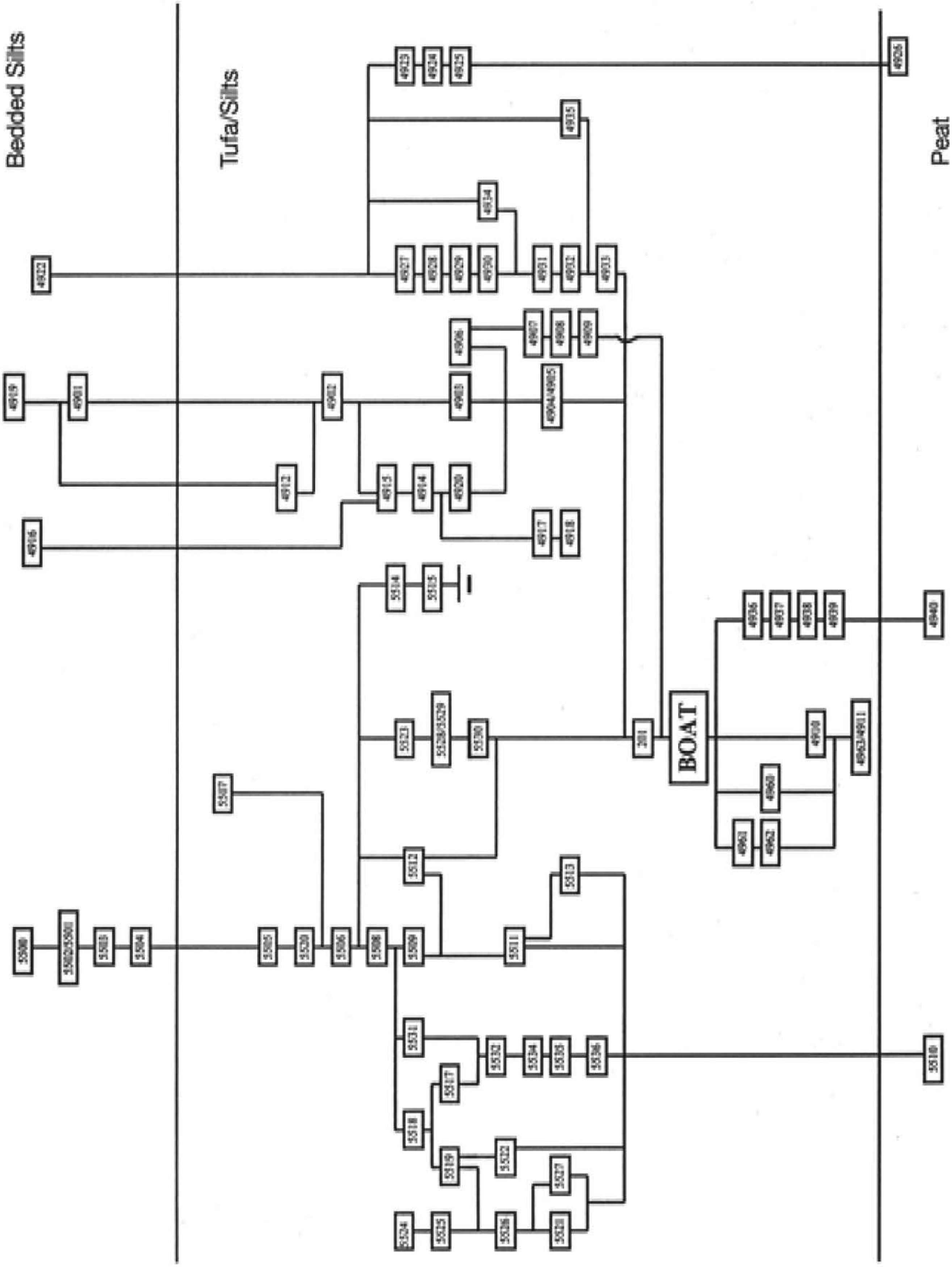


Figure 12.1 The site matrix.

valley is about 250m wide. Coastal erosion will have had the effect of progressively reducing the distance between the site and the sea throughout the period since the boat reached its final resting place.

Vegetation history

The vegetation history of Kent during the last 10,000 years (the Holocene) is still known only in outline, because few detailed pollen diagrams have been published from the area and there is no formally recognised type site. Our current knowledge, based on palynological investigations, has been summarised by Lowe, Branch and Ellis (1998). The scarcity of peat and sediment basins in south-east England, which contain continuous records of Holocene vegetation history, means that there is a dearth of knowledge about the pattern and timing of tree migrations, the nature of primary woodland and the localised effects of human activity in the region. This has resulted in recourse having to be made to sites that are not so suitable for pollen stratigraphy, such as buried soils and alluvial floodplain sediments, which have acute taphonomic problems, as discussed by Lowe *et al* (1998).

Lowe *et al* defined five broad palaeovegetation zones that summarise the temporal sequence of vegetation changes in south-east England, based upon a combination of Scaife's generalised scheme for south-east and southern England (1987) and new data for sites in south-east England. The pollen evidence from sediments closely associated with the boat suggests that it was abandoned in an area that had already been extensively modified by human activity, with widespread development of grassland on alluvial floodplain terraces. The mollusc evidence (Wilkinson 1998) indicates an open disturbed grassland environment, perhaps with longer stands of vegetation close to the channel side. There might have been standing pools of water in the vicinity, or periodic incursions of water over the nearby grassland surface. The local landscape appears to have been largely treeless with scattered hazel and perhaps sparse oak, birch and alder. The insect remains (Allison 1998) also indicate fairly open ground, with scrubby vegetation and poor-quality grazing. There are also suggestions from the plant macrofossil evidence (Fairbairn 1998) of arable land close to the site, although not immediately on the river bank, and chalk-grassland species were also found. The phase of sedimentation that covered the boat appears to have occurred rapidly, within a landscape of heavily weed-infested grassland similar to that seen in newly abandoned, cultivated or pastoral land today (Lowe *et al* 1998).

Past agriculture

During excavation of the Buckland Anglo-Saxon cemetery (Parfitt, in preparation), a series of artificial terraces was revealed, cut into the natural chalk hillside of the Buckland tributary of the Dour valley. These were of several different dates, including this century, but some could be dated to the prehistoric period and appeared to be the product of agricultural activity. It seems likely that the prehistoric terraces formed part of a more extensive system of 'Celtic fields' occupying the side of Long Hill, which could have been in use between *c* 500 Cal BC (*c* 2500 BP) and Cal AD 500 (*c* 1500 BP). The evidence from Buckland indicates that the slopes of Long Hill were quite intensively cultivated both before and after the Anglo-Saxon cemetery phase. The nature of the soil infilling the terraces clearly implies that there was also extensive cultivation of the upper slopes of the hillside over a long period of time, which led to inundation with soil of the existing terraces of the middle slopes. The first ploughing of the slopes appears to have taken place in the Middle Iron Age, if not earlier (a Bronze Age barrow mound was located on the summit of the hill). Similar evidence for ploughing on the sides of the Dour valley has been recorded in Lousyberry Wood above Temple Ewell, some 2.3km north-west of Buckland, and at Lydden, towards the head of the valley. Agricultural activities within the Dour catchment are suggested by the environmental evidence, which would have resulted in the downwashed sediments identified in the bottom of the river valley. The steep, chalky slopes of the Dour valley, however, can never have been prime agricultural land, and their cultivation in both pre- and post-Anglo-Saxon times might indicate periods when there was considerable demand for agricultural produce.

Sea level

Estuaries are complex interfaces between the fluvial upland systems and the wave- and tide-dominated regimes of the open coast (Townend and Dun 1998). An estuary is, therefore, subject to a wide range of natural variability, including changing climate, fluctuations in relative sea level and variations in the sediment supply and demand. In addition, an estuary might be subject to a variety of constraints that limit the way its shape can adjust to change, including the form of the catchment, the underlying geology and human developments (such as sea walls and navigation channels). Over the past 15,000 years, global sea-level rise appears to have been rapid between *c* 13000 Cal BC (*c* 12450 BP) and sometime between *c* 6000 to 4000 Cal BC (*c* 7100 – 5200 BP) – a result of climatic amelioration and release of melt waters from ice sheets and glaciers at the end of the Devensian glacial period (Bray *et al* 1992). As no single sea-level curve is valid globally (because no part of the Earth's crust can be regarded as stable), attention has been focused upon regional sea-level trends.

There are no detailed studies of the Dour estuary, but several areas of coastal lowland in Kent and East Sussex, and the lower reaches of several river valleys, have been investigated, and these are described by Green (1998). An important aim of these investigations has been to explore the evidence for sea-level change, and the data appear to show both that sea level had reached a position between approximately –2.0m OD and –5.0m OD by about *c* 2000 Cal BC (*c* 3600 BP), and that this level did not change significantly for a period of some 2,000 years (Long 1992). However, work carried out as part of the LOIS project (Shennan *et al* 1998) indicates that these levels might have been underestimated, and they are currently being revised. The main research on coastal geomorphology and sea level in Kent has centred on the East Kent Fens and Romney Marsh (Long 1992; Long and Shennan 1993; Long and Innes 1993; Long and Tooley 1995; Long *et al* 1996) and the Dour valley lies between these two areas. Although regional trends have been recognised, local processes have been shown to be operating, which makes extrapolation to the Dour valley somewhat problematic. This is exacerbated by the possible effects of the Variscan Thrust Fault, which can be traced across north-eastern France and the Strait of Dover, intercepting the coast of south-east England somewhere between Romney Marsh and the East Kent Fens. This fault appears to be still active today (Long and Tooley 1995). Different crustal movements associated with the front over this short length of coast provide one possible reason for the differences in recorded sea-level histories between the two areas.

In general, however, regressive (falling) relative sea-level episodes are represented in the stratigraphic record by terrestrial peat and freshwater sediments, whereas transgressive (rising) relative sea-level episodes are characterised by marine sedimentation (shingle, sand, silt, clay). Interpretation of the stratigraphic record is complicated by the fact that, from time to time during the Holocene, coastal lowlands and the lower reaches of the river valleys have both been protected from marine influences by the development of natural coastal barriers. These barriers take the form of sand and single spits, developing across the mouths of river valleys, or more extensive shingle systems, such as Dungeness, protecting larger areas of coastland. Investigations at Midley Church Bank, Romney Marsh, by Long and Innes (1993), indicate that peat formation took place between *c* 2100 and 250 Cal BC (*c* 3600–2200 BP) and would have been encouraged by the probable existence of a shingle barrier to the south-west and south-east. Marine inundation, and the local deposition of marine sediment, might follow the breaching of coastal barriers, but it has no significance in terms of relative sea-level change. It seems most likely that, at the time the Dover boat was abandoned, a natural barrier was in place across the mouth of the River Dour (Green 1998).

Sediment deposition in the Dour valley

The most complete record of the Holocene stratigraphy of the lower reaches of the Dour valley comes from investigations associated with the A20 road and sewer scheme (Bates and Barham 1993a), which led to the discovery of the Dover boat. The earliest sediments encountered on the floor of the Dour valley were angular flint gravels, overlain by freshwater organic silts, peats, tufa and tufa-pellet gravels. Similar deposits have been found recently at the Northern Quay, Western Docks (Palmer *et al* 1998). The basal-flint gravel, tufa and silt deposits were also found during investigations at the Royal Victoria Hospital site, to the west of the modern Dour channel (Bates and Barham 1993b). The Dover boat was found to be entirely enclosed in freshwater sediments and lay beneath a Roman quay, above which all deposits contained evidence of marine conditions. This sedimentary sequence appears to agree broadly with the general model for the lower reaches of river valleys in south-east England (Green 1998), that is, fluvial deposition has generally kept pace with rising sea level and, to a large extent, had excluded marine influences until quite late in the Holocene.

The sea might have been at a mean level of between 2m and 5m below the level at which the boat was emplaced, although the distance between the sea and the boat is not known. Marine influences might have been largely excluded, even from the lowermost reaches of the valley, by the development of a barrier structure across the rather narrow river mouth. This could have been continuous for much of the time, with a substantial part of fluvial discharge occurring by percolation through the barrier. However, a small component of marine and estuarine diatoms (Cameron and Dobinson 1998) suggests that the site might have been infrequently affected by very high tides (such as spring high tides). It seems likely, from the bulk of the environmental evidence, that the Dover boat was abandoned in a backwater area of the river valley subject to quiet water flooding, but was covered by sediments that quickly built up over the boat and led to its unusual preservation.

The mollusc evidence suggests there were probably relatively steep banks at the margin of the braided channels, with restricted areas of damp mud adjacent to the area of flow (Wilkinson 1998). Although the molluscs confirm that the boat was abandoned in a relatively shallow, freshwater environment, the species found indicated that the base of the channel would have consisted of a tufaceous gravel, not covered by mud or vegetation. The water would have been moderately fast-flowing, and there would have been no quieter water areas, zones of aquatic vegetation or mud exposure. Species present in sediments overlying the boat indicated that the southern end of the boat lay in an area of slower-moving water – the conditions for which might have been created by the placement of the boat itself. The insect remains also confirmed the freshwater nature of the aquatic environment and suggested shallow, well-oxygenated and unpolluted running water, perhaps with a gravely tufa substrate (Allison 1998). There were, however, indications of areas of slower-moving, or even still, well-vegetated water towards the channel margins or in backwaters. The insect remains also indicate that patches of mud were present in places, and there appear to have been plants – including sedges, rushes and umbellifers – standing in the water, or on damp ground close to it, although parts of the river bank might have been gravely or stony and rather barren.

The ostracods were all of freshwater character and indicate that the tufa gravels were not true *in situ* calc-tufas, but valley sludge deposits containing species typical of muddy, silty sediment accumulation associated with temporary shallow pools and flooded water meadows (Robinson 1998).

Fish bones were found that represent the natural death assemblage of small fish living in freshwater conditions with an overall preference for flowing water and vegetation to provide cover (Locker 1998).

The plant macrofossils (Fairbairn 1998) indicate that a freshwater environment of permanent slow-flowing shallow water must have been present along the river at some point, with disturbed, open rush marsh or pasture nearby, and rushes perhaps persisting on the open, sandy river banks and bed. These shallows and marginal marshes might have been quite extensive. In the area of the Dover boat's abandonment there might have been a considerable groundwater flow, emerging locally as springs or as less-concentrated seepage, although the boat appears to have been close to dry land.

Human activity associated with the boat

Examination of sediments laid down both before and after the boat's abandonment reveal the presence of material associated with human occupation of the Dour valley throughout the period represented. The most common evidence occurred in the form of the waste from flint working, burnt flint, charcoal, mammal bones and (more infrequently) marine shell fragments. The artefacts recovered from around the boat included diagnostic material of Middle Bronze Age date. The state of the objects indicated that they had been washed very little or no distance. Marine shell fragments were also identified in the silt immediately overlying the bottom timbers of the boat, associated with unusually large amounts of quartz sand and common grains of glauconite. It seems most likely that this distinctive combination of components was introduced into the boat outside the Dour valley, possibly on a marine beach – thus providing strong evidence for maritime use of the boat.

The Lower Cretaceous Greensands are glauconite-rich sediments, which now reach the coast between Folkestone and Hythe, at a distance of less than 10km from Dover (Green 1998). Further unequivocal evidence for human activity local to the site of boat abandonment is provided by the presence of a charred hazelnut fragment and cereal grain, probably from dumped rubbish (Fairbairn 1998). Other plant taxa might have been introduced into the sediments as a result of sewage disposal.

Summary

The Dover boat appears to have been abandoned in a backwater area of the river valley subject to quiet water flooding, predominantly freshwater but perhaps infrequently affected by very high tides (such as high spring tides), most likely with a natural sand/shingle barrier in place across the mouth of the River Dour. The sea was probably at a mean level of between 2m and 5m below the level at which the boat was emplaced, but it is not clear how far away it was. Shallow, well-oxygenated, unpolluted, moderately fast-flowing water ran through braided channels among rather diminutive gravel bars and sandbanks, with probably relatively steep banks at the margin of the channel system. In other places, permanent slow-flowing, well-vegetated shallow water with marginal, disturbed open rush marshes, temporary shallow pools, flooded water meadows and pasture existed within the floodplain. The channels had gravel or stony bottoms but patches of mud were also present in places where water flow was slower. The surrounding vegetation appears to already have been extensively modified by human activity, with open, disturbed grassland (probably providing poor-quality grazing for herbivores) in a largely treeless landscape and arable land further afield (probably on the hill slopes and cultivated terraces on the valley sides).

The large mammal bones found in sediments closely associated with the boat (Stewart 1998) were of cattle, sheep/goat, pig, red deer and dog and indicated the presence of people nearby, perhaps a form of habitation or settlement. Four bones showed signs of cut marks thought to be the result of butchery – one of these was a sheep; the others belonged to cattle. Other types of surface alteration to the bones was also recorded, including water wear, gnawing by carnivores, marks that could be attributable to trampling or similar mechanical processes, and evidence of weathering. These various marks signify that some bones were exposed for some time between death or disposal by man and eventual burial, and that others spent a relatively long period in the river prior to burial.

As to whether the Dover boat regularly worked the lower reaches of the River Dour, the environmental evidence clearly indicates that this was very unlikely. As Parfitt and Champion have concluded (Chapter 15), while the river would have been a valuable source of drinking water, it would never have been much use for water transport, certainly not for such a substantial vessel as the Dover boat. In fact, given the estimated dimensions of the boat, and despite its shallow unladen draft, it seems unlikely that it was emplaced as a result of floating unaided up the River Dour, which at most times probably comprised shallow streamlets flowing among rather diminutive gravel bars and sand banks. Also, the presence of quartz sand, glauconite and marine mollusc shells on the inboard surface of the boat provides strong evidence for its maritime use. There is no indication that the abandonment of the boat was associated with any sort of marine flooding event, but the River Dour in flood might have presented an opportunity for floating the boat into the position in which it was found. This would have involved propelling the boat against the flood flow – a difficult, but not impossible, task. Alternatively, the boat could have been hauled or carried into position.

The environmental evidence

The results from the individual specialist analyses have enabled us to build up a picture of the Dour valley at the time of boat's abandonment, and these are drawn upon below. Full analytical data and detailed interpretations can be found in the specialist archive reports held at Dover Museum.

The sediments

Investigations by Bates and Barham (1993a) associated with the Dover A20 road and sewer scheme recorded a sequence of angular flint gravels on the floor of the Dour valley (the earliest sediments), overlain by freshwater organic silts, peats, tufa and tufa-pellet gravels. Penetrating into this association of freshwater sediments were the footings of a Roman quay, and the overlying deposits all contained evidence of marine conditions. The same basic stratigraphic sequence was recorded in the boat trench and has been reported upon by Green (1998). The three elements most closely associated with the boat (the underlying peat, the tufa/silts, sands and gravels and the overlying bedded silts) are shown in the site matrix (Fig 12.1). The position of the main sections in relation to the boat is shown in Fig 3.4. The relation of the boat to the tufa/silts, sands and gravels and the overlying bedded silts is illustrated in Section 134 (Fig 12.2), which clearly shows how the sediments overlying the boat were eroded and replaced by the bedded silts.

The peat

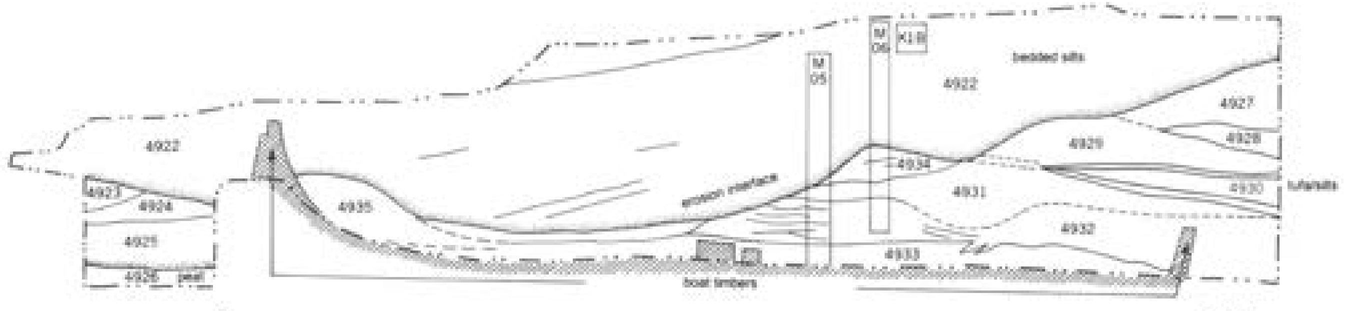
The peat forms a horizon that could be traced with reasonable confidence throughout the extent of the boat trench below the boat. The upper surface of the peat was uneven and had clearly been eroded. The bulk of the peat was well humified, with very little or no mineral material present, but there were partings in the peat formed by mineral grains, perhaps indicating episodes of sediment erosion upstream. Although the peat itself is known to be considerably older than the boat (Bates and Barham 1993a), only a thin veneer of tufa/silt was found between it and the base of the boat, indicating that the erosion event that truncated the peat had ended only a relatively short time before the boat was abandoned. The erosion of the peat, and its subsequent cessation, might have been caused by migration of the river channel within the floodplain.

The tufa/silts, sands and gravels

The tufa/silts and tufa-rich sands and gravels were present immediately below and above the boat and overlain by the bedded silts. There was some indication of scour beneath the eastern side of the boat, with subsequent infill with sands and gravels. The upper surface of the tufa/silts, sands and gravels was uneven, and the horizontal bedding appeared to be truncated in places, to the extent that one end of the boat had been exposed and then re-covered by bedded silts. The sediments surrounding the boat – which appear to have accumulated relatively rapidly – comprised mainly tufa debris but also included subround flint pebbles, subangular chips of flint, sharp flint flakes (including debitage) and pebbles of chalk. The mineral component was always accompanied by an organic component (including rolled peat clasts, twigs, pieces of wood, charcoal, moss fronds, seeds, bone, terrestrial and freshwater mollusc shells and shell debris, and ostracod valves). These organic components must have been derived from the erosion of the underlying peat, from sediments upstream and from material in the immediate contemporary environment. Marine shells were recorded in the immediate fill of the boat and sediment scraped off the outboard of the boat. Fine-grained sediment associated with the sands and gravels was generally silt-rich, formed in large part by tufa mixed with varying proportions of organic material, so that the silty sediments could be pale coloured and tufa-rich, or dark coloured and organic-rich (Fig 5.2).

Inside the boat, the bottom timbers were covered by a thin, distinctive, silty horizon, which contained marine-shell debris, relatively large amounts of quartz sand and common grains of glauconite. The silt is most likely to have built up immediately after the boat was abandoned, dropping out of water standing in or flowing slowly through the hulk. The sand and glauconite were probably trodden into the boat somewhere on a beach, before the abandonment of the boat, and this provides strong evidence for maritime use of the boat.

Figure 12.2 Section 134, showing contexts and sample locations.



The bedded silts

The tufa/silts, sands and gravels appear to have undergone a period of erosion after the boat was abandoned, after which they were overlain by silt-rich deposits, generally dark greyish brown in colour, containing plant debris and molluscs, and bedded or laminated in places. Evidence from the assessment indicated that the bedded silts had accumulated in an increasingly marine environment (Clark and Keeley 1997).

Pollen

The dispersal, preservation and interpretation of pollen and spores have been discussed in detail by Dimbleby (1978). The factors most conducive to pollen preservation in sediments are acidity (pH <5.5), anaerobic conditions (usually the result of waterlogging), extreme aridity (eg in desert environments) and extreme cold, all of which suppress the activity of bacteria and other organisms that destroy the pollen grains. The sediments associated with the boat were generally calcareous but also waterlogged, and thus the conditions for survival of pollen in an anaerobic environment appeared to be in place.

A generalised timescale of vegetation history, climatic change and archaeological periods in Britain during the Holocene is shown in Figure 12.3. Lowe *et al* (1998), who analysed the pollen from the deposits associated with the Dover boat, have produced a scheme for Kent that recognises five zones, slightly different from the general picture:

- Holocene I (*c* 8000 to 7500 Cal BC; *c* 8900–8400 BP) is characterised by birch (*Betula*) and juniper (*Juniperus*) and represents the expansion of woodland into south-east England during the earliest period of the present interglacial, after the end of the last cold stage (Devensian Glacial Stage).
- Holocene II (*c* 7500 to 5000 Cal BC; *c* 8400–6100 BP) is characterised by pine (*Pinus*), hazel (*Corylus*) and elm (*Ulmus*). The rise of *Corylus avellana* during this period was most likely the result of a climatic response owing to a drier and more continental climatic regime, which might have been facilitated by the possible higher incidence of fire, which allowed hazel to out-compete elm and oak (*Quercus*).

Years. BP.	Blytt-Serander climatic periods	Archaeological period	Pollen zone (Godwin, 1940)	Chrono-zone (Hibbert et al, 1971)	Generalised climatic change	
1000	Sub-Atlantic	Roman	VIII	F1-III	*Cold and wet*	Climatic deterioration
2000		Iron Age				
3000	Sub-Boreal	Bronze Age	VIIb		*Warm and dry*	
4000		Neolithic				
5000						
6000	Atlantic	Mesolithic	VIIa	F1-II	*Warm and wet*	Climatic optimum
7000						
8000	Boreal		V/VI	F1-I	*Warm and dry*	
9000						
10000	Pre-Boreal		IV		*Cool and dry*	Climatic amelioration

Figure 12.3
Generalised chronology (radiocarbon timescale) of vegetation history, climatic change and archaeological periods in Britain during the Holocene (adapted from Roberts 1989; Simmons and Tooley 1981).

- Holocene III (*c* 5500 to 3200 Cal BC; *c* 6100–4500 BP) is characterised by alder (*Alnus*) and lime (*Tilia*). Evidence suggests that the rise in alder is most likely to have been the result of human activity in inland areas, but it could be attributed to local natural succession in coastal or valley-bottom locations. *Tilia* appears to have expanded during this period into areas with base-rich soils.
- Holocene IV (*c* 3200 to 2500 Cal BC; *c* 4500–4000 BP) is characterised by hazel (*Corylus*), oak (*Quercus*) and birch (*Betula*) and also by the decline of *Ulmus* (the so-called 'Elm Decline') and a substantial change in the composition of vegetation communities. The 'Elm Decline' could be attributed to climatic change, human activity, factors affecting pollen distribution or survival, disease or competition, and, as strong cases have been made for all of them, the primary cause remains unresolved.
- Holocene V (from *c* 2500 Cal BC; *c* 4000 BP) is a deforestation phase, with reduction in deciduous woodland and increase in open grassland and heath associated with widespread human activity. Pollen evidence for human activity in the Bronze Age has been reported from sites in Sussex, Surrey and the Isle of Wight, often associated with peat initiation resulting from higher water tables following episodes of deforestation. There is also evidence for the decline of *Tilia* (lime) during the Bronze Age in south and south-east England, probably associated with human activity.

The cores/monoliths selected for pollen analysis were chosen to provide a sequence through the main deposits, concentrating on the tufa/silts, sands and gravels contemporary with the boat (Fig 12.4).

The peat

The junction between the upper peat and the overlying tufa/silts was best exposed in 4-inch Core 1, which had been taken close to the north-east side of the boat (Fig 3.4). The pollen assemblage from the upper peat suggested an open, herb-dominated community, a mixture of dry and damp grassland. The very low tree pollen totals, presence of *Fraxinus* (ash) and single occurrence of cereal grass pollen suggests clearance. The peat appears to date to the very end of the *Corylus* (hazel) decline and to post-date the elm decline and general loss of woodland in southern England – that is, to around the end of Holocene IV or the start of Holocene V (Lowe *et al* 1998). This confirms the assessed evidence for the truncated upper peat being about 1,000 years (or more) older than the boat (Clark and Keeley 1997). Indications are that the local environment at this time was of dry-to-marshy meadow vegetation, largely treeless or with only scattered hazel and perhaps birch and oak, but mainly a herb-dominated vegetation cover.

The tufa/silts, sands and gravels

One of the most coherent of the pollen sequences investigated in the Dover boat analysis project was provided by Monolith M02 (Section 144; not illustrated) that was taken immediately adjacent to the south-east end of the boat (*see* Fig 3.4). The pollen diagram is shown in Fig 12.4 (Lowe *et al* 1998). The monolith sampled the upper, truncated peat and the tufa/silts and sands surrounding the boat. Pollen in the calcareous tufa/silts and sands indicated a non-wooded landscape, with an open herb-dominated vegetation cover. There is a diverse record of herb plants, all indicative of dry grassland or occurring as weeds of cultivated ground. The very high percentages of *Plantago lanceolata* and *Pteridium* indicate weed-infested grassland and woodland clearance by humans for pastoral activity. The records of *Chenopodium* and *Plantago maritima* suggest a marine influence. The nature of this is unclear but might reflect the proximity of salt marsh and/or vegetation on the adjacent cliffs. The records of *Mentha* (mint), *Hydrocotyle* (pennywort), *Sparganium* (bur-reeds) and *Typha* (great reedmace) indicate that the local soils were damp and that the site was close to the river's edge or that standing pools of water occurred in the vicinity.

Another monolith analysed (M10, Section 136) was located within the tufa/silts, sands and gravels filling the boat and probably resting directly on the inboard surface of the boat timbers. This contained sediments that were calcareous and with generally very low pollen concentrations and poor preservation, so the pollen data have been interpreted with some caution. However, there are clear similarities between this pollen assemblage and the tufa/silts in M02 – in particular, high percentages of *Plantago lanceolata* and *Pteridium*. Many of the other pollen types recorded were characteristic of grassland communities, although there was evidence

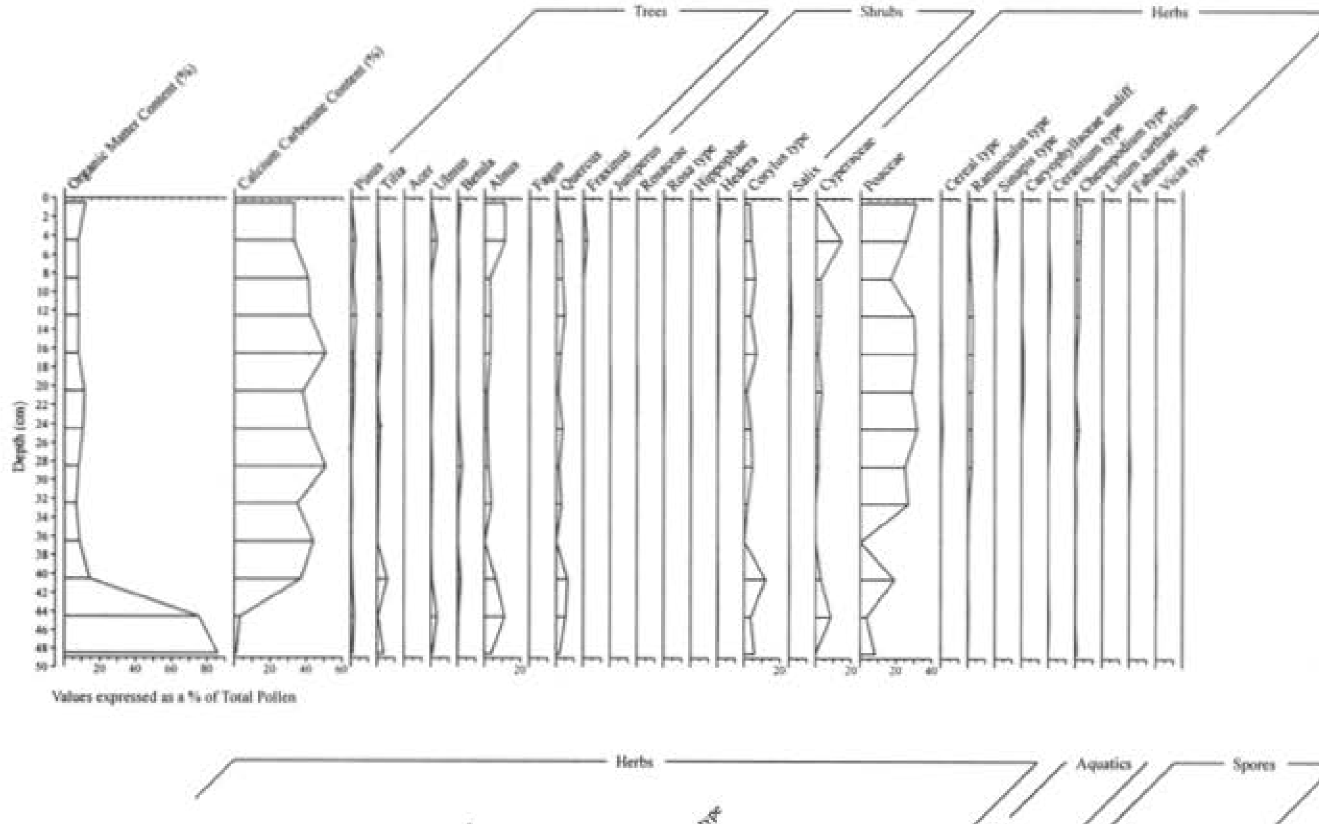
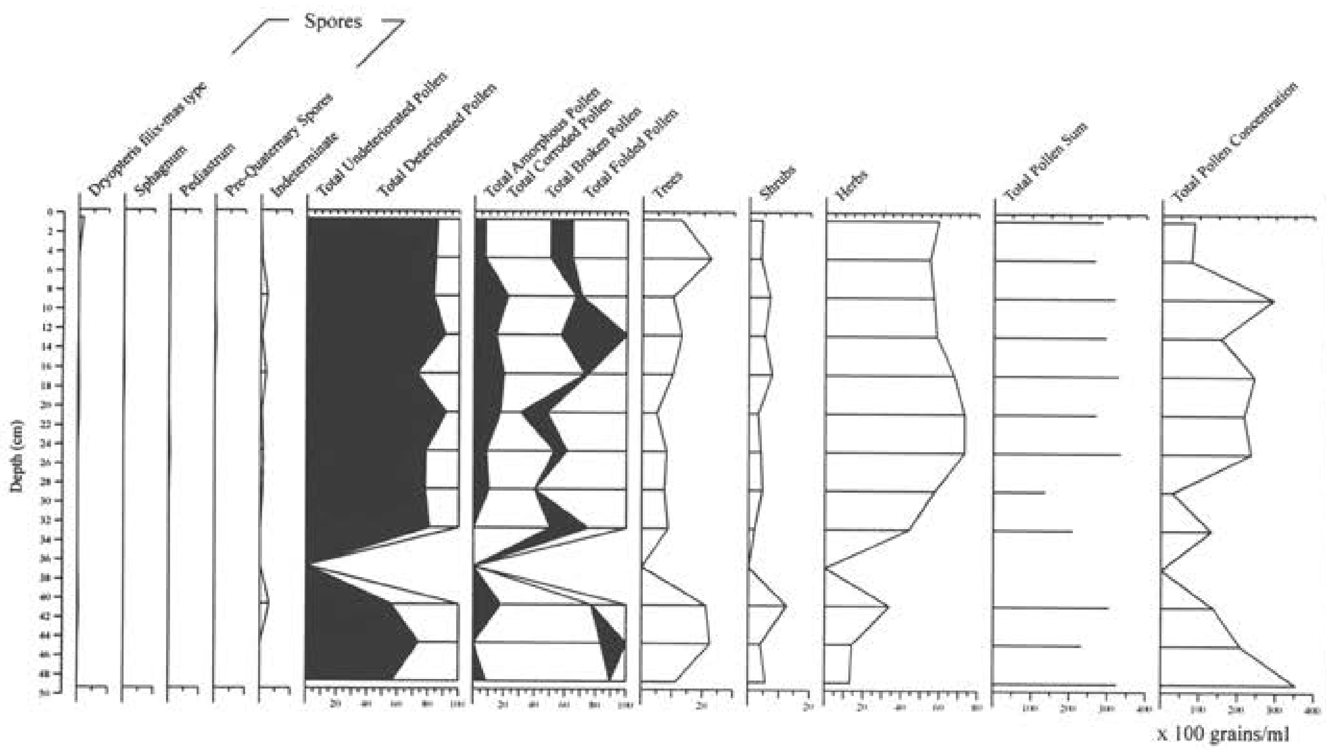


Figure 12.4
(above and opposite)
Composite pollen diagram.

in one level for quite a strong but short-lived recovery of woodland. This appears to be typical of records obtained for floodplain contexts and of human interference with floodplain vegetation from the Bronze Age to the Iron Age (Lowe *et al* 1998). There were also indications of pulses of sediment deposition, such as flooding events.

Samples of sediment scraped off the underside (outboard) of the boat contained pollen that showed many features in common with the pollen assemblages obtained from the tufa/silts in M02, including indicators of open grassland (dry to damp). Cereal pollen was also noted in a few of these samples.



Values expressed as a % of Total Pollen

In general, the pollen evidence indicates that the boat was abandoned in an area already extensively modified by human activity. There is little change in the overall pollen percentage data from the tufa/silts, sands and gravels, suggesting that the boat was buried rapidly, as indicated by the sediment studies (Green 1998), probably as a result of agricultural activities upstream. There is little evidence for boatbuilding materials close to the site. No yew (*Taxus*) pollen was found, although it should be noted that this is produced in low abundance and rarely survives in countable numbers. Oaks (*Quercus*) might have been present in the vicinity, but do not appear to have been widespread at the time the boat was abandoned.

Diatoms

Diatoms are microscopic unicellular algae, which live in water and are characterised by their ornamented silica outer shell. They grow as single cells or colonies that might be free-living in water, attached to submerged surfaces or motile in and on underwater surfaces and comprise one of the most abundant algal groups, distributed worldwide and found in freshwater, brackish, marine and terrestrial habitats. After the death of the diatom, the shells are often preserved in the sediments of ditches, ponds, lakes, rivers and in coastal or ocean sediments. The composition of species growing together is a sensitive indicator of water-quality factors, such as the level of acidity, phosphate and salinity. In view of the sensitivity of diatoms to salinity, the primary aim of analysis in the Dover-boat project was to determine the salinity conditions under which the sediments associated with the boat had accumulated (Fig 12.5). The samples studied were from the same suite analysed for pollen (excluding the peat) and these were reported on by Cameron and Dobinson (1998).

The tufa/silts, sands and gravels

The diatom assemblage from M10, Section 136, which sampled the tufa/silts filling the boat, was dominated by oligohalobous-indifferent (freshwater) taxa throughout the profile, although brackish and halophilous (slightly brackish) were more frequent in the lower part of the sediment column. Almost all the taxa were non-planktonic species (ie those that are associated with, or attached to, submerged surfaces), suggesting that the source of the diatoms is likely to be close by and the habitat represented is one of relatively shallow water.

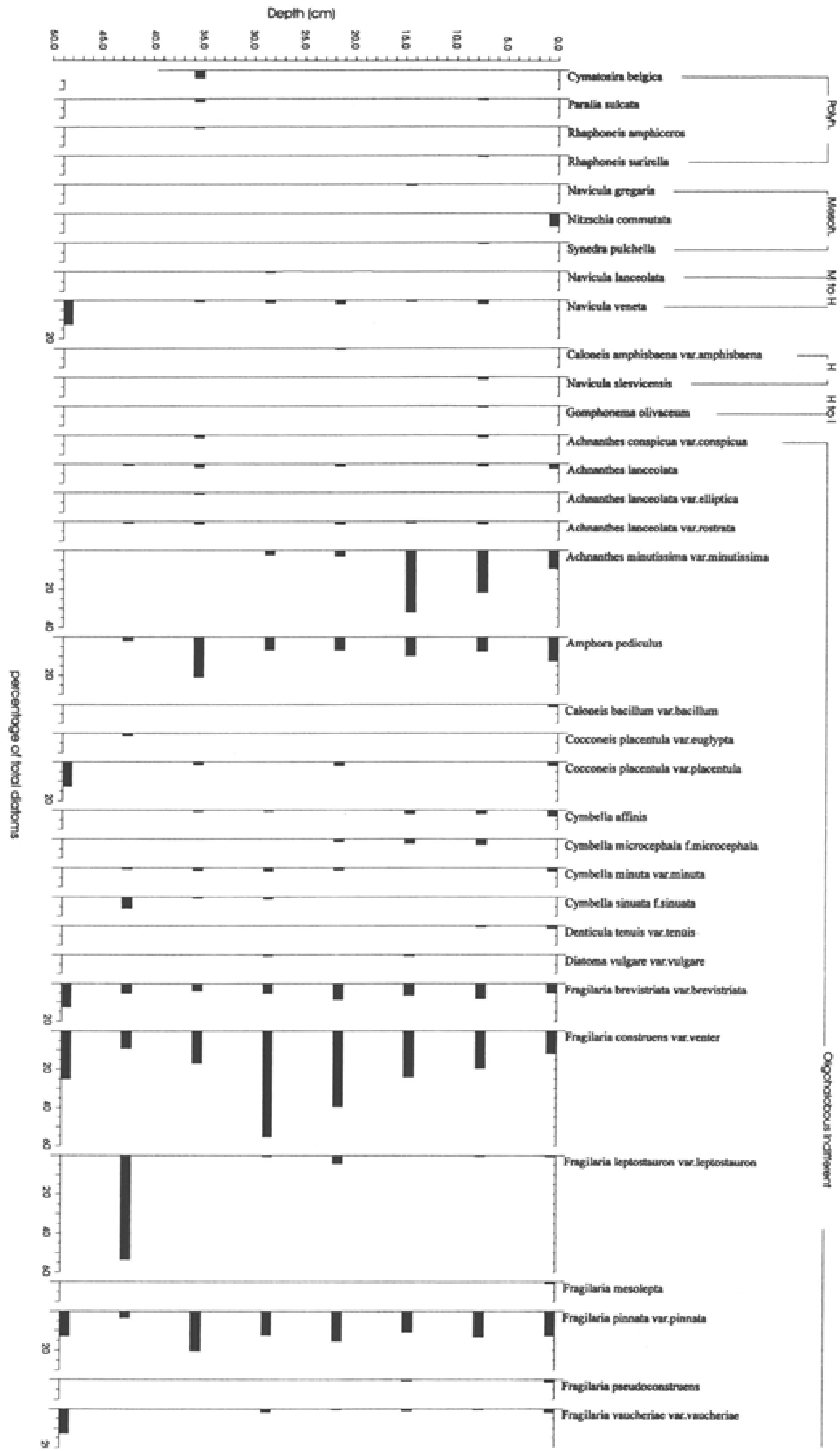
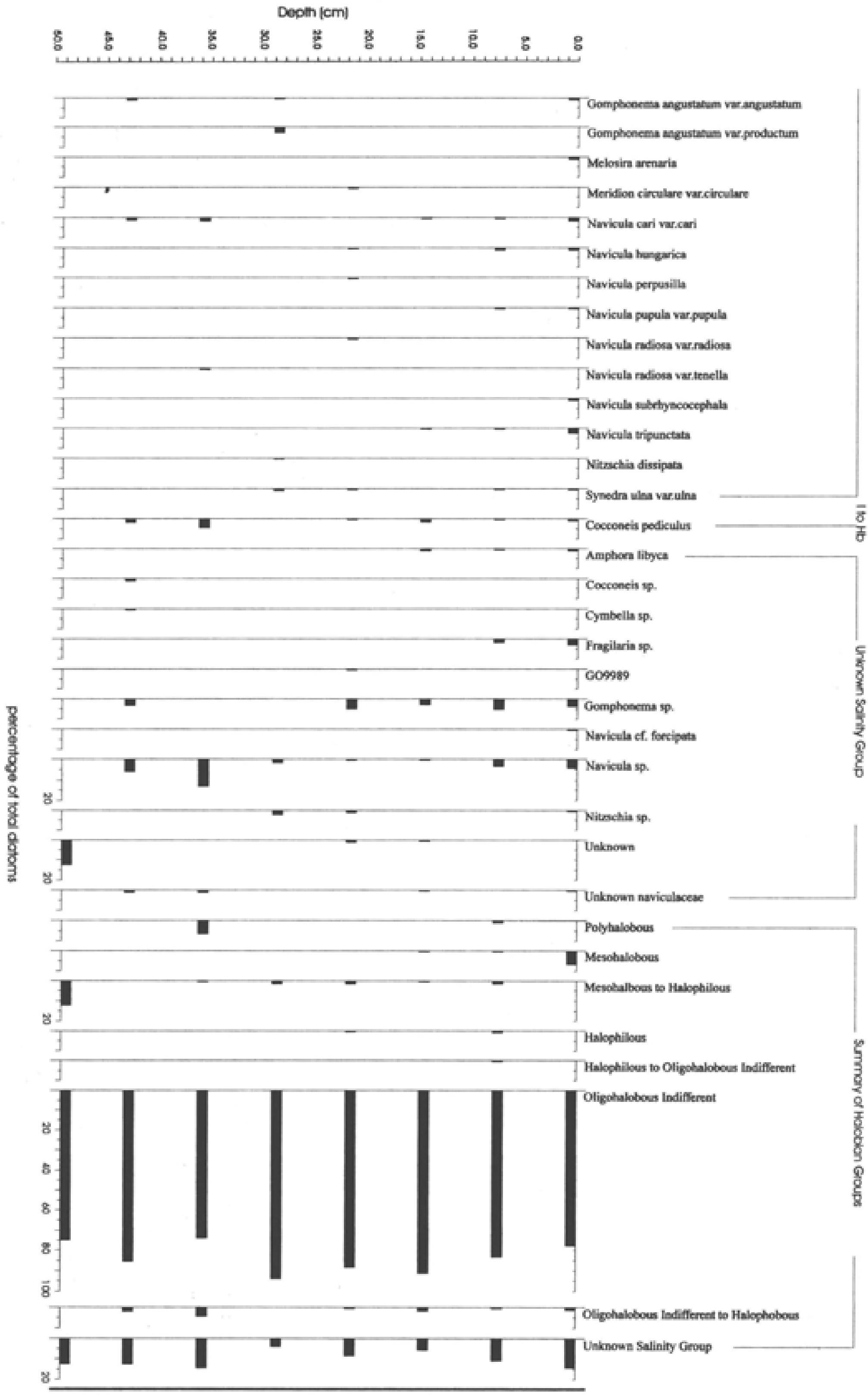


Figure 12.5
Composite diatom diagram.


Depth (cm)
60.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Gomphonema angustatum var.angustatum
Gomphonema angustatum var.productum
Melosira arenaria
Meridion circulare var.circulare
Navicula cari var.cari
Navicula hungarica
Navicula perpusilla
Navicula pupula var.pupula
Navicula radiosa var.radiosa
Navicula radiosa var.tenella
Navicula subrhyncocephala
Navicula tripunctata
Nitzschia dissipata
Synedra ulna var.ulna
Cocconeis pediculus
Amphora libyca
Cocconeis sp.
Cymbella sp.
Fragilaria sp.
GO9989
Gomphonema sp.
Navicula cf. forcipata
Navicula sp.
Nitzschia sp.
Unknown
Unknown naviculaceae
Polyhalobous
Mesohalobous
Mesohalbous to Halophilous
Halophilous
Halophilous to Oligohalobous Indifferent
Oligohalobous Indifferent
Oligohalobous Indifferent to Halophobous
Unknown Salinity Group
I to Hb
Unknown Salinity Group
Summary of Halobian Groups
percentage of total diatoms
20
20
20
20
40
60
80
100
20

Diatoms associated with full marine conditions were completely absent and taxa that grow in marine-to-brackish salinities occurred at cumulative abundances of less than 5 per cent, suggesting that, even during its most saline phase, the sedimentary environment was not in a fully tidal location.

Another monolith (M01, Section 132) taken along the north-south axis of the boat (*see* Fig 3.4) sampled the tufa/silts above the boat structure and the overlying bedded silts. The picture for the former was essentially similar to that for M10, being dominated by freshwater diatoms, including various *Fragilaria* taxa (*F. leptostauron*, *F. brevistriata*, *F. constuens* var. *venter* and *F. pinnata)*.

As for M10 and M01, the diatom assemblages in all samples from the tufa/silts above the boat in M02 Section 144 (the main pollen sequence; not illustrated) were dominated by the oligohalobous-indifferent (freshwater) halobian group and almost all were non-planktonic life forms, probably from a nearby source, indicating that the environment was one of shallow water (*see* Fig 12.5). As in M10, marine and brackish water species were rare, suggesting that the site was not regularly affected by tides but might have been reached infrequently, for example by high spring tides. The dominance of a species such as *Fragilaria leptostauron* (which is often associated with shallow-water mud habitats) might indicate a large area of mud surface for diatom colonisation, but, as the species is robust (heavily silicified), its dominance in one sample might be the result of differential preservation. The common occurrence of a number of 'opportunistic' *Fragilaria* taxa suggests that the aquatic habitat available was, to some degree, ephemeral – such as shallow pools that were subject to drying out.

The bedded silts

The uppermost sample from M01, Section 132, came from the overlying bedded silts and contained a mesohalobous (brackish) diatom *Nitzschia acuminata* and a semi-planktonic marine species (*Cymatosira belgica*), indicating a degree of direct contact with the marine environment. This confirms the results of previous assessment work on other biological remains from the bedded silts (Clark and Keeley 1997).

Ostracods

Ostracods are a diverse group of small bivalved crustaceans that occur in almost all aquatic environments. The animals themselves are essentially shrimp-like, but with a bivalved, calcareous shell (carapace). Many species occur in fresh waters, almost 100 of which are known from modern Britain and British Pleistocene and Holocene deposits, and are recognised as valuable indicators of hydrological and climatic conditions (Griffiths *et al* 1993). Ostracod valves preserve well in a wide variety of depositional environments, sometimes in very large numbers, and assemblages can provide quite specific information on the nature of the environment from which they derive. Ostracods might be expected to occur in almost any non-acidic, water-lain deposit, but, as ostracod shells are calcareous, optimal preservation occurs in calcareous deposits such as tufas and marls, although they also occur in other fine sediments. Thus it was expected that the tufa/silts, sands and gravels associated with the Dover boat could provide suitable conditions for ostracod preservation and useful information about the depositional environment of these deposits.

Analysis was carried out by Robinson (1998) but of the twenty samples examined only eight from the tufa/silts surrounding the boat provided an adequate ostracod fauna for study. All shared a relationship to calc-tufa sequences, although none represented a normal *in situ* calc spring deposit. Most seemed to testify to muddy, silty sediment and all were of a freshwater character. All contained specimens of *Prionocypris serrata* (some samples were dominated by it), which frequently occurs in temporary pools and flooded water meadows, where it survives successfully in wet grass. The species *Potamocypris fulva* and the entire genus is another ostracod which signifies temporary wetlands, often associated with spring emissions or spring-fed pools. The suggestion that part of the aquatic habitat at the time of boat abandonment might be temporary in nature ties in with the results of the diatom analysis (Cameron and Dobinson 1998).

Molluscs

In palaeoenvironmental reconstruction, molluscs share with beetles the advantage of occurring in a great variety of deposits – terrestrial, freshwater and marine –

although they are unusual in non-calcareous sediments from which the exoskeletons – formed predominantly of calcium carbonate – are leached. However, if preservation is good, molluscs can be identified to species level and the composition of assemblages can be used as an indicator of past environments. Molluscs are influenced by the microclimate (rather than the macroclimate) of the local site, and changes in the species composition of the assemblage are likely to reflect ecological change rather than climatic change. Thus, although molluscs cannot be used with any confidence in establishing the magnitude of climatic change, a strength of molluscan analysis lies in the detail with which local site conditions can be reconstructed. Molluscs can also be used to indicate changes in water quality and water depth (Simmons and Tooley 1981).

In view of the calcareous nature of the deposits surrounding the boat, molluscan analysis appeared to have considerable potential to provide a picture of the local environment and water conditions and was carried out by Wilkinson (1998), who examined both gastropods and bivalves.

A series of samples was studied that provided a complete sequence from the eroded top of the peat, through the tufa/silts, sands and gravels immediately underlying, within and directly overlying the boat and into the overlying alluvial-bedded silts, thus providing a 'master sequence' with which other assemblages could be compared. The results are shown in Figure 12.6. The relationship between the contexts and the boat is shown in the site matrix (*see* Fig 12.1) and the samples came from three sections (134, *see* Fig 12.2; 135, not illustrated; 131, not illustrated), all running at right angles to the length of the boat (*see* Fig 3.4).

The peat

Mollusc preservation in Context 4963/4911 (Section 131, not illustrated) was surprisingly good and more mollusc shells were recovered from this horizon than from any other. However, despite the large number of shells recovered, the diversity of the assemblage was low. The main species were indicative of a slow-flowing stream or river rich in vegetation and a bed of plant debris. The sample came from where the base of the tufa/silts overlay the eroded peat surface and it seems likely that this molluscan assemblage post-dates the peat formation and has subsequently been incorporated in the upper part of the peat, along with the tufa granules. The small terrestrial component indicated that the 'dry' land was some distance from the sample site and was probably shaded.

A sample was analysed from Context 4926 (Section 134) in a pit adjacent to the boat, which probably pre-dated 4963/4911 (Section 131, not illustrated) and was related to the peat accumulation. The assemblage was diverse but consisted largely of several species characteristic of marshland and other wet, muddy areas such as *Carychium minimum*, *Lymnaea truncatula*, Succineidae and *Vertigo angustior*. The fully aquatic species were either tolerant of all conditions (*Pisidium nitidum* and *Lymnaea peregra*) or preferred highly vegetated aquatic environments (*Valvata cristata*). The terrestrial species (*c* 35 per cent) were overwhelmingly dominated by shade-loving species – such as *Discus rotundatus*, *Aegopinella* sp. and *Oxychilus* sp. – indicating there was a great deal of tall vegetation. These data tie in closely with the pollen and sediment results, suggesting that the peat developed at the margin of a stream channel as a 'backswamp' or a cut-off channel still exposed to occasional flooding, possibly in a relatively calcareous environment. The peat would have been characterised by areas of exposed mud, zones of pools or rivulets containing aquatic vegetation and drier areas on which plants, including trees, could grow.

The tufa/silts, sands and gravels

Below the boat

Samples from tufa/silts, sands and gravels immediately underlying the boat contained mollusc assemblages of a broadly similar nature to that in the underlying peat but with fewer shells of species preferring moving water. Shell preservation was generally poor. The earliest assemblage (Context 4938, Section 135, not illustrated) was dominated by *Pisidium nitidum* (which inhabits most aquatic environments) and to a lesser extent *Valvata piscinalis* (which generally inhabits moderate to large size bodies of moving water). The less numerous component included species and families (*Lymnaea peregra*, *Lymnaea truncatula*, Succineidae) indicative of rather quieter water conditions than before, with reduced flow and limited areas of mud. The proportion of fully terrestrial species was higher than in Context 4963/4911 and the dry-land component mostly consisted of shade-loving species, suggesting that the dry land was closer to the sample site than before. The shade could have been the result of the development of long grassland rather than woodland, as no compulsive arbophiles were noted. The change of environment from before could have been the result of local changes to the river-bed morphology. The braid of the river in which the boat was abandoned might have become marginalised from the main area of flow, or there might have been a broader reduction to the flow of the Dour.

In Contexts 4937 and 4936 (Section 135, not illustrated) there was a major change in the assemblages from earlier deposits, with species indicative of large bodies of water declining further and being replaced by another species indicative of moving water, *Ancylus fluviatilis*. The latter requires a hard substrate, which is likely to have been provided by the tufa that had accumulated above the peat, and fast-to-moderate moving water. The species indicative of marsh and mud-rich environments rapidly declined and the shade-loving terrestrial species were replaced by species indicative of open-country conditions, such as *Pupilla muscorum* (a significant proportion of which, however, might have been derived from sediments of late glacial age) and *Vallonia costata*. The impression given is that a sharp divide was forming between the aquatic and terrestrial environments.

Accumulation of tufa was the main factor in the change in aquatic conditions, including accretion on the muddy channel margins previously occupied by mud banks. The increase in open-country species might have been the result of human clearance of the longer vegetation for agricultural purposes. The environment immediately prior to the abandonment of the boat (Context 4936, Section 135, not illustrated) seems to have been within a freshwater, highly calcareous, braided channel system surrounded – perhaps on individual bars between channels – by areas of open country – probably grazed grassland.

Above the boat

The first sample that post-dates the abandonment of the boat was from Context 4933 (Section 134, *see* Fig 12.2), which represents the primary fill of the boat. This had a very unusual mollusc assemblage, overwhelmingly dominated (98 per cent or more) by *Lymnaea peregra* – a species that can tolerate a wide variety of different aquatic conditions and, thus, an extremely efficient coloniser of newly created environments. It is most likely that, following the abandonment of the boat, sediment-rich pools developed within the interior. These were colonised by *Lymnaea peregra*, which might have entered in water seeping through the decaying structure.

In Contexts 4932 to 4929 (Section 134, *see* Fig 12.2) the mollusc assemblages were similar both to each other and to those from 4936 and 4937 (Section 135, not illustrated). These lay beneath the boat, being dominated by *Ancylus fluviatilis, Lymnaea peregra* and terrestrial open-country taxa, indicating that the environment following the boat's abandonment remained much as before. There are some notable changes, however, which might indicate subtle alterations to the local environment. The reduction in *Ancylus fluviatilis* (and freshwater species in general) towards the top of the tufa/silts, sands and gravels, accompanied by an increase in marsh dwellers and fully terrestrial species, might indicate further marginalisation of the area around the boat from the zone of predominant water flow.

Other samples from the tufa/silts, sands and gravels were comparable with those from the 'master sequence', indicating an environment characterised by moderately fast-flowing water on a tufa substrate with the area around the stream largely occupied by short grassland. Context 4932 (Section 134, *see* Fig 12.2) appeared to be primarily derived from dry-land material, possibly including cultural debris, and could have accumulated on the margin of one of the braided channels. It contained two shells of the marine species *Littorina littorea*, which are likely to have been introduced onto the contemporary ground surface by man.

Samples from tufa/silts, sands and gravels at the southern end of the boat showed some differences from the 'master sequence', indicating that conditions in the former were more marginal to the main area of water flow, although there was still a relatively sharp divide between dry land and the channel. Samples taken from sediment attached to the underside (outboard) of the boat contained species that indicated slow-moving water in the watercourse in which the boat was abandoned and there do not appear to have been areas of semi-flooded, mud-rich marsh. The terrestrial component was dominated by open-country species and indicated that the area immediately surrounding the river most likely comprised grazed grassland with occasional stands of longer vegetation (but no trees) and damp grassland at the water's edge.

The bedded silts

Mollusc preservation in the overlying bedded silts (Context 4922, Section 134, Fig 12.2) was highly variable, but the results indicate, as do the sediment data (Green 1998), an alteration in stream behaviour to deeper, slower-flowing water, which probably took the form of a change from a braided to a single channel bedform (or at least to fewer, larger channel bedforms). Terrestrial molluscs are overwhelmingly dominated by open-country and catholic species and the lack of shade-loving species in the upper deposits suggests that the area surrounding the stream channel was almost totally devoid of vegetation.

Plant macrofossils

The remains of plants of economic importance, such as cereals, vegetables and fruits, can provide evidence of agriculture, social organisation and diet. Plant remains from natural or human-influenced ecosystems can point to local vegetation history and, by proxy, local environmental conditions in river systems. Plant macrofossils are those remains that can be seen with the naked eye (although species identification usually requires microscopy) – such as seeds, fruits and vegetative structures – as opposed to microfossils, which can be viewed only under magnification – such as pollen, spores and diatoms. Preservation usually requires an anaerobic environment (commonly waterlogging) or charring of the material, although extreme dryness or cold can also result in excellent resistance to decay. Remains might also be silicified in ash or preserved by mineralisation – usually in deposits extremely rich in calcium and phosphates.

Plant macrofossil assemblages reflect mainly the local flora, with several important caveats. For example, in channel and channel-bank deposits, plant remains are derived mainly from the vegetation of the river banks, but these deposits can also preserve macrofossils from more distant sources, especially taxa with buoyant seeds. Most vegetative matter is damaged in these environments, limiting identifiable fossils to fruits and seeds. Raised sediments accumulated on levees and around tree hummocks preserve few remains owing to oxidising conditions, and preservation in overbank sediments depends upon maintained water levels.

The waterlogged conditions of the boat sediments indicated good conditions for the preservation of plant macrofossils (Fairbairn 1998). Samples were examined from deposits scraped off the underside (outboard) of the boat and from tufa/silt, sand and gravel contexts associated with the boat. No samples from the peat or the overlying bedded silts were analysed. Seeds and fruits constituted the most diverse and abundant group of plant macrofossils. A small number of mosses was recovered (probably including small fragments of caulking used in the boat construction) and rare leaf fragments and epidermis (with the exception of bracken pinnules, which were common), bud scales, thorns and prickles were noted. The identified macrofossils were from plants of several distinct habitats: wetland trees (alder); submerged and floating aquatics; emergent aquatics; herbaceous riparian (river bank), marsh and mire taxa; dryland trees, shrubs and woody scrub taxa; dryland ferns and climbers; grassland taxa of wide distribution; chalk-grassland taxa; mesotrophic grassland taxa; domestic plants; and species indicative of arable and disturbed ground, waysides and wasteland.

The plant macrofossil assemblages, and the pattern of habitat representation, were generally similar throughout the deposits within which the boat was preserved. Taxa of arable, wetland and aquatic habitats dominated the assemblages in terms of numbers of taxa and numbers of macrofossils. Characeae (stonewort) oospores and the seeds of *Juncus bufonius* (toad rush) were occasionally very abundant, otherwise being present throughout the sample set in small numbers. Regularly abundant taxa included *Ranunculus acris* (buttercup), *Ranunculus* sub-genus *Batrachium* (water crowfoot), *Juncus acutiflorus* (rush) and *Chenopodium album* (fat hen). Many other taxa were less abundant but regularly present, including *Neckera crispa* (moss fragments), *Rubus fruticosus* (bramble), *Potentilla reptans* (creeping cinquefoil), *Mentha* (mint), *Eupatorium cannabinum* (hemp agrimony), Rosaceae (sloe/hawthorn type; thorns) and *Pteridium aquilinum* (bracken; pinnules). Rare taxa included *Zannichellia palustris* (horned pondweed) and *Clematis vitalba* (traveller's joy). The variation in taxon occurrence in individual samples did not affect the overall interpretation, suggesting that plant macrofossil assemblages were largely deposited in a similar range of depositional environments, with inputs from an identical range of source habitats throughout the period of deposition.

Two samples from the fill of the boat (Context 4933, Section 134, Fig 12.2; Context 5512, Section 144, not illustrated) contained macrofossil assemblages significantly different to those of the surrounding sediments, including low-diversity, abundant assemblages dominated by aquatic and wetland taxa. The dominant remains were small seeds and oospores, which do not float and are dispersed by wind, overland flow or in suspension in moving water. These concentrations might suggest that conditions inside the boat were of standing water, which allowed suspended macrofossils and fine-grained sediment to fall out of suspension and accumulate in the boat's hull, which ties in closely with the mollusc evidence (Wilkinson 1998) described previously.

All of the aquatic, riparian and wetland taxa identified grow in freshwater habitats. Although most of the remains were probably derived from local plants, the seeds of non-floating taxa might not be of local origin and the flora along the whole river course might also be represented. Permanent slow-flowing shallow water must have been present along the river at some point, indicated by the presence of *Callitriche* (starwort) and *Nymphaea* (water lily). The presence of *Juncus bufonius* (toad-rush) suggests that disturbed open-rush marsh or pasture existed nearby and this plant might have persisted on the open sandy river banks and bed, as it frequently colonises such areas today. Seeds of *Montia fontana* (blinks) and *Chrysosplenium oppositifolium* (golden saxifrage), which are not easily distributed in water, might indicate that there was a considerable groundwater flow emerging locally as springs or as less-concentrated seepage, as indicated by the ostracod evidence (Robinson 1998).

The presence of the aquatic and wetland taxa mentioned above, and of dryland taxa throughout the sample set, indicates that the river might have had extensive shallows and marginal marshes directly adjacent to dryland habitats. Seeds of some important and abundant taxa, however, such as goosefoots (*Chenopodium* sp.), which are well dispersed in water, might have come from upstream. It is unclear how close to the site the marshes would have been, as the mollusc evidence (Wilkinson 1998) suggests the lack of a local, developed bank-side habitat. Direct evidence for human activity included a charred hazelnut shell fragment identified in Context 5528, and a cereal grain recovered from Context 5512 (both specimens post-date the boat). These are most likely to have been incorporated through dumping of rubbish locally into the river, as evidenced by the large quantity of burnt flint, charcoal and animal bones in the deposits. This might also explain the presence of other taxa, such as the seeds of strawberry (*Fragaria vesca*) and blackberry (*Rubus fruticosus*), which might have been introduced as a result of sewage disposal. Less direct evidence comes from the range of disturbed and possible grassland habitats present around the site, all of which require human action to be maintained. Primary woodland taxa are almost totally lacking in the assemblages, the dryland flora being composed of open or scrub/secondary woodland species with an abundance of open-country taxa, indicating a cleared local environment, consistent with the site pollen record (Lowe *et al* 1998).

A developed Bronze Age weed flora was present which, with the waterlogged cereal grain, might indicate open arable land close to the site, if not on the river bank. The presence of *Chenopodium* (goosefoots), *Urtica dioica* (nettle) and *Glechoma hederacea* (ground ivy) indicate that some of the surrounding habitats were enriched with nitrogen, possibly because of human activity. Open-country and grassland species were present throughout. Chalk-grassland species were present, as well as taxa of more neutral or acidic soils and one possible source of these (as well as the river flow) could be animal dung, which the insect remains suggested was entering the river (Allison 1998). The common occurrence of *Thymus* (wild thyme) in the assemblages almost certainly indicates the presence of grazed or mown grassland in the vicinity of the site. The non-calcareous taxa might have grown on the alluvium.

Insect remains

Beetles (Coleoptera) and bugs (Hemiptera) are found in most terrestrial and freshwater habitats, including coastal ecosystems such as sand dunes and salt marshes. Although the beetle fauna of Britain is impoverished compared with that of the rest of Europe, there are about 3,700 species, and these are widely spread. Those species that have narrow ecological ranges are of particular value in environmental reconstruction (Simmons and Tooley 1981). For instance, some beetles are phytophages and live exclusively on particular plants, and others are carnivores. Beetle analyses have also made significant contributions to climatic interpretation. The remains of insects are best preserved under waterlogged conditions. Thus the sediments associated with the Dover boat appeared to offer suitable conditions for finding them, and samples from the tufa/silts, sands and gravels were analysed by Allison (1998). In practice, preservation varied somewhat between samples, but, generally, fragmentation was very high and some samples contained specimens showing a degree of chemical erosion, so that many small fragments could not easily be identified.

Tufa/silts, sands and gravels from below the boat

The two earliest samples came from the underside (outboard) of the boat. The deposits were clearly laid down in fresh water and aquatic taxa accounted for between 21 per cent and 35 per cent of the total. The most numerous beetles were running-water taxa, in particular the elmids *Elmis aenea*, *Limnius volckmari* and *Normandia nitens*, which require well-aerated water with a high oxygen content. All three of these species live under stones on the bottom of rivers and streams, and the tufa gravel might have provided a suitable substrate here. The presence of *Coelostoma orbiculare* and *Chaetarthria seminulum* suggest that slower moving, or stagnant, well-vegetated water might have been present in places.

The assemblages include part of a rich terrestrial fauna but many remains were very fragmentary and the plant-associated species, therefore, only hint at the terrestrial vegetation. The presence of fairly open, drier ground in the vicinity is suggested by the presence of the ground beetle *Calathus fuscipes* and the bug *Syromastus rhombeus*. The latter occurs in dry sandy habitats of all types and its foodplants are spurreys (*Spergularia*), sandworts and other Caryophyllaceae. Other indications of plant life included the *Phyllotreta nemorum* group found on crucifers, and two species of leaf weevils (*Phyllobius* or *Polydrusus*) found on various trees and bushes. Two chafers were recorded – the larvae of *Phyllopertha horticola* feed on the roots of turf and usually infest poor-quality pasture on light soil, preferring chalky soil in south-east England. *Cetonia aurata*, a larger species known as the rose chafer, has larvae that develop in rotten wood and humus. Scarabeid beetles usually associated with herbivore dung were common in the samples. Several species of *Aphodius* were represented, most commonly *Aphodius sphacelatus*, which occurs in dung of all kinds and also in rotting vegetable matter. Three species of *Onthophagus* were recorded, of which *Onthophagus ovatus* is found in horse or sheep dung, especially on chalky and sandy soils and *O. coenobita* feeds on corpses and fungi in addition to dung. No synanthropic insects were noted, which could have indicated human activity in the vicinity of the site.

Tufa/silts, sands and gravels from above the boat

Nine samples were examined from deposits post-dating the abandonment of the boat. Only a small sample was available from the thin silt layer lying on the timbers inside the boat (Context 4933), which contained *Normandia nitens* (a running-water species) and appeared to be a small extract of the fauna represented in the other, larger samples. The rest of the assemblages were all so strikingly similar that they can be treated together and they were also very similar to the samples from the underside of the boat. All indicated deposition in a freshwater environment. Aquatic beetles and bugs made up a major component of all the insect assemblages. Ephippia (resting eggs) of a water flea (Cladocera: *Ceriodaphnia*) were noted in two of the samples and, as with the earlier deposits, the most numerous beetles among the aquatic group were running water taxa, notably the elmids *Elmis aenea*, *Limnius volckmari* and *Normandia nitens*. Members of the genus *Ochthebius* provided further indications of water conditions: *O. exsculptus* lives in shallow running water and *O. bicolon* is found in rivers and streams mainly among vegetation in more slowly flowing water at the edges and also on muddy banks. Remains of *Hydraena* were also recorded, most of which are found in clear, unpolluted water.

The ground beetles (Caribidae) were a mixture of species found close to water and others typical of rather dry and open ground. Parts of the river bank might have been gravely or stony and rather barren – *Bembidion saxatile* is predominantly found in such situations. *Calathus fuscipes* was the most common ground beetle, which is mainly found in open country on rather dry soil. The range of waterside taxa suggested that slow-moving or still, well-vegetated waters were present in places, with areas of waterside mud indicated by *Chaetarthria seminulum*, *Platystethus cornutus* group and *Dryops* sp. A greater range of plant feeders could be identified, with emergent or floating vegetation indicated by at least two species of Donaciinae. *Prasocuris phellandrii* is a leaf beetle found in damp localities on umbelliferous plants standing in or by water, duckweed (*Lemna*) is indicated by the tiny weevil *Tanysphyrus lemnae*, and the froghopper *Conomelus anceps*, *Kateretes* sp. and the weevil *Limnobaris* sp. all indicate that rushes (*Juncus*) and sedges (*Carex*) grew at the water margins or on nearby damp ground.

Remains of four chafers were present, the most common being *Phyllopertha horticola*, whose larvae usually infest poor-quality pasture on light soil. A range of plant-associated taxa suggestive of scrubby vegetation were represented, including *Gymnetron ?labile* whose larvae develop in the heads of ribwort plantain (*Plantago lanceolata*) which was common in the pollen record (Lowe *et al* 1998), *Apion craccae* group found on vetches and vetchlings (*Lathyrus* or *Vicia*) and *Phyllotreta nemorum* group found on Cruciferae. Little evidence was obtained for the presence of trees, although fragments of leaf weevils were recorded from several samples and *Ramphus pulicarius* from two – this small weevil is associated with birch (*Betula*), willow (*Salix*), poplar (*Populus*) and sweet gale (*Myrica gale*).

In all samples, remains of scarabeid beetles usually associated with herbivore dung were common, the most numerous being *Aphodius sphacelatus*, a rather generalised dung feeder that also exploits foul decomposing vegetable matter. *Aphodius scrofa* was recorded from one sample. This species is now thought to be extinct in Britain. In the 19th century it was recorded in association with the dung of sheep, cows and horses. Several other *Aphodius* species, *Colobopterus erraticus* (most often found in sheep, pig or horse dung), possibly two *Geotrupes* spp. and two *Onthophagus* spp. were represented. *O. ovatus*, which is found in association with horse and sheep dung, was recovered from four samples. Again there were no synanthropic species that could have indicated human occupation or activity nearby.

Animal bones

Fish bones were recovered from thirty-one samples of tufa/silt, sand and gravel deposits both surrounding and adhering to the boat, and these were identified by Locker (1998). The following species were present: eel (*Anguilla anguilla*), Salmonidae, stickleback (*Gasterosteus aculeatus*), bullhead (*Cottus gobio*) and possibly thin-lipped grey mullet (*Liza ramada*). The bones were generally in good condition and represented the natural death assemblage of small fish inhabiting fresh water.

The eel remains included many small individuals, which might have been elvers migrating upstream from the sea during the late winter to spring. Two salmonid caudal vertebrae and a fragment of operculum were identified from the underside (outboard) of the boat. The vertebrae were from an individual of approximately 40cm in length and were the largest fish bones from the entire assemblage. Nevertheless, it was not possible to distinguish between salmon (*Salmo salar*) and brown trout (*Salmo trutta*) on morphological grounds, but on the evidence of current distribution this specimen is more likely to be the latter. Of the stickleback bones, those with distinctive features were closest to the three-spined stickleback (*Gasterosteus aculeatus*). The bullhead is a wholly freshwater species and is a bottom-living fish, hiding among stones and among weeds, and usually preferring a fast current and a stony bottom. A single, small precaudal vertebra has been very tentatively attributed to the thin-lipped grey mullet, a marine, shallow-water fish that will enter fresh water but could have entered this deposit as the remains of the meal of a seabird.

The rest of the vertebrate remains (Stewart 1998) comprised forty-five large mammal bones that were retrieved by hand during the excavation of the boat, and bones from sieved bulk samples. The large mammal bones were found in sediments immediately above and below the boat and inside the boat itself. Only a small number of bones came from the bulk samples, including those of a slow worm (*Anguis fragilis*), some frog or toad (*Rana* sp./*Bufo* sp.), a mouse (*Mus musculus*/*Apodemus sylvaticus*) that could not be identified to species, and a passerine bird. The large mammals comprised cattle, sheep/goat, pig, red deer and dog. The amphibian remains (frog/toad) are not out of place in a fluvial deposit, but the slow worm is not aquatic and its remains must have been introduced into the river sediment. Similarly, the small mammals are likely to have been introduced into the sediment as a result of bank collapse or seasonal flooding.

Four of the large mammal bones showed signs of cut marks, one of which belonged to a sheep, while the others belonged to cattle. They were:

- *Bos taurus*, right scapula, showing marks from disarticulation of the scapula from the humerus and a second set of filleting marks, removing muscle from the scapula;
- *Bos taurus*, proximal left metatarsus, with cut marks around the circumference of the bone that appear to be the result of skinning the carcass;
- *Bos taurus*, distal right humerus, with cut marks on the medial side of the condyle appearing to represent the disarticulation of the humerus from the radius and ulna; and
- *Ovis aries*, distal left humerus, with possible cut marks on the trochlea that might have been made during the disjointing of the humerus from the radius and ulna.

In addition to the cut marks, there were clear signs of water wear on three specimens, gnawing by carnivores on three (possibly four) specimens, marks that could be attributable to trampling or similar mechanical processes on two specimens, and evidence of weathering on nine (possibly thirteen) specimens. These marks signify that some bones were subject to a delay between death or disposal by man and eventual burial (the gnawing, trampling and weathering) and that others spent a relatively long period in the river prior to burial (the water wear).

The large mammal bones are mostly domesticated species, suggesting the presence of people in the area at the time of boat abandonment. As animal bones and human artefacts were only found immediately above, in and below the boat, it seems reasonable to suggest that habitation lay nearby, as some of the bones showed signs of being fresh and possessed cut marks, which ties in with evidence from the plant macrofossil analysis and the finds evidence (Chapter 11).

Summary

The environmental investigations described here have allowed us to address most of the questions originally posed in the introduction. It seems most likely that the boat was used in the sea, as the lower reaches of the Dour valley would hardly have been navigable at the time, although it is not possible to say how far away the sea was. This, and other general information about the Dour estuary, should emerge from study of the samples from the Dover A20 road and sewer scheme and more recent excavations in Dover. It is still not clear why the boat was abandoned where it was in the Dour valley, although some effort was evidently involved in getting it to its final resting place in a backwater area of the river, as the braided channels were shallow and probably quite narrow. It might even have been carried or dragged across the banks and shoals. The sea was probably at a mean level of 2m to 5m below the level at which the boat was emplaced. The edges of the channel system had steep banks and there might have been a main river channel as well as the braided channels, although its location and width are not known for certain. It appears, however, that, not long before the boat was abandoned, and then some time after it was covered by the tufa/silts, sands and gravels, a river channel passed through this area of the valley, first eroding the surface of the peat and later the tufa/silts overlying the boat. The boat was abandoned in freshwater, perhaps infrequently affected by very high tides, and there might have been a protective sand/shingle barrier across the mouth of the Dour at the time.

There seems to have been a settlement nearby at the time the boat was abandoned and the people appear to have been grazing animals on the valley floor, with arable agriculture further afield that resulted in considerable soil erosion and alluviation. Trees seem to have been sparse and it is unlikely that suitable timber for boatbuilding was available nearby, although there might have been wood for small repair work. There is no evidence for yew but this is not surprising as it rarely survives in the environmental record. The preservation of the boat was the result of rapid sediment deposition following its abandonment, probably caused by extensive soil erosion in the river catchment. We do not know how long this took, but it is likely to have been a matter of a few years rather than decades.

13
Dating

by Alex Bayliss, Cathy Groves, F Gerry McCormac, Christopher Bronk Ramsey, Mike G L Baillie, David Brown, Gordon T Cook and Roy V Switsur

From the time of the discovery of the Dover boat in 1992, precise dating has been a major aim of the project. Two absolute dating methods were used in order to establish the date of the boat: dendrochronology and radiocarbon measurement.

Initially, in order to achieve a reliable date for the boat, five samples were submitted for radiometric radiocarbon dating soon after the excavation. This was largely in response to the considerable media interest surrounding the discovery of the boat. Three of the five samples were measured at the Godwin Laboratory, University of Cambridge, and two at the Scottish Universities Research and Reactor Centre at East Kilbride (Table 13.1; Fig 13.1). These measurements demonstrated that the boat was indeed Bronze Age, but they were statistically inconsistent (T'=63.3; T'(5%)=9.5; v=4; Ward and Wilson 1978). Obviously, for more precise dating, further work would be required.

As the boat had been sawn into pieces during recovery, there was potential for tree-ring analysis to be carried out with minimal intervention, as long as the revealed cross sections could be measured. Prior to conservation, the tree-ring patterns were observed to be compressed and distorted. Such features reduce the opportunities for successful dendrochronological analysis (Chapter 6). The difficulties were exacerbated after conservation; none of the conserved sections could be prepared sufficiently well to allow reliable dendrochronological analysis to proceed. Fortunately, one piece (Piece A) had been reserved for wiggle-matching by high-precision radiocarbon dating in case the tree-ring analysis failed to produce absolute dating (*see* Fig 4.2). Piece A had not undergone conservation and was the only section on which dendrochronological analysis could be undertaken.

Table 13.1 Radiocarbon results

laboratory number	*material dated*	*radiocarbon age (BP)*	*$\delta^{13}C$ (‰)*	*calibrated date range (95% confidence)*
UB-4142	rings 21–40	3440±24	–26.9±0.2	Cal BC 1875–1680
UB-4143	rings 41–60	3464±24	–25.7±0.2	Cal BC 1880–1685
UB-4144	rings 61–80	3386±19	–26.4±0.2	Cal BC 1745–1620
UB-4145	rings 81–100	3372±24	–25.5±0.2	Cal BC 1740–1535
UB-4146	rings 101–120	3388±25	–25.7±0.2	Cal BC 1750–1610
UB-4164[1]	yew ties	3324±18	–23.8±0.2	Cal BC 1685–1520
GU-5291[2]	moss caulking	3490±50	–25.5	Cal BC 1940–1680
GU-5292	yew ties	3830±70	–26.3	Cal BC 2470–2030
Q-2340	oak from the boat	3285±50	–	Cal BC 1690–1430
Q-3241	oak from the boat	3225±80	–	Cal BC 1690–1310
Q-3242[3]	moss caulking	3205±60	–	Cal BC 1680–1320
OxA-7995	DST/T/1992-4901-3; wood, *Alnus* sp.	4195±60	–26.4	Cal BC 2920–2580
OxA-7996	DST/T/1992-4901-3; wood, Pomoideae	3720±75	–27.1	Cal BC 2400–1880
OxA-7997	DST/T/1992-peat-1; wood, bark	3985±65	–28.8	Cal BC 2840–2290
OxA-7998	DST/T/1992-4901-2; wood, *Alnus* sp.	3420±65	–27.5	Cal BC 1890–1520
OxA-7999	DST/T/1992-4901-2; wood, *Alnus* sp. bark	4570±75	–29.2	Cal BC 3520–3020

[1] The two results from the yew withies are statistically significantly different at 95% confidence (T'= 49.0; T' (5%) = 3.8v = 1; Ward and Wilson 1978).

[2] The two results from the moss caulking are also statistically significantly different from each other at 95% confidence (T'= 13.3; T'(5%) = 3.8v = 1; Ward and Wilson 1978).

[3] This result is not statistically significantly different from UB-4164 at 95% confidence (T'= 3.6; T'(5%) = 3.8v = 1; Ward and Wilson 1978). It seems that the GU results might be too old.

Dendrochronology

Analysis was carried out (at the Sheffield Dendrochronology Laboratory) on various subsections of the unconserved Piece A, following methodology described in English Heritage (1998). Details of dendrochronological principals and techniques are also discussed in, for example, Baillie (1982; 1995), Eckstein *et al* (1984) and Schweingruber (1988).

To summarise relevant issues, dating is usually achieved by cross-correlating, or crossmatching, ring sequences within a phase or structure and combining the matching patterns to form a phase or site master curve. A master curve is used for absolute dating purposes whenever possible as it enhances the common climatic signal and reduces the background noise resulting from the local growth conditions of individual trees. This master curve is then tested against a range of reference chronologies. However, in this analysis, no master curve could be produced and it was necessary to compare a tree-ring sequence derived from a single timber, with the reference material. Cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The Student's *t* test was then used as a significance test on the correlation coefficient. The *t*-values quoted 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 (Baillie 1982, 85–6), provided that high *t*-values are obtained at the same relative or absolute position with a range of independent sequences and that the visual match is satisfactory. The position at which all the criteria are met provides the calendar dates for the ring sequences.

The ring sequences were revealed by paring using scalpel and razor blades. Subsections B and D were rejected, as the ring sequences were so badly distorted that precise measurement was impossible, and it was not even possible to obtain an accurate ring count. Measurement was attempted on subsections A and C at points where the ring pattern appeared least distorted, although staggering of rings either side of the medullary rays on the measured radii still caused difficulties. Concern about the accuracy of the derived ring sequences led to the laboratories at Sheffield (Groves) and Belfast (Brown) both undertaking dendrochronological measurements in an attempt to ensure the validity of the tree-ring data. The two sets of measurements taken from subsections A and C were comparable and were combined to form single sequences for both subsections.

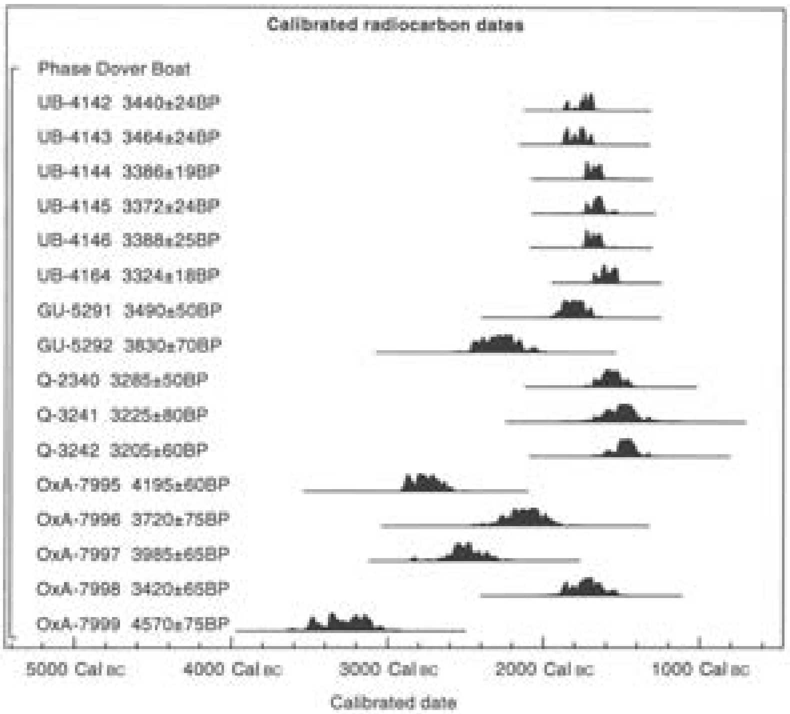


Figure 13.1 Probability distributions of radiocarbon dates from the Dover boat and the related sequence of sediments. Each distribution represents the relative probability that an event occurred at a particular time. These distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

The ring sequences from A and C were compared with a suite of reference chronologies from England, Ireland and other parts of northern Europe. The initial series of radiocarbon dates (Table 13.1) suggested that the boat was Bronze Age, thus the reference chronologies selected spanned the period 3500–01 BC. Unfortunately there is an extreme paucity of reference data for England spanning the Bronze Age period, so it appeared that dendrochronological dating would probably have to rely on long-distance comparison – unless, of course, the boat timber was derived from a non-local source. Although matches can be found between chronologies over long distances (such as Ireland to Germany), they are usually between long and well-replicated data-sets rather than single-timber ring sequences. Consequently, because of these two notable difficulties, the chances of successful dendrochronological dating were considered to be somewhat poor.

No reliable results were obtained for subsection C, but subsection A produced consistent results against a series of reference chronologies from the Irish Midlands when its ring sequence spanned the period

1742–1589 BC (Table 13.2). No other date came up consistently during the comparison with reference chronologies from northern Europe. The *t*-values produced at this 1742–1589 BC date are low, although this is perhaps not surprising considering the distance between the location of the boat and the source of the reference chronologies, and the fact that it is a ring sequence from a single timber.

This was the only possible date identifiable using current dendrochronological techniques and data availability, and was subsequently supported by the results from the wiggle-matching of high-precision radiocarbon measurements. It was accepted by both laboratories that, without this additional evidence, this would not be considered an acceptable dendrochronological date.

Radiocarbon dating

Radiocarbon analysis

The three radiocarbon samples measured in 1992 by the Godwin Laboratory, University of Cambridge, were processed according to methods outlined in Switsur and West (1973) and Switsur and Wright (1989). Those dated in Glasgow were analysed according to methods outlined in Stenhouse and Baxter (1983).

Following the failure of dendrochronological analysis to produce a match that could be accepted independently, six consecutive bi-decadal samples of a single-oak timber were submitted for high-precision radiocarbon dating to the Radiocarbon Laboratory at Queen's University, Belfast in 1997 (*see* Table 13.1). The tree-ring sequence was measured and divided into bi-decadal blocks by David Brown of the Palaeoecology Centre, The Queen's University of Belfast. The individual blocks of wood were prepared and dated using methods outlined in Pearson (1984) and McCormac (1992).

A series of five plant macrofossils from the sequence of sediments around the boat was submitted for accelerator mass spectrometry (AMS) dating in 1998, in order to provide dates 'bracketing' the tufa silt deposits in which the boat was found (Clark and Keeley 1997). These macrofossils were processed at the Oxford Radiocarbon Accelerator Unit using methods outlined by Hedges *et al* (1989; 1992).

Table 13.2 Dendrochronology matches for subsection A

reference chronology	*t-value*
MID1500	4.06
BLC7000	3.65
Corlona, Co Leitrim	3.26
Derryville, Co Tipperary	3.72
Lough Carra, Co Mayo	3.42
Derryfada, Co Tipperary	2.98
Garry Bog, Co Antrim	3.34
Timahoe, Co Kildare	3.58
Cullyhanna Lodge, Co Armagh	2.96
Kilnagarnach, Co Offaly	3.34

All four laboratories maintain continual programmes of quality-assurance procedures, in addition to participation in international inter-comparisons (Scott *et al* 1990; Rozanski *et al* 1992; Gulliksen and Scott 1995). These tests indicate no laboratory offsets and demonstrate the validity of the precision quoted.

Results

The results of the radiocarbon analysis are given in Table 13.1, and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). They are conventional radiocarbon ages (Stuiver and Polach 1977).

Calibration

The simple calibrations of these results, which relate the radiocarbon measurements directly to the calendrical timescale, are given in Table 13.1 and Figure 13.1. All have been calculated using the data-set published by Stuiver *et al* (1998) and the computer program OxCal (v3.3) (Bronk Ramsey 1995; 1998). The calibrated date ranges cited in the text are those for 95-per-cent confidence. They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to ten years if the error term is greater than or equal to twenty-five radiocarbon years, or to five years if less than this. The ranges quoted in italics are ranges derived from mathematical modelling of archaeological problems (see below). The ranges in Table 13.1 have been calculated according to the maximum intercept method (Stuiver and Reimer 1986); all other ranges are derived from the probability method (Stuiver and Reimer 1993).

Wiggle-matching

The actual chronological separation of the bi-decadal tree-ring samples submitted for high-precision dating is known by counting the tree rings. For example, UB-4145 consisted of rings 81–100 of the floating tree-ring sequence from the timber of the boat. This is twenty calendar years earlier than UB-4146, which consisted of rings 101–120. This additional information can be combined with the results of the radiocarbon measurements from the timber and the calibration curve to produce an estimate of its date. It should be emphasised that the distributions and ranges produced are not absolute; they are interpretative *estimates*, which can and will change as further data becomes available.

The technique used is a form of Markov Chain Monte Carlo sampling and has been applied using the program OxCal (v3.3) (http://www.rlaha.ox.ac.uk/), which uses a mixture of the Metropolis–Hastings algorithm and the more specific Gibbs sampler (Gilks *et al* 1996; Gelfand and Smith 1990). Details of the algorithms employed by this program are available from the online manual or in Bronk Ramsey (1995; 1998), and fully worked examples are given in the series of papers by Buck *et al* (1991; 1992), Buck, Litton *et al* (1994), and Buck, Christen *et al* (1994). The algorithms used in the models described below can be derived from the structure shown in Figures 13.2 and 13.3.

In this case we have five bi-decadal blocks (UB-4142 to UB-4146). The sixth sample failed to produce a result because the benzene yield on the synthesis rig was below the acceptable limit. Beyond this undated sample were 11 tree-rings that were not submitted for dating. Three further rings were present on the timber and were measured in Sheffield, although they did not form part of the timber sent for radiocarbon dating. The model that estimates the date of the outer ring of this tree from the radiocarbon evidence is shown in Figure 13.2.

Initially, this analysis was performed using the data published by Stuiver *et al* (1998). This suggests that the outer ring of the timber that was sampled for wiggle-matching dates to *1665–1640 Cal* BC *(at 32% probability)* or *1625–1585 Cal* BC *(at 64% probability)*. As this distribution includes the suggested tree-ring date of BC 1589, the analysis was repeated with this calendar date included as the final ring of the sequence (Fig 13.3; see Bayliss *et al* 1999). Overall, the radiocarbon results are

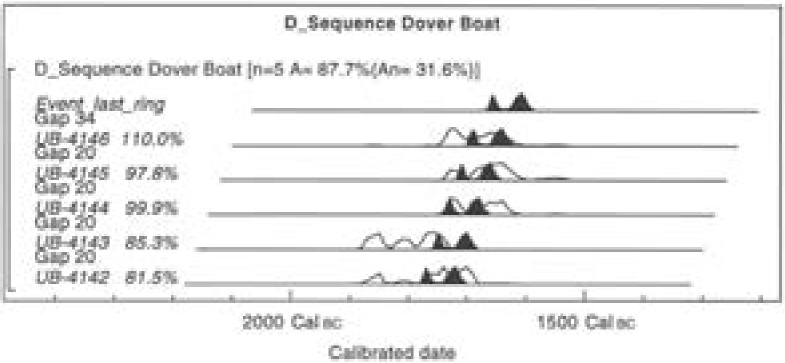


Figure 13.2
Probability distributions of dates from the bi-decadal samples of oak from the Dover boat. Each distribution represents the relative probability that an event occurs at a particular time. For each radiocarbon date, two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one based on the chronological model used. The large square brackets down the left-hand side and the OxCal keywords define the overall model exactly.

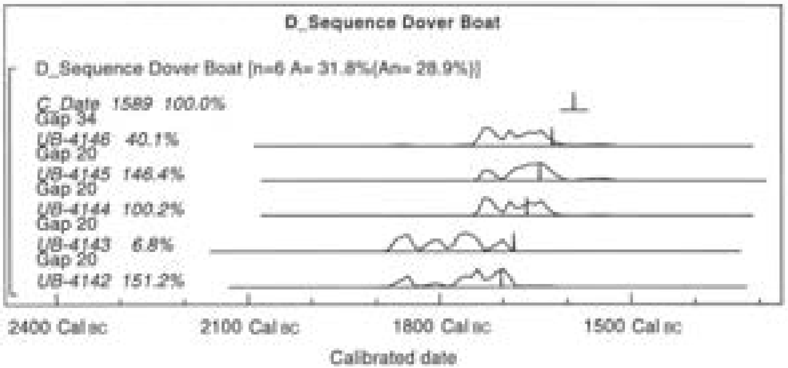


Figure 13.3
Probability distributions of dates from the bi-decadal samples of oak from the Dover boat. Each distribution represents the relative probability that an event occurs at a particular time. For each radiocarbon date, two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one based on the chronological model used, in this case including the date of 1589 BC *for the final ring of the measured tree-ring sequence. The agreement indices (A) provide a measure of how well the radiocarbon measurements agree with the absolute date suggested by dendrochronology. The large square brackets down the left-hand side and the OxCal keywords define the overall model exactly.*

in good agreement with the date suggested by the dendrochronological analysis (A=31.8%), although the agreement for UB-4143 is rather low (A=6.8%).

Sensitivity analyses (Buck *et al* 1996, 351–2) were then performed to test the robustness of these estimates in relation to the concerns expressed by Kromer *et al* (1996). Re-analyses of the model shown in Figure 13.2, using the data of Pearson and Stuiver (1986) and Pearson and Stuiver (1993), both provide slightly earlier estimated date ranges of *1685–1635 Cal BC (at 95% probability)* and *1675–1615 Cal BC (at 95% probability)* respectively. Re-analysis of this model using the measurements on wood from the British Isles processed by Gordon Pearson at the Queen's University, Belfast in the early 1980s (Pearson *et al* 1986) suggests that the outer ring dates to *1685–1635 Cal BC (at 95% probability)*. Re-analysis of this model using this data, but doubling all the quoted errors on the calibration curve (Kromer *et al* 1996, 609), suggests that the outer ring dates to *1685–1595 Cal BC (at 95% probability)*.

The suggested tree-ring date for the final ring of the timber submitted to Belfast for wiggle-matching is 1589 BC. The wiggle-matching analysis of the results is consistent with this suggested dendrochronological date, although most of the calibration curves that have been in use over the past decade provide estimated dates that are rather older. This suggests that inter-laboratory offsets, errors, and regional variations in the radiocarbon content of the atmosphere might be significant when producing precise archaeological chronologies (McCormac *et al* 1995).

Dating the boat

The tree-ring date of 1742–1589 BC provides a date for the measurable rings in subsection A of piece 'A', indicating the period over which this tree was growing, but this is not what archaeologists wish to know. It is the date of the construction of the boat that is of interest, which is not the same as the date of the measured ring sequence of the timber from piece 'A'. The lack of bark edge and sapwood prevents the determination of a precise felling date. However by adding an empirical probability distribution of the expected number of missing sapwood rings a date after which the timber was felled is indicated. The sapwood estimate used (Hillam *et al* 1987, 167) is applicable to England in the prehistoric period, though at present there is no evidence to indicate where the boat was constructed or where the timber came from. This is a reflection of the relative scarcity of Bronze Age chronologies and their limited geographical distribution. As the network of prehistoric reference chronologies available for northern Europe is extended, it might become possible, in the future, to obtain more accurate information concerning the source of the timber by, for example, dendro-provenancing (eg Bonde and Jensen 1995; Bonde *et al* 1997). It might then be decided that another sapwood estimate would be more appropriate. This date is simply a *terminus post quem* for the construction of the boat as the number of missing heartwood rings, trimmed off during timber conversion, is unknown. Later than this, the materials closest in date to the boat's construction are probably the short-lived yew withies and mosses that were used to stitch the oak timbers together and as caulking.

The model used to estimate the construction date of the Dover boat is shown in Figure 13.4. If we add an empirical distribution for the number of missing sapwood rings (Hillam *et al* 1987) to the tree-ring date of 1589 BC, this provides a *terminus post quem* that can constrain the calibration of the reliable results from the yew withies and moss (*see* Table 13.1). Using data from Stuiver *et al* (1998), it can be seen that this model suggests that the Dover Boat was constructed in *1575–1520 Cal BC (at 95% probability)*.

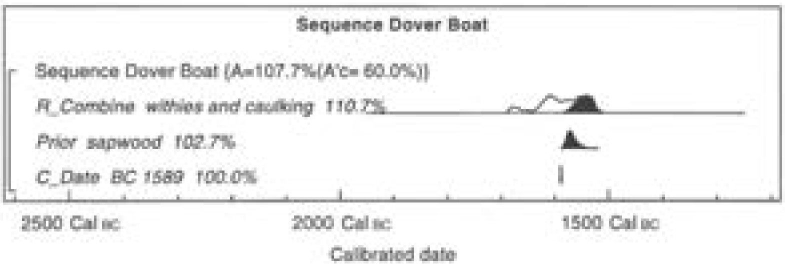


Figure 13.4 The probability distribution of the date of the Dover boat. The format is identical to that in Figure 13.3. The large square brackets down the left-hand side and the OxCal keywords define the overall model exactly.

Dating the sediments around the boat

The radiocarbon dates from plant macrofossils within the sediments above and below those that surrounded the boat are shown in Figure 13.1 and listed in Table 13.1. Figure 13.5 shows these results in relation to the stratigraphic sequence of the contexts from which they derive. OxA-7997 was from the eroded peat deposit beneath the boat. OxA-7995–OxA-7996 and OxA-7998–OxA-7999 were from the bedded silts above the boat. Layer 4901-3 was deposited earlier than layer 4901-2.

As already ascertained from the pollen assessment (Clark and Keeley 1997, 12–17), it is readily apparent that the surviving surface of the peat layer is considerably earlier than the boat. On stratigraphic evidence, the bedded silts must be later than the boat, although it is also apparent that the macrofossils contained within them have been reworked and are also considerably earlier than the boat. It is likely that these macrofossils were derived either from earlier deposits upstream that were eroded and carried downstream by the river or from more local deposits reworked in the increasingly active riverine environment. Thus, unfortunately, the dating of the overlying bedded silts cannot provide a *terminus ante quem* for the deposition of the tufa silts surrounding the boat.

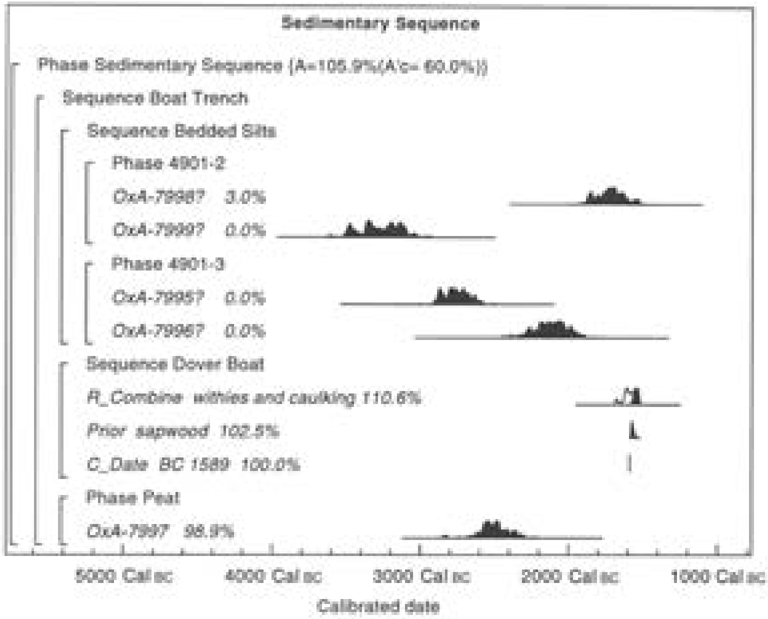


Figure 13.5
Probability distributions of dates from the Dover boat and the associated sequence of sediments. The format is identical to that in Figure 13.3. The large square brackets down the left-hand side and the OxCal keywords define the overall model exactly.

14
Affinities and differences

by Edward Wright

Introduction

This section seeks first to establish the Dover boat's close relationship to other plank-built boats of the British Bronze Age, then to examine whether or not this apparent group can be linked to any known parallels. Prominent individual features of construction are studied in an attempt to fit the techniques of the assemblage into a worldwide pattern, ancient or modern. At each stage, where hard evidence is missing, commentary includes varying degrees of conjecture. Finally, it touches briefly on the scope of long-range water transport through prehistory and reflects on possible origins for the invention of the various known forms of watercraft in antiquity.

The British Isles

Ferriby

Fortunately, there are a few examples of Bronze Age plank-built boats from Britain with which the Dover boat might usefully be compared (Fig 14.1). The closest parallel is Ferriby 1 (Fig 14.2; Wright 1990), found in 1937 in an intertidal situation on the north shore of the Humber Estuary. Roughly the same proportion of this original craft survived as in the Dover case. Ferriby 2 and Ferriby 3 add little to our knowledge of the construction of the boats, beyond showing the existence of variations in minor details. The Ferriby group, and the Kilnsea and Caldicot Castle planks, are significantly older than Dover, which suggests that, to the extent that they have features in common, the Dover design might be derivative of a type of craft that was current in British waters for a long period from Early Bronze Age times onwards.

A major difference between the reconstructed forms of the Dover boat and Ferriby 1 can be seen in the treatment of the stern. Accepting Owain Roberts' hypothetical reconstruction of the Dover boat as having a scow-shaped bow and a squared-off transom stern (Chapter 10), the favoured reconstruction of Ferriby 1 is that it was more or less equal-ended, based on the fore-and-aft symmetry of the remains, and on the layout of integral features on the bottom structure. Only one end in Ferriby 1 survived or was observed, as in the Dover find (Fig 14.2).

Next in significance is the use of hollowed-out iles to 'turn the bilge' between the flat bottom and the sides in the Dover boat, making full use of the chine-girder effect to give fore-and-aft stiffness to the structure. Something of the same effect, although to a much lesser degree, is yielded by the treatment of the ends of the side-strakes in Ferriby 1, shaped in three dimensions to mate with the extension of the keel plank.

Figure 14.1
Map showing Bronze Age boat finds in Britain.

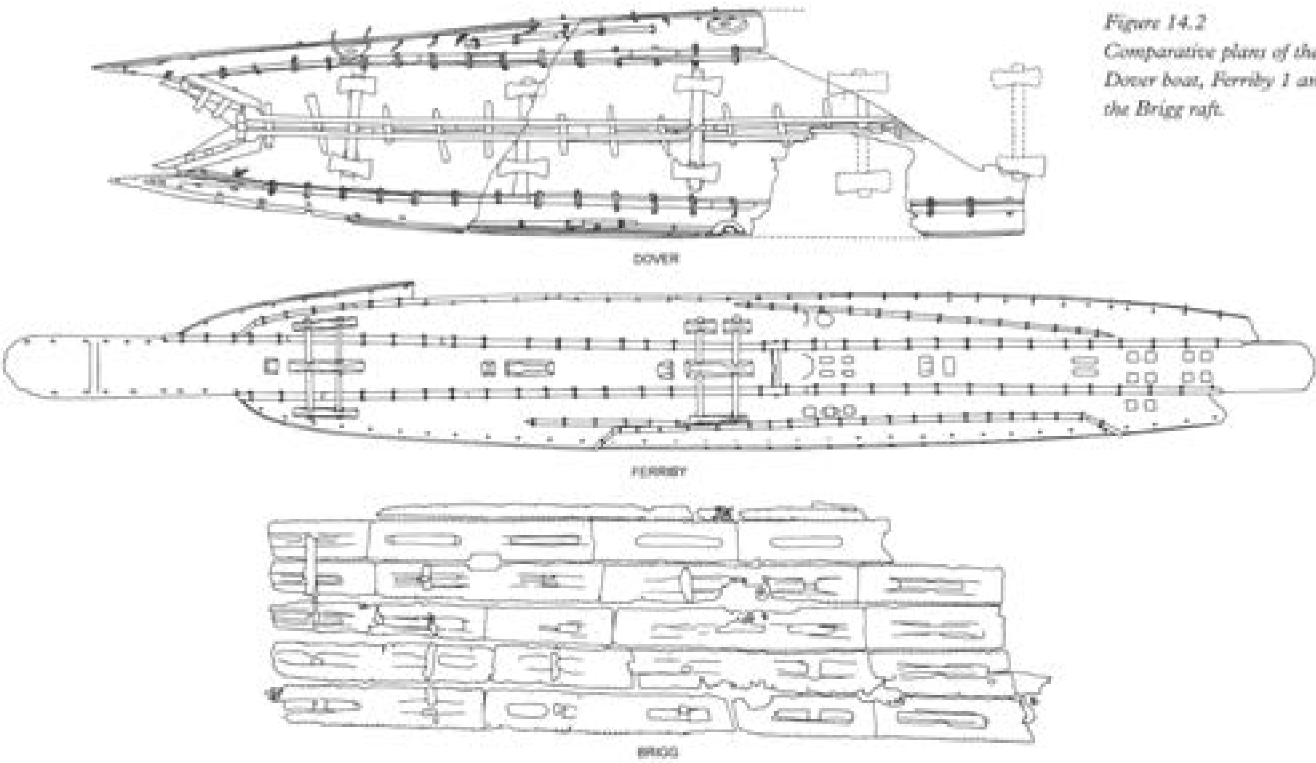


Figure 14.2 Comparative plans of the Dover boat, Ferriby 1 and the Brigg raft.

The technique for closing the ends in the Dover boat is markedly different from that in Ferriby 1. In the Dover boat, what must have been a huge and ingeniously shaped end board was fitted into the swallow-tailed space between the ends of the bottom planks, the iles and the missing upper side planks. In Ferriby 1, the ends of the keel plank were shaped with a marked upward curve, accentuated by a degree of rocker in the bottom structure, and the side strakes shaped to fit this projection. Only one pair of upper side planks outboard of the iles are postulated to complete the hull in the Dover boat case (iles plus one), whereas a third such plank on each side has been proposed in Ferriby 1 (lowest side strakes plus two). This conjecture is supported by the number and spacing of the surviving fastenings on the projection of the keel plank, although in both vessels fastenings were observed for only one additional side strake on each side.

Surface finishing

A very noticeable aspect in the comparison of the Dover boat with the Ferriby vessels is the surface finishing of each. Generally speaking, in the case of the Dover boat, little attempt has been made to smooth the surface of the planks or the finish of the upstanding features (such as the cleats) or to fair these into the adjoining planks (Chapter 8). Tool marks are apparent at many places, and are still obvious on the conserved and reassembled hull. In contrast, tool marks were hard to detect on Ferriby 1 and 2, and were hardly present at all on Ferriby 3. In the Ferriby case, the main surfaces of the planks were left remarkably smooth and unscarred by axe, adze or chisel marks. Where these could be observed, they were confined to closed or restricted spaces where the scope for tool working was likely to have been limited. Moreover, many of the upstanding blocks, cleats and other features were carefully faired into the surfaces from which they projected. The impression left by the Dover boat is that its builders carried out their work on the timbers only as far as was practically necessary. In the Ferriby boats, however, much additional and laborious craftsmanship was apparently employed to embellish the finished construction. This raises the possibility that in the Dover boat we have a basic workboat, while, at Ferriby, some deference might have been paid to status or tradition beyond this in aiming for a more refined finish.

In both the Dover boat and Ferriby 1, significant breadth of the hull was clearly a sought-after feature, compared with that attainable in a log boat. This was achieved in markedly different ways. In the Dover boat, a nearly parallel-sided bottom structure was provided by two broad planks arranged side-by-side. The method by which they were fastened to each other (or the virtual absence thereof) is discussed in Chapter 5, but the use of transverse timbers passing through integral cleats is common to both the Dover boat and Ferriby 1 – albeit employed more extensively in Ferriby 1 than in the Dover boat, and even more so in Ferriby 2. In the Ferriby case, however, the planks forming the bottom structure were fastened to each other with yew withies throughout, except where the transverse timbers obtruded. The nearly parallel-sided planks in the Dover boat formed the entire bottom structure, excluding the ends. In the Ferriby find, an elegant bottom-structure with curved edges (when viewed in plan) was achieved by the addition of outer bottom-planks on either side of the keel-plank, which was made up of two pieces with a scarf joint amidships.

The hypothetical reconstruction proposed for Ferriby 1 depends substantially on internal bracing, in addition to the transverse timbers across the bottom-structure, for the necessary strength and rigidity. For the Dover boat, no such extensive system is thought necessary, nor is there evidence for such a system. The reconstruction offered in Chapter 10 is shorter than that generally accepted for the Ferriby boat.

The use of wedges to connect the two planks of the bottom structure (Chapter 5, pp 68–9) is in no way paralleled at Ferriby.

The proposal that the cleats on the vertical faces of the iles were for the purpose of housing posts as anchorages for a transverse lashing below the middle thwart (Chapter 10, p 192) is, as far as this author knows, without parallel in ancient British boats. There is, however, a modern ethnographic parallel for a feature akin to this in the posts fitted in similar locations to support the sheer strakes in the Bangladeshi 'Balam', and in other vernacular boats based on an extended log hull with added strakes.

Seams and plank edges

In each example, the treatment of the seams is evidently governed by a variety of objectives, some common to each. Clearly, the first is to render them, as far as possible, waterproof. There are two separate caulking agents used in both the Dover boat and the Ferriby boats – moss and covering laths (although a plastic stopping material was also used at Dover). Moss was used more extensively in the Ferriby find than the Dover example, being tightly packed not only above the joints but especially between adjoining plank edges, whereas the caulking material did not spread more than marginally between plank edges in the Dover example. In comparable seams, sealing laths were fitted under the stitches in both; in the case of Dover perhaps being knocked into position after the stitches were formed, thereby increasing the tightness of the bindings – a process that has been conjectured for Ferriby but not positively proven. As can be seen in Figure 14.3, however, the shaping of the plank edges was markedly different in the two, although the objective in each was to ensure that stitching did not protrude on the underside of the hull, where stitches would be damaged on grounding or hauling up a beach. The attachment of the lower flanges of the Dover iles was to ridges left standing along the upper edges of the bottom planks. In Ferriby, stitch holes were cut with a bend of 90 degrees, so that they came out within the thickness of the inner planks. Only in the repairs to splits, where it was not possible to cut stitch holes in this fashion, were they cut straight through the plank edges on either sides of the split, and the risk of damage to protruding stitches when the boat was in use was accepted as unavoidable. The other major difference was in the shaping of the plank edges, butted with plain edges in Dover, or given various forms of grooving in Ferriby, where this might have marginally reduced working between adjoining planks but clearly would have improved retention of the moss caulking within the seams. Some of these variations in different positions in the hull are shown in Figure 14.3. The builders of each used a very similar form of edging for the seams between the sides, largely above the waterline, as recorded on the upper edges of the iles in Dover and on the upper edges of the side strakes in Ferriby 1 and 3. A similar technique was recently noted by Weski (1999) and described as a 'rabbeted carvel seam', occurring in ancient Chinese boats and in modern working boats in northern Germany.

The situations where the two boats operated are not dissimilar. At Dover a shallow, braided stream channel led to the open waters of the Dover strait, whereas, at Ferriby, the boats worked in the wide and

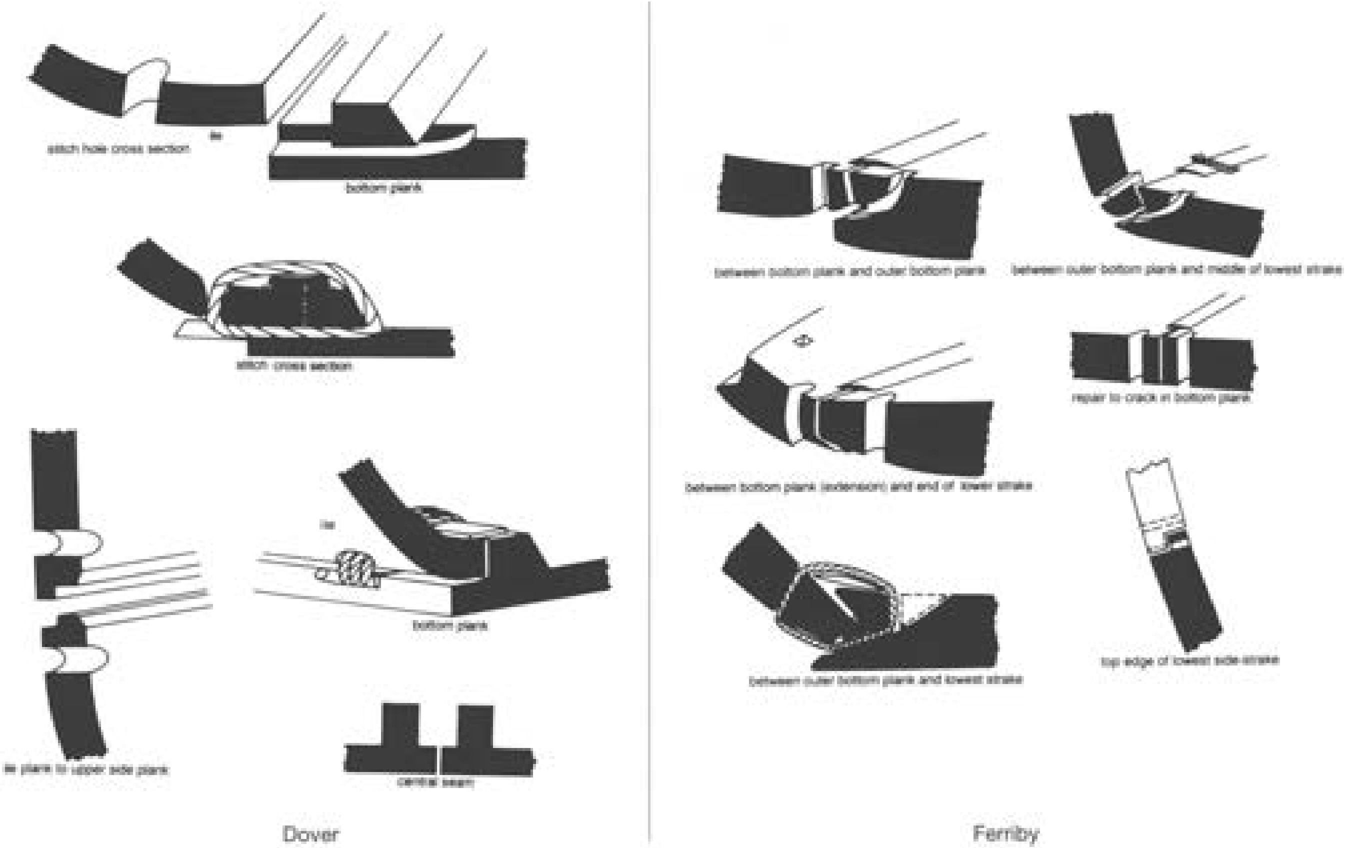


Figure 14.3
Comparison of the plank edges and fastenings of the Dover and Ferriby boats.

sometimes choppy estuary of the Humber. The case for open-sea passage is put forward more forcibly for the Dover boat than has been done hitherto for Ferriby. However, it is difficult to resist arguments that boats of such relative sophistication would necessarily be restricted to inland or sheltered waterways.

Internal bracing

The comparative hypotheses for internal bracing of the hull call for some comment, and a summary is shown in Table 14.1.

The object in each case would be to construct, as nearly as possible, a rigid box to complement the substantial planking of the bottoms and sides. The fore-and-aft rigidity of the Dover boat would have been

Table 14.1 Comparison of internal bracing elements from Dover and Ferriby

Dover	*Ferriby*
5 systems of cleats and transverse timbers*	8 systems of cleats and transverse timbers (Ferriby 1)*
	18 systems of cleats and transverse timbers (Ferriby 2)*
12 wedges between side-by-side bottom planks*	
2 thwarts in combination with posts through upper cleats on iles and sheer strakes‡	up to nine thwarts across hull at level of tops of second strakes and notched over them‡
transverse lashing below middle thwart‡	girth-lashings round each end, plus detached thwarts to lock tourniquets‡
transom at stern‡	'inserted boards' in planes of girth-lashings
	six ribs with floors located in slots in keel plank and tops protruding through holes in rails on sheer strakes (third strakes)‡

* = actually present ‡ = hypothetical

greatly enhanced by the chine-girder effect provided by the ile planks. To a lesser extent, in the Ferriby case, the shaped form of the ends of the side strakes would perform similarly.

Brigg

So far we have considered the two variants of a broadly similar class of boats operating in the Middle Bronze Age or earlier. The third Bronze Age planked boat found in Britain, the Brigg raft or boat (McGrail 1981), is of markedly different construction to either the Dover boat or the Ferriby finds. A broad, flat structure with fastenings for sides and a small piece of side strake was found in brickworkings beside the River Ancholme in Lincolnshire in 1888, and re-excavated in 1973–4 (*see* Fig 14.2). Whether it was a 'raft' with shallow sides, or possessed a curved hull form, need not concern us here (Roberts 1992; 1995; McGrail 1994). Suffice to say that the planks of the bottom were stitched with continuous sewing of twisted willow branch, caulked with moss and the seams covered with laths as at Dover and Ferriby. Likewise, this structure was braced with equally spaced transverse timbers, passing through integral cleats. The Brigg find was significantly younger, at *c* 810–780 Cal BC, than the others (Q-1199; 2545±100 BP, Q-1200; 2545±100 BP, Q-1255; 2605±50 BP, Q-1256; 2605±50 BP, Q-1257; 2592±50 BP, Q-1258; 2670±70 BP, Q-1261; 2560±50 BP, Q-1263; 2570±60 BP, weighted mean 2603±21 BP, T′=3.5; T′(5%)=14.1; v=7; Ward and Wilson 1978). Its situation near the presumably sluggish River Ancholme suggests that its use was primarily on inland waterways.

Other British finds

Other pieces of boat plank of Middle Bronze Age or earlier date have been found elsewhere in Britain. One plank fragment was found at Kilnsea on the East Yorkshire coast in 1996 (van der Noort *et al* 1999); despite its worn state, this was identifiable, by the presence of stumps of cleats, as clearly resembling the Ferriby vessels. At Caldicot Castle, near Chepstow in South Wales, in an infilled channel of a tributary of the Severn Estuary, another fragment was discovered, again identifiable, by cleats and stitch holes of a size comparable with those in the Dover and Ferriby boats, as belonging to the same class (McGrail 1997). It is difficult to say with certainty where the Caldicot Castle plank might fit into the sort of hull known from Dover and Ferriby, although, at first sight, the existence of cleats and stitch holes on both sides suggests it would be somewhere in the bottom structure. Nevertheless, this find adds one more to the geographical distribution of large and elaborate plank-built boats around the coasts of Britain in the Middle Bronze Age, so far unmatched anywhere in north-west Europe.

Two other fragments of boat plank have been found in intertidal deposits around British coasts, both substantially later in date than either Dover or Ferriby. The first, from the same site as Ferriby 1, 2 and 3, is referred to as Ferriby 4 and is almost certainly a short piece of sheer strake. Radiocarbon dating placed it at 520–380 Cal BC (Q-3212; 2350±40 BP (Har-8972); 2390±60 BP, weighted mean 2362±33 BP, T′=0.3; T′(5%)=3.8; v=1; Ward and Wilson 1978). Certain details of edge treatment have been borrowed for incorporation in the hypothetical reconstruction of a Ferriby boat, although it is several centuries younger in age. The second fragment, from Goldcliffe in South Wales (Bell 1993a; 1993b), not much different from Ferriby 4, has a felling date of after 1017 BC, and shows signs of having been reused and incorporated in a trackway. There is not enough surviving of this to offer any valid conclusion about its original nature, except that it belonged to a boat with the thickness of planking typical of the Dover and Ferriby boats.

The ages of the British Bronze Age plank-built boats

The published estimates of the relative ages of the plank-built boats referred to above are set out in Table 14.2. This suggests that sewn-plank boats, broadly of a comparable sort, existed in Britain during much of the Bronze Age, and might have persisted into the Early Iron Age.

There is no reason to suppose that they were built other than close to where they were found. The evidence for deliberate dismantling of the Dover and Ferriby boats, together with small finds of craftsmen's debris at Ferriby, point to the likelihood that, at the very least, repair and refitting took place there – if not construction *ab initio*.

It is a fair presumption also that these elaborate boat designs were the product of a

Table 14.2 The ages of the British Bronze Age plank-built boats

boat	*date or date-range (Cal)* *	*remarks and references*
Ferriby 4	520–380	radiocarbon (Wright 1989)
Brigg raft	820–780	radiocarbon (Switsur and Wright 1989)
Goldcliffe planks	after 1017	dendrochronological (Bell *et al* 2000)
Dover	1575–1520	AMS (this volume)
Kilnsea plank	1740–1630	AMS (van der Noort 1999; revised 2001)
Ferriby 1	1880–1680	AMS (Wright *et al* 2001)
Caldicot Castle plank	1870–1690	AMS (McGrail 1997)
Ferriby 2	1940–1720	AMS (Wright *et al* 2001)
Ferriby 3	2030–1780	AMS (Wright *et al* 2001)

* Calibrated using the maximum intercept method of Stuiver and Reimer (1986) and the data of Stuiver *et al* (1998).

long lineage, of perhaps several centuries' duration. It is to be hoped that more finds will be made, to extend both the territorial and the temporal ranges of the 'class', and shed some light on its origins.

Prehistoric water transport

Arguments for seaborne traffic around the British archipelago in periods before and during the Middle Bronze Age are now, with the discovery of the Dover boat, supported by actual evidence. There is no requirement in Europe for more than an ability to cross rivers to account for the dispersion of Palaeolithic man, and this requirement could be met by rudimentary rafts or floats owing to the periodic prevalence of very much lower sea levels during this period. What is now the North Sea was, during the Mesolithic, a scene of low-lying islands separated by rivers (B Coles 1998), some of major size, but probably traversable by rafts or log boats of the period. These vessels include the sophisticated craft excavated in Denmark, and the even more efficient, expanded Neolithic versions, with broad beam amidships and upturned ends. These were in marked contrast to the more usual heavy, monoxylous craft, whose shape was constrained by a simple tree trunk, thereby limiting stability and capacity (Rieck and Crumlin Pedersen 1988). Overseas contacts in the Neolithic, when rising sea levels had cut Britain off from the mainland of Europe, must have required some sort of vessel to effect sea crossings, the occurrence of which is attested by the archaeological record. In this context, it must be remembered that some of the earliest radiocarbon dates for the Neolithic period have been recorded from Northern Ireland, but no appropriate boats have been found.

We have archaeological evidence that contact took place by the Early Bronze Age, so that it is generally accepted that there must have existed a capability for cross-Channel voyaging and coastwise travel along the Atlantic seaboard extending from Iberia, round Brittany, to western England. In what form of vessel this travel would have been undertaken is unknown, the only dated examples of this period being log boats unsuitable for open-sea travel. However, the scene changes from the Early Bronze Age onwards, with the discovery of the examples of plank-built boats found to be widely distributed round the British coasts. Some of these might reasonably be believed to have had the ability to travel coastwise or, when conditions were favourable, to make short sea crossings. Although the Humber group of Ferriby and Kilnsea boats could have found ample demand for their services in the estuary itself – either as ferries, or for the carriage of passengers and merchandise along the tidal estuary or the river systems draining into it – the capability for open-sea navigation becomes a more persuasive hypothesis with the revised dates (Table 14.2). The Langdon Bay hoard of bronze implements, largely of French origin, found by divers just east of Dover harbour – clearly lost in the wreck of a sea-going vessel and of Middle Bronze Age date – is good enough evidence that there was routine traffic between Britain and mainland Europe at this period. The Dover boat provides convincing evidence of an actual vessel with appropriate capability.

Vessels whose shape and size are attested by the Caldicot Castle or Goldcliffe planks would have been similarly effective in the Severn Estuary, although they can be assumed to require greater seaworthiness than the Humber ones. Coasting voyages would have been realistic possibilities in either case, a point reinforced by the careful attention given to protection of the vulnerable stitching of the bottom in all the known examples, thereby fitting them for beaching as routine, whenever sea conditions deteriorated.

By the Early Iron Age, the picture has continued to improve, so that the Gallo-Roman ships – such as those found at Blackfriars (Marsden 1994, 33–104) or St Peter Port, Guernsey (Rule 1990; Rule and Monaghan 1993), entirely different from the Roman ships of Mediterranean style of construction – would have made sea navigation around these islands commonplace. We even have an historical report of their attributes and performance in the writings of Caesar himself (Bell Gall III, 13, 1–5).

Reflections on origins

There are, effectively, only three ways of producing floats in the most primitive societies. First, using the floating log, which could be multiplied by joining logs together to form a raft, or hollowed out to increase capacity in the shape of a one-tree boat or log boat. Second came the observation that certain types of vegetable, such as reeds, are of their nature buoyant and can be bound in bundles to produce substantial bundle-boats. A third source of invention is the hide boat, for which waterproof animal skins are stretched over a suitable framework of wood or other material. This last option can be put aside when considering the possible origins of the Dover–Ferriby group, if only because the concept of a hull made of massive planking is quite foreign to that of a comparatively lightweight construction consisting of a braced framework covered with waterproof material.

We are left, therefore, with either rafts of already buoyant material, extended to form watertight shells in which displacement gives a great increase in effective capacity, or expanded or extended log boats, in which the confines of a single tree trunk are overcome to act similarly. Some of the earliest log boats excavated in Denmark have the shells of hollowed-out logs manipulated and expanded to give the characteristic 'spoon' boat, with much improved capacity and stability compared with the plain log boat. The question is: which type of boat was the ultimate parent of the class?

The broad, and substantially flat, bottoms of the Dover and Ferriby boats seem, at first, to be consistent with a raft parentage; but the use of hollowed out iles to 'turn the bilge' in the Dover boat, and the less obvious shaping of the ends of the side strakes in Ferriby, suggest rather a descent from extended log boats. The emphasis on the aim of the builders to achieve breadth, in comparison with a simple log boat, is referred to above. In both cases, perhaps the ultimate inventors began with a log boat and fabricated the constructions that we have before us with the objective of creating boats in which the strength of the hull remained essentially in the massive shell – thereby retaining log-boat practice where appropriate, while extending the breadth as far as possible.

Discussion

The examples cited represent the sum total of finds of anything resembling this type of construction in north-west Europe at that period, or, for that matter, anywhere else. Looking further afield for parallels for the main features in the class of plank-built boats, there are two that appear significant: the fastening of plank to plank by means of stitching or sewing with suitable vegetable fibre; and the bracing of the bottom structure by means of transverse timbers passed through integral cleats left standing proud of the surface when the planks were formed.

The stitching or sewing of planks to planks was a common practice in antiquity (Prins 1986). Before the invention or availability of the nail, few methods existed for achieving this other than stitching – or lashing, or binding; whatever the chosen term. The most common alternative was some form of mortise-and-tenon joint within the thickness of the plank edge, or the variant, used by the ancient Egyptians, of the double-dovetail tenon let into the surface across the seam. Stitching or sewing goes back as far as the great ceremonial boat of *c* 2600 BC, found dismantled in a rock crypt in front of the great pyramid of Cheops (Chephren) at Giza in Egypt (Lipke 1984). It was possibly practised by the ancient Greeks (Casson 1964), who subsequently adopted the mortise-and-tenon technique that became prevalent throughout the Eastern Mediterranean and persisted into Roman times and later. Stitching, however, survived in parallel with this well into Roman times; witness the light and fast ships known as 'Liburnians' (Casson 1994, 94–6). The early trading vessels of the Persian Gulf and Arabian coasts were sewn, as observed by Marco Polo and replicated by Tim Severin in his Omani 'bhoom' which he sailed to China as described in his published account (Severin 1982). There are notable examples still in use around the southern and eastern coasts of Asia, especially the 'masula' surfboats of eastern India (Kentley 1985) and the 'madel paruwas' of Sri Lanka (Kentley and Gunaratne 1987). The writer first saw the latter in 1963, with the seams sewn with coir twine (coconut fibre), but, by 1976, the coir twine had given way to pink binder-twine of polyester fibre. Similar techniques have been observed in recent times as far as the islands of the Pacific Ocean. Stitching and sewing were commonplace well into historic times in the far north of Russia and Scandinavia and some of the earliest examples of the typical Scandinavian practice of clinker-fastening of overlapping planks was done by this method (Prins 1986). So there is nothing unusual about the stitching of the planks of the Dover boat, although it might seem startling to modern eyes.

The use of cleat systems for transverse bracing of the bottom structure is, however, very rare indeed, confined almost entirely to the British examples cited above and reaching its most highly developed form in Ferriby 2, in the Dover boat, and in the Brigg 'raft'. Something broadly similar was employed to secure the extensions to the hull of the Hasholme log boat of 322–277 Cal BC (Millett and McGrail 1987). The only more recent example that the writer has been able to identify is one from the 8th century AD in South Korea, where a pleasure boat, found submerged in a boating lake, was formed from two halves of a log boat joined together with cleat systems (Fig 14.4). This feature is quite different from the Scandinavian practice of using integral cleats for securing the inserted ribs in 'clinker' boats (Wright and Switsur 1993, fig 8).

It can be seen that in the 2nd millennium Cal BC, boats of a broadly similar kind were dispersed around estuaries on the coasts of Britain. Only a handful have so far been found, although in prehistoric times they might have been common enough in parallel with log boats, of which many more – both older and younger – have been discovered. Log boats are still being used to this day.

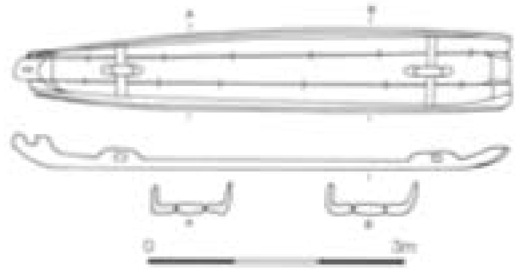


Figure 14.4
The Anapche Pond boat (South Korea), with cleats and transverse timbers fastening the two halves together.

The absence of direct parallels outside of Britain is no proof that such boats did not exist in other parts of the world, only that none has yet been found. The fact that those that have been found are reliably dated to the 2nd millennium BC suggests that the complex techniques employed to construct plank-built boats in this (or a similar) fashion were invented perhaps centuries earlier. This might have occurred somewhere either in the Early Bronze Age, when metal tools became available, or even the Neolithic, as the shaping of the components could conceivably be achieved with stone tools, if recent ethnographic examples are a reasonable guide. The great war-canoes of the Maori of New Zealand, for example, were fashioned with stone adzes. The presumption can safely be made that, by the estuaries of the Dour, the Humber and the Severn, such boats were built and operated by local Bronze Age people. Whether the vessels were invented there also is another matter, but there is no evidence to the contrary.

15
The boat in its cultural setting

by Keith Parfitt and Timothy Champion

Introduction

The Dover boat is one of the most striking artefacts to have survived from the Bronze Age anywhere in Britain. As the previous chapters have shown, it can tell us much about contemporary skills of boatbuilding and seamanship, and also, more generally, about woodworking and other technologies. But the impressive nature of its construction should not restrict our discussion of its significance, or the wider context within which it needs to be assessed. Whether or not this boat was actually built, owned and used by people who lived near its final resting place, we can be sure that the inhabitants of east Kent were familiar with such vessels, which would have played an important role in their everyday lives. To understand that role better, we need to look at the evidence for contemporary occupation in the hinterland of the Dour estuary, and at the evidence for maritime activity in the region during the Bronze Age.

With a few notable exceptions, studies of prehistoric Kent have not been particularly well developed. Until recently, a relatively small amount of work had been undertaken. Modern researchers in many other areas benefit from detailed fieldwork, excavation and data-recording of prehistoric remains stretching back into the last century. But much of the early data from Kent is poorly recorded, and a significant proportion of it, in any case, has been lost, which has deterred many from examining the material in detail. As a consequence, the two most recent overviews of the county's Bronze Age – both now nearly twenty years old – were depressingly negative in their approach (Champion 1980; 1982).

The situation has improved somewhat in recent years. The region has experienced a high level of major infrastructure and other development projects, and the increased presence of both professional and amateur archaeologists has added a new layer of better-recorded excavations and observations. The activities of metal detectorists have also added considerably to the known archaeological record. It remains true, however, that large parts of Kent's prehistory have not been systematically investigated, that much of what has been found has not been well recorded, and that what has been recorded has often not been systematically analysed or synthesised.

These difficulties still exist for the study of Kent's prehistory, but two further problems are relevant to any attempt to put the Dover boat in its context. In the first place, the archaeological record for the period at the middle of the 2nd millennium Cal BC, when the boat was in use, is still one dominated by funerary monuments. In east Kent, as in most of southern England, occupation sites of this period are rare, and it is not until several centuries later, from around 1000 Cal BC (*c* 2850 BP), that evidence of human impact on the landscape in the form of substantial settlements and enclosures begins to become more common. The other archaeological evidence that is available to us from the period contemporary with the boat is, therefore, rather restricted in range. We cannot, for example, complement the evidence of the boat for maritime activity with evidence from a settlement site for terrestrial activity, as none is known in detail.

In addition, evidence for maritime activity is most likely to be found – as in the case of the Dover boat – in locations near to, or on, the prehistoric coastline. In Kent, however, this is particularly difficult, as much of the line of the prehistoric coast is unknown, inaccessible or no longer extant. As will be discussed in more detail below, erosion has removed the prehistoric coast in some areas, while in others it has been buried under later deposits. Only very occasionally, as in the discovery of the Dover boat or of the collection of bronzes on the seabed at Langdon Bay (Needham and Dean 1987), can we catch a glimpse of the Bronze Age coast and the activities of Bronze Age people associated with it.

The evidence, such as it is, consists mostly of individual settlements, burials and artefacts. These must be seen as the locations of specific human activities in a wider landscape that was itself heavily modified by human activity. By the time the Dover boat was in use in the 2nd millennium BC, the landscape of Kent had already been greatly altered as a result of more than 2,000 years of agricultural economies. The evidence for this impact, in the form of vegetational change, suggests that woodland clearance was in progress well before 3000 Cal BC (*c* 4400 BP), and that, by the early part of the 2nd millennium Cal BC, the landscape was largely an open one used for pastoral and arable agriculture (Godwin 1962; Kerney *et al* 1964; Kerney *et al* 1980; Burleigh and Kerney 1982). It is possible that, by the later part of the 2nd millennium, some of the landscape was being divided up into organised field systems such as have been documented in the middle and upper Thames Valley (Yates 1999). If the archaeological record is unfortunately limited, it still represents a Bronze Age landscape in which farming communities lived and worked. These people also moved around in their landscape, by land and by sea. Much of this movement is now invisible, but the Dover boat gives us a rare clue to its importance.

Bronze Age activity in the Dour valley and its environs

The hinterland of the River Dour is represented by a block of chalk downland that constitutes the eastern extremity of the North Downs dip-slope, bounded by the Strait of Dover on the east and south-east, the scarp face of the North Downs to the south-west, the valley of the Little Stour to the west, and the marshlands of the former Wantsum Channel to the north and north-east. Reaching a maximum elevation of about 180m OD at the top of the North Downs scarp above Folkestone, the land in this region dips gently down at about two degrees to the north-east, finally reaching marsh-level in the Sandwich area. Around Dover there is a marked platform, generally termed the '400ft plateau'. A series of dry valleys cuts across the region. The great majority of these valleys follow the dip-slope and create a series of well-defined ridges aligned south-west to north-east. In the central part of the area, flowing rivers and streams are completely absent, creating dry chalk country, very reminiscent of the Wessex downlands. The River Dour – occupying part of a more extensive dry valley system, and entering the sea to the south-west of the South Foreland – thus represents an important source of fresh running water in an area where such a basic commodity is very scarce.

The discovery of a substantial wooden boat within the silts of the lower reaches of the Dour immediately raises the question as to whether the vessel regularly worked this river. The overall size and draught of the boat have been considered in detail above and the nature of the river in relation to these details must now be examined. Without any recent tradition of use for transportation, and extensively harnessed to power mills for centuries, the modern River Dour is just 6km (3.75 miles) long and forms the last remnant of a more extensive local river system cut into the chalk between Dover and Folkestone. The system is now largely represented by a series of dry, downland valleys that have, almost certainly, not contained permanent streams since the melt-waters of the Ice Ages originally created them. Unconnected to any other river system, it seems likely that, by the Bronze Age, the course of the Dour was very much confined to the two valleys that it presently occupies.

Once probably rather wider and shallower than it is now, the River Dour today is rarely more than 10m wide or 1m deep. From the extent of the valley system alone, it is readily apparent that this little stream could never have formed any major waterway giving access into the Kentish heartland, even allowing for lengths of the river that may have dried up since the Bronze Age (particularly the winterbourne section in the Alkham Valley), and the truncation of the seaward end of the main valley. While the river was, without doubt, a valuable source of fresh water, its course, size and length strongly suggest that it was never much used for water transport – beyond perhaps very locally by shallow-draft canoes and rafts. Whatever its purpose, it seems unlikely that a substantial vessel such as the Dover boat could ever have successfully plied such a small river beyond the lower reaches adjacent to the sea.

A significant quantity of artefacts was discovered in the water-laid sediments surrounding the Dover boat and these included fairly large amounts of struck flint flakes, much fragmented calcined flint (pot-boiler), animal and fish bone (some showing evidence of butchery), small pieces of worked wood (some unrelated to the boat), and a single, large pot-sherd from either a collared or a biconical urn of Bronze Age date (Chapters 11 and 12). This material seems mostly to represent typical domestic rubbish such as might have been derived from a nearby settlement site. Although contained within waterlain sediments, the generally fresh, unabraded nature of the individual objects, which included animal and fish bones that were still in articulation, indicates that these finds have been washed very little or no distance from their original place of deposition. There is also clear evidence for the deliberate dismantling of the vessel on the site. All of this combines to imply very strongly the existence of a contemporary occupation site nearby.

The precise location of such a settlement would be dictated by the local topography. It seems clear that the boat was abandoned near the western edge of the broad Dour floodplain, and, in all probability, any associated occupation area would have been situated close by, above the river on the lower slopes of the Western Heights. Excavations to the west of the Market Square in the 1970s and 1980s led to the identification of a broad natural spur 'largely centred on Queen Street' projecting from the western side of the valley in this area (Philp 1981, 7). Barham and Bates (1990) have confirmed the existence of this feature and mapped its general contours. It is now clear that the extensive Roman settlement that was established at Dover was built largely across this ideally suited spur, overlooking the river. A series of deep excavations has shown that the spur is primarily composed of a solifluxion deposit of coombe rock, capped by a layer of brickearth.

Evidence for pre-Roman occupation has also been identified on the spur, although the associated levels are generally deeply buried below a complex sequence of subsequent archaeological deposits. Despite a series of useful excavations undertaken by the Dover Excavation Committee in this area soon after the Second World War (Threipland and Steer 1951; Threipland 1957), the salvage recording work conducted by Philip Rahtz on the site of the church of St Martin-le-Grand in 1956 seems to have been the first investigation that recognised the existence of prehistoric occupation below the earliest Roman deposits (Rahtz 1958, 117). A small assemblage of struck flints was then recovered, which included at least two worked scrapers but no particularly datable pieces (Higgs 1958, 137).

The very much more extensive excavations conducted by the Kent Archaeological Rescue Unit throughout the 1970s and 1980s revealed that the prehistoric horizon extended 'right across the lower slopes of the Western Heights' and was 'found to contain large quantities of worked flint' (Philp nd, 3; 1989, 13 section A). Occasional features, mostly pits, also seem to have been located during the course of the work (English Heritage 1988) and two areas produced pottery provisionally dated to the later Neolithic period. The region producing this prehistoric material runs from the northern side of Queen Street at least as far north as the south side of New Street, a distance of some 150m along the valley side, while Rahtz's work has shown that the horizon extended down to the very edge of the pre-Roman estuary. Later prehistoric occupation on the spur is also represented. Work on the line of the York Street bypass in 1971 revealed the postholes of a small, circular hut, together with several storage pits that have been broadly dated to the Middle to Late Iron Age period (Philp nd, 5).

Although the subsequent archaeological history is very different, the *in situ* lithic material recovered on the western side of the main Dour valley is broadly comparable with the discoveries made under Archcliffe Fort, situated in a side valley at the foot of the Western Heights, 1km to the south-west. Here, a small assemblage of prehistoric struck flints and calcined flints was recovered from an undisturbed clay deposit over the natural valley-bottom brickearth. The general absence of colluvial material in both areas is noteworthy and presumably implies that the steep slopes of the Western Heights were never ploughed in prehistoric times.

From the details outlined above, it seems highly likely that any occupation site associated with the Bronze Age boat would have been positioned on the brickearth spur under the Roman settlement, a short distance to the north-west of Bench Street. Later Neolithic occupation now seems well attested here, together with structural remains of a less extensive Iron Age settlement. No clear evidence for Bronze Age occupation has so far been identified, but, as yet, there has been no detailed analysis of all the prehistoric discoveries.

Further inland along the Dour valley, a series of finds provide more general evidence for Bronze Age activity, although specific occupation sites have yet to be positively identified. A number of characteristic round barrows occur on the surrounding hills. In the 18th century, William Stukeley (1724, 128), writing of the topography of the Dour valley, noted 'many barrows on the sides of those hills'. Although several of these mounds still survive – all probably standard bowl barrow types – at least two sites, on Long Hill at Buckland and on Ewell Minnis, have been largely destroyed by the plough (Grinsell 1992, 357).

Several barrows have been opened but none has been excavated under modern conditions; the opportunity to examine the remains of the site on Long Hill was unfortunately largely missed in the 1950s (Evison 1987, 13–5). Work during the late 18th century on the mounds above River (a small village just outside Dover) produced finds suggesting that they were of Anglo-Saxon rather than prehistoric date, while digging at about the same time on the barrow near Little Watersend Farm apparently yielded nothing of significance (Hasted 1800, 428). A trench cut in the 1930s through one of the barrows on Whinless Down produced a single potsherd that may now be identified as being of Deverel-Rimbury type, but no contextual details concerning this find are available, and which of the four mounds on the ridge was excavated is not known.

Extensive surface scatters of struck flints have been recorded on the clay capped plateau above the Dour valley in a number of areas, particularly around Capel, St Radigund's Abbey, on Whinless Down and along the line of the eastern bypass through Whitfield and Guston. Similar flint spreads have been noted on the valley sides at Lousyberry Wood, Temple Ewell; Old Park Hill; Long Hill, Buckland; and at Coombe Hole, Guston. In the valley bottom, small groups of probably derived flakes have recently been recovered from sites at Beresford Road, River (Parfitt 1982); Crabble Mill (Barham and Bates 1990, 69); Granville Street (Canterbury Archaeological Trust archives); and the Royal Victoria Hospital (Canterbury Archaeological Trust archives). Earlier last century, at No. 9 London Road (Lloyds Bank), struck flakes were recorded, apparently in association with sharpened wooden stakes (Bates and Williamson 1994).

Although not closely datable, the bulk of the flint material from all these locations is likely to be of Late Neolithic or Bronze Age date, suggesting general settlement in the region throughout this period. A fine, stone mace-head, discovered at Buckland many years ago, could be of Late Neolithic or Bronze Age date. A typical Bronze Age, barbed-and-tanged arrowhead comes from the St Radigund's area, and another was found at Clark's Nursery on the eastern side of the Dour valley.

Apart from an Early Bronze Age collared urn discovered on Round Down Cliff, some distance to the west, and the Deverel-Rimbury sherd from the Whinless Down barrow, the only significant finds of Bronze Age pottery in the immediate area of the Dour valley are the decorated beakers that came from Connaught Park in 1883 (now lost) and the Dover (Swingate) Aerodrome, east of Dover Castle in 1915. Both vessels, classified by Clarke as being of East Anglian type (1970, Corpus nos 395 and 396), were apparently discovered by workmen; any association with human remains is not recorded.

There have been a number of finds of Bronze Age metalwork in the area. Gold ornaments (Taylor 1980, 82, Kt 13–5) are represented by torcs from the valley side at Castlemount (Scott Robertson 1878) and an unknown locality 'near Dover' (Pretty 1863, 42), while Jessup (1930, 114) records a gold ear-ring 'from Dover' in the Evans collection. Several hoards and a number of single finds of bronzework have also been recovered, especially in the Buckland area. Of particular interest here is a hoard of Early Bronze Age material, recovered in 1856 during brickearth digging in Coombe Valley, below Whinless Down. Comprising three bronze-flanged axes and a tanged spearhead, the hoard belongs to the Arreton Down tradition (Megaw and Hardy 1938). Of broadly similar date is a flanged axe discovered elsewhere at Buckland in 1756 (not 1856, cf Ashbee and Dunning 1960, 54).

Another axe of Middle Bronze Age date comes from Buckland, a looped palstave with a median ridge down the blade. It was also discovered in 1756, by labourers repairing the road. Late Bronze Age metalwork is slightly more common in the area, represented principally by a now-unidentifiable hoard of about forty implements discovered during brickearth digging somewhere between Buckland and Old Park in 1877 (NMR No. TR 34 SW 37). A looped and socketed axe and a leaf-shaped, socketed spearhead were found at separate locations at Buckland many years ago and another spearhead has more recently been found in a garden off Melbourne Avenue on the north-east side of the valley, above Long Hill.

By far the most important metalwork evidence are the finds from the Langdon Bay wreck site. In 1974, divers of the Dover Sub-Aqua Club recovered a large quantity of bronze implements from the seabed outside the Eastern Arm of the modern harbour (Muckelroy 1981; Needham and Dean 1987). Regular dives since have produced more pieces and these now total over 400 individual items. The majority of the implements are continental types, datable to about 1100–1000 Cal BC (*c* 2900–2850 BP) and many show signs of damage or deliberate breakage, suggesting this was scrap material. There seem few reasonable alternatives to the notion that these bronzes represent the cargo from a vessel that foundered while trying to make the safety of the Dour estuary, when sailing from the Continent, fully laden with scrap intended for recasting. As one likely scenario, Muckelroy (1981, 288) has postulated that a craft sailing from the French coast was driven past the haven mouth by a strong south-westerly gale, and foundered on the rocky shore below the South Foreland.

There is, thus, scattered evidence for activity in and around the Dour Valley throughout the entire period of the Bronze Age. The bulk of the evidence is in the form of isolated chance discoveries, many of which have subsequently been lost. The only visible field monuments in the area are a number of typical bowl barrows placed upon the hills above the valley. No definite remains of any settlements have so far been revealed, but the presence of at least one such site on the lower slopes of the Western Heights may strongly be suspected based on the evidence of the abandoned boat and associated domestic rubbish found in the adjacent river, together with the presence of Late Neolithic and Early Iron Age occupation in the same general area.

There is an apparent concentration of Bronze Age material in the region immediately adjacent to the River Dour, and, while this may in part be fortuitous or a product of modern activity, it seems likely that it does reflect the reality of the Bronze Age period. The fresh water available in the Dour valley, and its favourable location as a landing place for cross-Channel traffic, no doubt readily explain the reason for the increased level of local activity in prehistory, just as they do today.

Bronze Age activity in south-east Kent

Our knowledge of prehistoric settlement in the Dover region has been shaped by the extent of agricultural destruction in the upper parts of the Dour valley and its flanking hills. Under Dover itself, Roman and medieval urban occupation has given the prehistoric layers some degree of protection, and redevelopment in the period since the Second World War has provided the opportunity for archaeological exploration. Elsewhere in south-east Kent, agricultural destruction, and a comparative lack of intensive observation, have left a rather limited archaeological record. There are enough finds, however, to give some indication of the density of settlement, and recent aerial photography, especially on the chalk downlands between Canterbury and Dover, has confirmed this picture (Figs 15.1; 15.2).

Evidence for actual occupation sites is still very rare. Structural traces of Neolithic settlements may be represented by isolated pits, as at Wingham (Dunning 1966). Elsewhere, there are extensive surface scatters of flint. These appear to form an almost unbroken blanket cover, at least in the coastal zone around Dover and Deal, although they are not closely datable. Significant groups of undisturbed material come from the submerged land surface sealed by alluvial clay and peat in the nearby Lydden Valley (Halliwell 1981; Halliwell and Parfitt 1985). In several areas, significant quantities of lithic material have been associated with sherds of domestic Beaker pottery. Work ahead of the construction of the Channel Tunnel revealed further evidence for Beaker settlement in the vale below the North Downs scarp to the west of

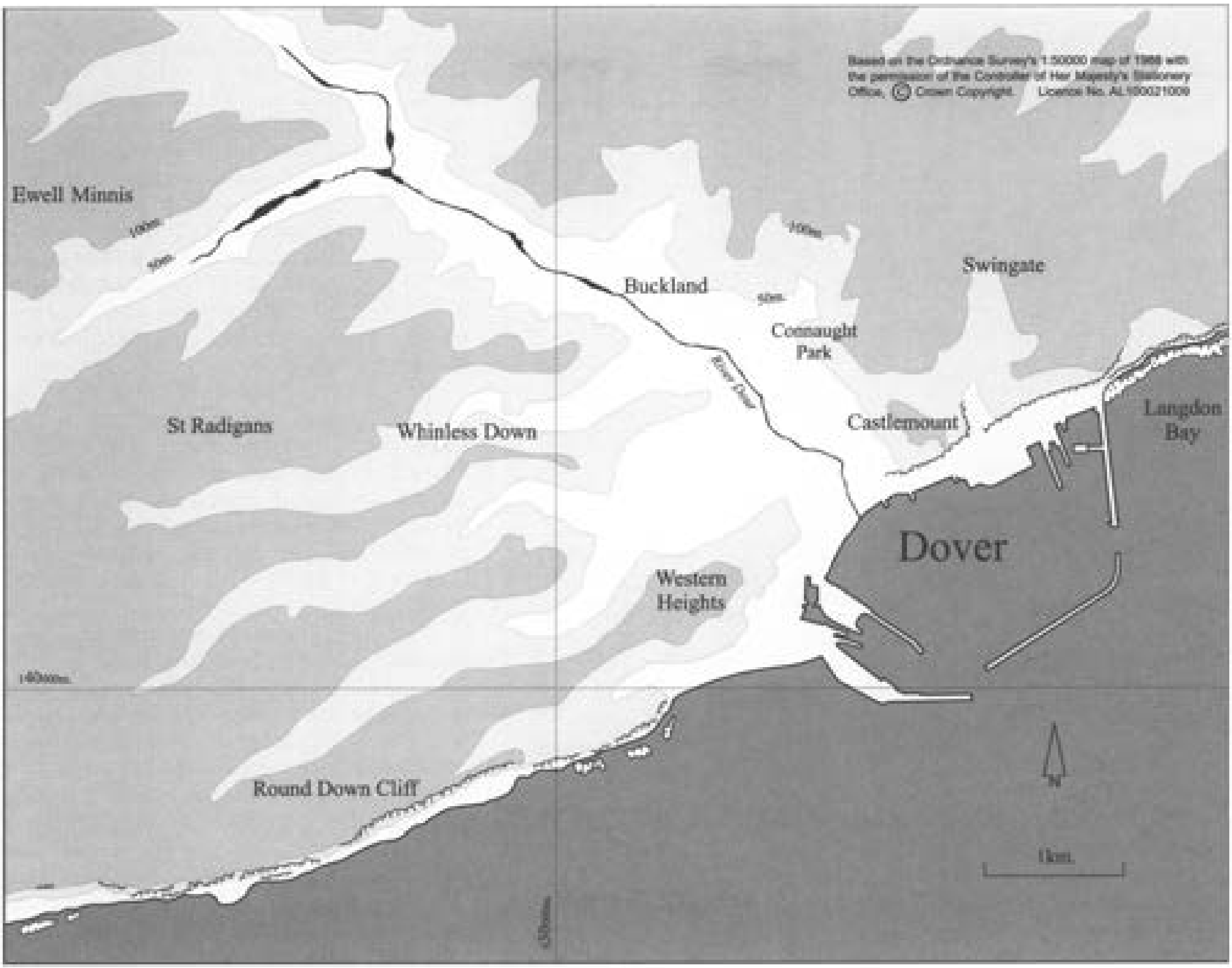


Figure 15.1
Map of the Dover valley, showing some of the sites mentioned in the text.

Folkestone. Several significant sites were located, the most extensively examined being that set in Holywell Coombe, where postholes and stakeholes relating to timber huts and fenced enclosures were recorded, along with a length of sunken trackway (Bennett 1988).

There is no evidence yet for settlements dating to the Early Bronze Age. In the Middle Bronze Age, some evidence exists, but is very fragmentary. Two locations rapidly investigated during the construction of the Eastry bypass have now provided some evidence for occupation on the chalk during this period (Willson 1993), while ^{14}C dating of a hearth deposit at nearby Hacklinge has indicated that there was occupation in this low-lying area of the Lydden Valley until around 1300 Cal BC (*c* 3050 BP; Halliwell and Parfitt 1985). Ellison (1980, 135; 1981, 239–42) has suggested that a group of large, Middle Bronze Age defended enclosures in central southern England – characterised by concentrations of metalwork in their immediate hinterland – perhaps represented major redistribution centres. On the basis of hypothetical location at fairly regular intervals across the region, Ellison predicted the existence of another similar centre somewhere in east Kent. As yet, no likely sites have been positively identified, and, more recently, Needham and Ambers (1994) have raised doubts about such a pattern, questioning both the chronology of the alleged clusters and the functions of defended sites at this period.

Evidence for settlement is more widespread in the Late Bronze Age, but still fragmentary, with few sites being excavated to any great extent. From the evidence that is available, however, it seems clear that a whole range of different types of settlement site is represented (*see* Needham (1992) for

Figure 15.2
Map of east Kent, showing the conjectural coastline of the Bronze Age and a number of the sites mentioned in the text.

more general discussion). One of the most characteristic types of site appears to be the circular ditched enclosure identified in the early excavations on Mill Hill at Deal (Champion 1980, 233–7).

Evidence for burials is much more extensive, mostly in the form of round barrows. Grinsell's study (1992) lists about 60 barrows, but has now been overtaken by the recognition of many new sites surviving only as ring ditches visible in aerial photographs. Most of the barrows are likely to be of Early Bronze Age date, although excavation evidence indicates that they were being constructed over a considerable length of time. The earliest appears to be represented by the Beaker barrow on Neavy Downs at Wingham (Ogilvie 1977, 123). Others, such as Barrow 2 on the Bridge bypass, seem to be of Middle Bronze Age date (Macpherson-Grant 1980).

Some of the burials and other finds of the Early and Middle Bronze Age are of particular interest, as they demonstrate connections with other regions. Links with Wessex are demonstrated by a number of finds (Ashbee and Dunning 1960). Among them is a group of slotted or fenestrated ceramic 'incense cups'. Four examples are now recorded in east Kent, although information about two of them, those from Luddington (Jessup 1936) and Tilmanstone (Ashbee and Dunning 1960, 50, fig 2), is only partial. The third vessel, from Ringwould, was found at the site of a cremation burial in association with four faience beads and a biconical urn (Woodruff 1874; 1877). A fourth example has been found further north at the Lord of the Manor on Thanet (Perkins nd, 18–20). A further example of a biconical urn is known from Capel-le-Ferne (Ashbee and Dunning 1960, fig 4).

Probable continental imports of the Middle Bronze Age are represented by a decorated Picardy pin from near St Margaret's Bay, and three more examples from further north at St Lawrence College, Ramsgate on Thanet (Hawkes 1942). It is possible that two others, now lost, came from a flat grave near Walmer (Parfitt 1994a; 1994b).

The distribution of other artefacts, taken together with this evidence in the form of settlements and burials, suggests that, throughout the Bronze Age, human activity was increasingly concentrated on the lower land and the coastal zone. In particular, the known quantity of Bronze Age metalwork, especially of Late Bronze Age date, has been greatly increased through the activities of local metal detectorists. These new finds have, to a large extent, confirmed the previously known distributions, and show an increased concentration in the Late Bronze Age in the coastal zone. This is particularly marked in the area around the former Wantsum Channel, both on mainland Kent and, more especially, in Thanet (Perkins 1991, 258–64).

The maritime environment of Bronze Age Kent

Today, Kent is an intensely maritime region. Although it is difficult to reconstruct the prehistoric geography of the county in much detail, it is clear that, in the Bronze Age, when the Dover boat was in use, Kent would have been even more heavily influenced by the proximity of the sea. Geographical changes since then have greatly altered the line of the coast and the nature of the coastal zone, but the influence of the sea would have been even more pervasive on the landscape and its inhabitants.

The dominant factor influencing the state of south-east England over the last 10,000 years has been the rise in the height of the sea relative to that of the land, as the glaciers melted and the land masses readjusted (*see* Long and Roberts, 1997, for a summary of the available dating evidence). In east Kent and the Thames estuary, sea level rose rapidly until about 2000 Cal BC (*c* 3600 BP), and then more slowly for the next 2,000 years, until it reached a level of approximately –3m to –4m OD. This process caused the inundation of vast areas of land occupied in the Mesolithic, now under the waters of the North Sea (B Coles 1998). Sea levels continued to rise, and the sea encroached on land inhabited in the Neolithic and the Early Bronze Age as the coastline retreated still further. At some point in this process large offshore islands such as the Isle of Wight and the Isle of Thanet were formed, as their connections with mainland England were flooded or breached. Most significantly, England itself became an island, as the land bridge with the continent was finally destroyed. The date of this event is not yet clearly established; it may have been before *c* 6000 Cal BC (*c* 7100 BP), but could have been as late as *c* 3800 Cal BC (*c* 5050 BP; B Coles 1998, 67).

At the time the Dover boat was in use, England had been separated from the continent of Europe for at least 2,500 years, and possibly 5,000 years. The English Channel was both a barrier that separated Britain from France, and, at the same time, the means of communication across that barrier, once the problems of open-water navigation had been overcome. From that time onward, all interaction with the continent required sea travel, and the broad pattern of shared innovation in later prehistory, including such important steps as the introduction of agriculture and the development of pottery and metalwork, show that such interaction must have been intense. The narrowness of the Strait of Dover made it one of the more obvious and attractive cross-Channel sea routes, despite the problem of finding a suitable landing place. The only harbour in the stretch of chalk cliffs facing France was in the estuary of the River Dour; otherwise, the only possibilities lay further along the coast to the north, beyond the site of modern Deal.

The final destruction of the dry-land connection with France and the opening up of the Strait also shaped the physical identity of Kent as an intensely maritime region. For much of later prehistory it had something of the character of a peninsula; to the north it was bounded by the wide estuary of the Thames, to the east by the southern North Sea, and to the south by the English Channel. To the south-west was the Weald, an area which was, at best, thinly occupied, and which formed a physical and cultural barrier between Sussex and Kent. Throughout prehistory, east Kent shows closer affinities to regions to the north across the Thames than to the south across the Weald.

The configuration of the coast of Kent at that time would have been very different from that today (Champion 1980). One major effect of the post-glacial rise in sea level was to turn the chalk uplands of Thanet into an island, accessible from mainland Kent only by boat. The density of archaeological evidence for occupation of the island from the Neolithic onwards makes it inconceivable that there was not regular traffic by boat across the Wantsum Channel. The channel was also a navigable route for traffic around the coast, offering a shorter, easier and safer journey than would be possible on any attempt to round the north coast of Thanet. The Wantsum was certainly navigable for coastal traffic, at least into the late Saxon period, and regular access for land transport to Thanet may not have been possible until the Late Middle Ages (Hawkes 1968). For at least 5,000 years, therefore, the Wantsum Channel played a vital role in transport around the coast from the English Channel to the Thames Estuary, and across from mainland Kent to Thanet. The shores and estuaries on either side of the Wantsum Channel, and the settlements that grew up there, would have been important links in such communications.

Relative sea level was governed by large-scale geological and climatic processes, and is not a good guide to the actual position and nature of the changing coastline, which is determined by a complex set of much more local processes, terrestrial, maritime and climatic. Much less effort has been devoted to studies of the line of the prehistoric coast in Kent than to its relation to sea level through time (although *see* Long 1992). It is, therefore, not yet possible to describe the physical geography of the coastal zone in this region in prehistory in the detailed way that has been attempted for the Fenlands of East Anglia (Waller 1994).

Nevertheless, it is possible to sketch some of the changes in broad outline. There has been extensive erosion of the chalk cliffs along the coast of Thanet (So 1965) and between Deal and Folkestone, and of the low cliffs in the softer tertiary deposits on the north coast west of Reculver (So 1966; 1971). Elsewhere, there has been a long history of deposition, masking the prehistoric coastline. To the west of Dover, the formation of Romney Marsh and of the Dungeness foreland which gives the modern coastline its characteristic shape is largely a phenomenon of post Bronze Age times (Long and Hughes 1995). In the Bronze Age, the Rother would have flowed into the Channel through a wide estuary near Appledore, and, from there to Folkestone, the south coast of Kent would have stretched eastwards in a more-or-less straight alignment. To the north of Deal, complex processes of coastal sedimentation led to the formation of the east Kent fens and eventually to the closure of the Wantsum Channel. This process seems to have speeded up after the formation of a spit across the eastern entrance to the channel, which was in place at least by the Roman period, but had clearly begun much earlier (Long 1992). In the Bronze Age, a long, low coastline would have stretched from north of Deal in a north-westerly direction to a point somewhere beyond Reculver, with rivers such as the Great Stour and the Little Stour and many smaller streams flowing into it.

Rising sea levels also produced major changes in the valleys of the rivers flowing into the Wantsum, North Sea and English Channel, as the reduced speed of water flow caused alluvial deposition, and a complex pattern of fen and marsh development began. These processes have not been much explored in the valleys of east Kent, but occasional chance observations provide at least a glimpse of the possible pattern. A cross-section of the valley of the Durlock Stream, a tributary of the Little Stour, was revealed during construction of a water main near Wingham (Ogilvie 1977, 121 and fig 14); the section shows that the bottom of the valley was filled with a bed of organic deposits 300m wide and 7m deep. The dating of these deposits is very uncertain. Investigation of organic deposits at Wingham in the valley of another tributary stream of the Little Stour suggested that deposition had begun there around the beginning of the Bronze Age (Godwin 1962).

These Bronze Age coastlines, in so far as they can be reconstructed, gave Kent a very different shape from that which it displays today. The long exposure to the Channel on the south and the low coastline along the Wantsum emphasised its nature as a sea-girt peninsula. The landmass of east Kent, especially along the coastline south of the Wantsum, would have been much more dissected by the estuaries of the wider rivers flowing into it. And the rivers themselves would have been much more prominent features of the contemporary landscape, as well as offering much greater opportunities for travel by river and by sea.

In the middle of the 2nd millennium Cal BC, these river estuaries – in Kent and, more widely, in eastern and south-eastern England – would have been much wider than they are today, with broader stretches of open water, possibly tidal for some of their length. The rapid post-glacial rise in sea level had formed the estuaries, and it was only after the rate of this rise had begun to decline that the conditions favouring the build up of estuarine deposits began to develop. There would, therefore, have been a period of time before the processes of deposition had a serious effect, when the estuaries would have been at their maximum extent of open water and offered the greatest opportunity for exploiting the possibilities of maritime communication. The precise timing of this would have varied with the specific local conditions prevailing in each valley, but the period seems broadly to have corresponded with the 2nd millennium Cal BC. It may, therefore, be no coincidence that this is also the time of the peak occurrence of sewn-plank vessels such as the Dover boat, which were ideally suited to navigating the waters of estuaries and river mouths (van der Noort *et al* 1999).

Human occupation of Kent has been greatly affected by the environment, as people have, throughout the ages, sought to exploit its potential. Today, much of its population is clustered into the narrow strip along the north Kent coast and in the major ports and resorts of east Kent, and much of its economy is dependent in some way upon the exploitation of its location and of the sea. Despite the effects of modern developments, such as new forms of transport and the rise and decline of seaside resorts, this pattern is a well-established one. In the medieval period, the distribution of population was characterised by concentrations in the Greensand vale, the North Kent Plain on the dip slope of the Downs, the main river valleys through the Downs, such as the Stour and Medway, and some of the major dry valleys leading up into the Downs from the north (Everitt 1986). The higher ground of the North Downs themselves, much of it covered with Clay-with-Flints, was mostly exploited for wood pasture. The origin of this general pattern of land use is unknown. Although it is best documented from the Anglo-Saxon period onwards, there are suggestions that it may have originated earlier. The known distribution of finds and settlements from the Iron Age (Cunliffe 1982, fig 15) and the Middle and Late Bronze Age (Champion 1982, figs 13–14) suggest that, at least in very broad terms, it may be of considerable antiquity. If so, then a large proportion of the prehistoric population of Kent, and in particular in the middle of the 2nd millennium Cal BC, at the time of the Dover boat, may already have been concentrated in the coastal zone to the north of the North Downs and in the major river valleys.

But if this is correct, then the more peninsular nature of Kent in prehistory and the broad configuration of the coastline described above mean that, in the Bronze Age, an even larger proportion of the population would have been living in closer proximity to the sea than today. The relationship of the land and the sea was changing in the middle of the 2nd millennium Cal BC, as erosion cut back into some familiar landscapes, and elsewhere new environments were being actively created as alluvial deposition in the valleys and fen formation around the Wantsum Channel progressed. Through all these developments, there may have been few people in Bronze Age Kent who were not aware of the changing opportunities offered by the coast and the sea.

Maritime activity in Bronze Age Kent

The long coastline, the offshore island of Thanet, the short cross-Channel journey to France, and the deep river estuaries, even if they were beginning to be transformed by alluvial deposition, all conspired to make the sea a central factor in the life of Bronze Age Kent. Archaeological evidence for the importance of boats and the sea will come from varied sources. The direct evidence for sea travel in the form of the boats themselves will be available only in rare contexts, since they were built of organic materials, and, as the Dover boat itself shows, the survival of any material trace will require very special environmental circumstances. The most likely environment for the discovery of such boats is in the present or former intertidal zone of river estuaries, as in the case of the Dover boat, but these are environments that have not yet been systematically explored. Although the number of such boats presently known is quite small, the total is growing, with more systematic exploration and recording. There may indeed be many other such boats awaiting discovery.

Indirect evidence for sea travel can be found through examination of the material culture surviving from the Bronze Age, especially in the presence of raw materials, objects or ideas that could not be indigenous to the area and must therefore have been imported. Such evidence will necessarily give a minimal view of the extent of such external contact. First, it depends on our ability to recognise the non-local items. It is possible, for instance, that there may have been an intensive and socially important traffic in live animals, but, as we have not yet developed a method for distinguishing the bones of animals reared locally from those reared elsewhere, such a traffic would be archaeologically invisible. Second, it depends on the physical survival of the raw material transported or of the items showing foreign influence. Objects of stone, metal or fired clay – the traditional staples of prehistoric archaeological study – will be well represented, but organic materials – whether foodstuffs or craft products such as textiles, leather or woodwork – will be almost impossible to find. Third, it emphasises the importance of any physical objects transported, rather than the social interaction of people in the past. Humans did not live in a vacuum, but lived out their lives in a web of social relationships with others. The physical evidence that remains for archaeologists to discover is but a very scanty reflection of those relationships and of the many episodes of travel and meeting that would have been needed to enact them. The most important cargo on such boats may have been the people themselves, using the sea as the only – or the most convenient – way in which they could travel in order to engage in many varied contacts with their neighbours.

The geographical location of Kent as the nearest point to continental Europe gives it a central role in many of the developments of prehistoric society from the Neolithic onwards. Unless we are to think of Britain and Ireland as culturally isolated from the rest of Europe throughout prehistory, and to rely on unlikely premises of independent and parallel invention, then both the general processes of social change – such as the development of agriculture, the innovation of metalworking, and changes in the manner of the disposal of the dead – as well as the more specific stylistic similarities seen especially in pottery and metalwork from at least the Beaker period onwards, will necessarily require an intense and regular cross-Channel system of communication. The most likely routes for such traffic will have included those from the Rhine to the Thames and across the Strait of Dover (McGrail 1987, 272).

More specific evidence for Kent's external contacts can be found in the archaeological record. The Dover boat itself contained a small fragment of shale from Kimmeridge, in the Isle of Purbeck, suggesting that one of its voyages had been along the coast from Dorset to Kent (Chapter 11). No other shale is known from Kent in the Early or Middle Bronze Age, but it was widely transported for the manufacture of ornaments, and fragments of shale bracelets are known from the Late Bronze Age site at Mill Hill, Deal (Champion 1980, 237). Other geological raw materials may also have been brought by boat. The number of stone axes recorded as found in Kent is not large (Woodcock *et al* 1988), and not all have been identified to their geological origin, but some at least came from the south-west, and they too, like the shale, may have travelled by sea along the coast.

All the objects of copper and bronze found in Kent must have been imported, either in the form of raw metal or as finished items, as there are no sources of copper or tin in the region. Their ultimate origin could have been from across the Channel in continental Europe, or alternatively from south-western or western Britain. The general similarity in metalworking traditions on both sides of the Channel has been an important theme of Bronze Age studies for some time – for example through the work of Burgess (1968), Rowlands (1976) and O'Connor (1980) – and this implies regular cross-Channel communication, if not actual transport of metal or finished products. Some continental imports are known in Kent. The decorated Picardy pins found at Ramsgate, St Margaret's, and possibly Walmer, are most likely to have been made in northern France, but, in general, objects of continental type are rare in Britain. The most important evidence for this trade is the collection of bronzes from the seabed at Langdon Bay. It contained more than 400 items, the majority of types common in France but almost unknown in Britain. Bronze transported in this way must have been valued as raw material; the imported objects were not put directly into circulation, but melted down and recast in locally acceptable forms. If the collection shows how important sea transport was in the supply of metal, it also shows how rarely, at least in typological terms, the trade is archaeologically visible. Cross-Channel traffic might have been frequent, but it is only the occasional disaster that is recorded.

Further evidence for the importing of bronze comes from chemical analysis of the metal itself. The identification of characteristic patterns of trace elements can be used to associate a particular type of metal with a possible geological origin, although there are problems associated with the mixing of metal from different sources (Ixer and Budd 1998). In the Early Bronze Age, sources in western Britain or Ireland seem to have been exploited, possibly by transport along the south coast, but much of the metal used in the Middle and Late Bronze Age must have been imported from the continent. This is especially clear with a distinctive type of metal widely used in the Wilburton phase in the 11th century Cal BC, which suggests extensive imports into southern England ultimately from an Alpine source (Northover 1982). The precise route taken by this and other supplies of metal will remain unknown until other wrecks are discovered, but a short route across the Channel near Dover seems very possible.

Pottery can also indicate the likely network of maritime connections. Sherds of Trevisker ware, a characteristic style of Bronze Age pottery made in west Cornwall (ApSimon and Greenfield 1972; Parker Pearson 1990; 1995), was found in a grave excavated at Monkton on the Isle of Thanet (Gibson *et al* 1997). Another has also been found at Hardelot in the Pas de Calais, in northern France. Together, they form clear evidence of transport along the full length of the south coast of England and across the Channel.

Although there are no other certain imports of Bronze Age pottery in Kent, similar patterns of communication must underlie stylistic similarities seen in other types of pottery found there with those elsewhere. Most distinctive are the small, perforated cups – the so-called incense cups – found at Ringwould, Tilmanstone, Luddington Wood and Lord of the Manor, Ramsgate. These are of a type otherwise found predominantly in Wessex, but with a coastal distribution through Hampshire and Sussex to Kent. The biconical urns found in the barrow graves at Ringwould and Capel-le-Ferne also belong to a class of pottery with a strong concentration in Wessex, but with other known find-spots along both sides of the Channel in southern England and northern France. The urns are made in a technique new to southern England, and possibly derived from France; the distribution of this ceramic technology and its characteristic biconical urn products would have required a high level of cross-Channel communication (ApSimon 1972; Tomalin 1984).

The incense cups and the biconical urns are found in burials in Kent, and point to a tradition of burial shared by Kent and areas further west, especially in Wessex. In particular, the most richly furnished of the Kentish burials, that at Ringwould, which also contained three segmented and one plain faience bead, has its closest affinities with a group of burials mainly in Wessex (once the so-called 'Wessex Culture'). The use of biconical urns, incense cups and faience beads demonstrates not just a shared tradition of pottery making (or possibly the importation of non-local pottery) and access to the same supply of faience, but also a common tradition of customs appropriate for the disposal of the dead, which can have come about only through a network of human interaction and communication.

There can be no doubt that these examples of maritime contacts and transport are little more than a pale reflection of the reality of Bronze Age communication. The limits imposed on our knowledge by the survival and recovery of archaeological evidence are too great. Fortunately, finds such as the Dover boat offer us a unique opportunity to go beyond these limits, and to think about the true role played by the sea in the everyday lives of the people of Kent in the Bronze Age.

16
The deposition of the boat

by Timothy Champion

One very important question about the boat remains to be addressed directly, although all the evidence needed to illuminate it has now been presented. That question concerns the final resting place of the boat: how and why did the boat come to be where it was found three and a half millennia later? The boat was a human artifact, albeit a very complex and technically demanding one, and presumably an important item of material culture. Its life history, including its final disposal, therefore needs to be considered just as much as the deposition of any other Bronze Age material. The fact that the Dover boat – an artifact intended for use in the water – was found in a watery environment, does not in any way make the reasons for its final deposition simple or obvious, and the final stages of its history deserve to be considered in the same way as any other object. It is not clear whether the boat and the other objects found near it are the remains of a single act of deposition, or of a series of separate acts spread over a period of time. Certainly, nothing was found in the layers above the boat, but artifacts were discovered in the layers underneath and beside the boat. It is possible that there were different reasons for the deposition of each of the items, but, equally, they may all have been deposited with the same basic motivation.

Bronze Age deposition practices

Deposition of Bronze Age metalwork in watery contexts has long been recognised, and it is now clear that this represents an established practice of deliberate deposition (Bradley 1990). Some recent criticism of this concept (Pendleton 1999, 89–94; Pendleton 2001) has focused on the detailed examination of the find circumstances of metalwork allegedly from wet fenland locations in northern East Anglia. However, although this criticism has questioned how many of these were originally from wet contexts, it has not demonstrated that the objects were not deposited in a deliberate and structured way, and nor has it raised serious doubts about the wider picture.

The location of depositions – not only of bronzes, but also of many other types of material remains – may be as significant as the items themselves. 'Instead of considering the cultural biography of the objects that were used as offerings, we could turn our attention to the biographies of the different places where that process happened' (Bradley 2000, 48). In some cases, artificial structures were built at sites of deliberate deposition in watery places. At Flag Fen (Pryor 2001) there was a history of deposition spanning more than a millennium, and including carefully structured deposits of metal, pottery and animal bone; the presence of many objects of tin, otherwise very rare in prehistoric sites, is especially notable. Flag Fen may be the most spectacular example of such a practice, but others are known in the south east of England, nearer to Dover. At Shinewater Park, Eastbourne, a wooden platform and possible causeways were associated with the deposition of pottery, bone and bronzes (Woodcock 1995). In Kent, an important site at Princes Road, Dartford, showed evidence of a wooden palisade at the edge of the floodplain of the River Dart, associated with Late Bronze Age pins (unpublished excavations by Canterbury Archaeological Trust). There are also important collections of Bronze Age metalwork from the River Medway (Jessup 1930, 102, 105, 253; Champion 1982, figs 13 and 14). Thus, deliberate deposition of Bronze Age material in watery contexts such as river estuaries follows an increasingly well-documented pattern, even if the precise meaning of such acts is still obscure.

More recently, much attention has been paid to the deliberate and structured nature of many deposits on terrestrial prehistoric sites. Many of these are not easily explained by modern 'rational' notions of discard or disposal, but Brück (1999a) has argued that these should not be regarded as evidence of some sort of irrational or non-functional 'ritual' behaviour, but as acts that made sense within a prehistoric logic of effective action. There are repeated patterns to the nature of such acts, especially within Middle Bronze Age settlements (Brück 1999b). Many such deposits comprise domestic debris such as animal bones or pottery, and many of the items, such as pottery or querns, were deliberately broken before deposition. Many deposits are in liminal locations, such as boundary ditches or entrances. The location of the deposits may thus have helped to define the social group, and the occasion for them may have been a significant event in the lifecycle of the group. Some could have been foundation deposits marking the beginning of a phase of occupation, while others are associated with the end of the use of a structure or settlement. The changes in the physical nature and organisation of the settlement may, in turn, have reflected changes in the composition of the group, such as the death of a member.

These studies have all underlined the importance in the Bronze Age of the use of material culture in the mediation of social relationships, for defining the nature of the group and for symbolising significant stages in its history. The nature of the archaeological record means that we find especially the last act in the history of an object or structure, but many of them would have played important roles in these relationships during their life. It has become common to talk of the life history of an object, and some items of material culture – perhaps especially those larger or more complex items such as houses or boats – may have had a particular association with an individual or a group. The social significance of the items would have been derived as much from their history as from their technological difficulty, functional utility or worth as raw material. This is important, as it bears on the question of recycling – one possible explanation for the dismantling of the Dover boat. Pottery and metalwork were regularly recycled. Pottery was ground up to make grog for tempering (eg Sherd 1 from the Dover boat, where at least two episodes of 'recycling' could be seen in thin section; *see* Fig 11.2) and bronze and other metals could be broken up and melted down for recasting. In these cases, the processes of fragmentation and firing could produce a new object. With wood, and especially a boat, it is a different matter. The wood could not go through the same transformative processes, and there is also a basic technological question of whether the hardened oak from a boat could actually be successfully reused in another vessel. It is quite possible that a boat, and all its constituent parts, had a particular social value that would have prevented its reuse in this way. Even today, many boats are ascribed identities symbolised by naming them, and the same may well have been true in prehistory. Bronze Age artifacts had a social meaning beyond their functional or commodity value, and that meaning could have determined the possible ways that an object could have been reused.

The evidence for deposition

One explanation that can certainly be excluded is loss in the course of use, whether by sinking or running aground. Although the boat shows signs of use, it has been argued that it was too large to be used in the narrow and shallow waters of the River Dour upstream from its estuary. The environmental evidence from the immediate surroundings of the boat suggests that it could have been floated into its final location only in exceptional flood conditions, and would more likely have had to have been hauled into position. The final condition of the boat, partly dismantled when apparently *in situ*, also suggests that it was not actually in its normal use at the time. Loss during use can therefore be firmly ruled out.

Another theoretical possibility to be considered is that of deliberate discard of a damaged or worn-out object. Again, however, this seems highly unlikely. Although the boat showed signs of use, there is nothing to suggest that it was anywhere near the end of its useful life. The timbers were generally robust and showed no sign of rotting or insect infestation. Another variant of this type of explanation might be that the boat, even though not worn out, had been beached for repairs or to be used to provide parts for another boat, but was never subsequently reused. Again, the evidence for the environmental context of its final location argues against these suggestions, as it would make little sense to haul a boat into a place that was inaccessible to boats in order to carry out such operations, and even less just to discard an object of no further use. The idea that it had been partially fragmented in order for some timbers to be recycled also seems improbable. In addition to the question raised above as to whether such recycling would have been ideologically possible in the Bronze Age, the experimental reconstruction of the Dover boat has shown how important it was to maintain high standards of accuracy in the shaping of the timbers to ensure a good fit. Timbers from a vessel such as the Dover boat would have been very much harder and more difficult to work than was the new oak used in the experiment. It is unlikely that, either in the construction of a new boat or if repairs were needed to an old one, timbers would have been cannibalised from a vessel that was still viable. In fact, none of the Bronze Age sewn-plank boats shows any sign of the use of recycled timbers. The only known example of the reuse of a boat timber is the fragment found at Goldcliffe, where it had been incorporated into a trackway or slipway of some sort, and a peg-hole in the timber indicates a possible intermediate stage of non-boat use (Bell *et al* 2000, 74–82). All these explanations therefore seem unlikely.

The arguments against loss or discard are themselves strong arguments in favour of another explanation – deliberate deposition in a ritual act. This is supported by many of the other features of the evidence recovered from the area surrounding the boat. The location of deposition was, as argued above, not one where the boat would have been found in the course of its normal use, and it was clearly moved there deliberately. It was a liminal location in the extreme, on the edge of land and water, possibly affected by the rising and falling water levels in the river in response to tides, and, in the longer term, a place where any object deposited would remain visible for a while but would in the end be gradually but permanently incorporated into the developing marsh. The environmental evidence for the initial phase after the deposition of the boat is important; the mollusca and plant macrofossils show a distinctive microenvironment within the boat, with damp conditions and still water, as the boat remained partly submerged. For some time it would have been possible to see the remains of the boat as a visible reminder of the act of deposition.

The physical state of the boat is also important. It was in good working order when deposited, but had been deliberately dismantled, with the removal of the side planks and the destruction of the bows. There is no obvious functional explanation for this, but it does recall the fragmented state of many other deposits in the Bronze Age, whether on settlement sites (Brück 1999b) or in barrows (Woodward 2000, 116–7).

Then there are the objects found with the boat. The piece of shale could possibly represent the remains of a cargo, but it is perhaps more likely to be a deliberate deposition placed in the boat in the final stage of its life. Shale was a common item deposited in the waters at Flag Fen (Pryor 2001, 321, 427–8). The flint assemblage is an important one, especially in an area where few such collections have been properly excavated and studied, but it is questionable whether it is typical of settlement-site assemblages. Some of the flints were placed within the boat, and the location of a hammerstone and a flake from it on either side of the boat may also be deliberate. The presence of refitting flakes also suggests not just deliberate deposition but also actual flint-working at the location. It is unlikely that such flakes would have survived together if they were derived as secondary debris from a settlement on dry land, as the material would be much more scattered and recovery much more partial. The animal bone shows signs of butchery and the burnt flint is the residue of cooking. These items together represent cooking and eating. Perhaps more specifically they represent the social act of feasting, possibly linked to one or more of the acts of deposition at the site.

Comparative evidence

It is instructive to compare this conclusion for the disposal of the Dover boat with the evidence from other prehistoric boats, especially other Bronze Age sewn-plank vessels. The circumstances of discovery and excavation have not always been as good as those at Dover, and, in many cases, uncertainty is inevitable. Nevertheless, there are some suggestive indications.

The Goldcliffe boat planks had clearly been reused in a trackway or slipway of some sort, possibly after an intermediate phase of secondary use for some unknown purpose. There is, therefore, no direct evidence for the context or circumstances of the primary deposition of the boat. Nevertheless, the authors (Bell *et al* 2000, 82) 'hypothesised a palaeochannel ... where sewn-plank boats were being landed and repaired and their planks reused as part of the platform'. This suggests the utilitarian explanation of a boat-repair area, where boats came and went without being deposited or abandoned, and only their discarded planks were left behind for reuse. It would be equally possible, however, to interpret the setting of the boat planks as indicating reuse of timbers derived from a boat that had been deposited in the vicinity for some other reason, possibly ritual.

There is much more evidence for the context of the boat parts at Caldicot (Nayling and Caseldine 1997). A number of possible boat fragments were found in various phases of the river channel, but the most important are those from Phase III, comprising large plank fragments and part of a yew withy stitching. There is little discussion in the report of how the artifactual material came to be in the river channels, although it is suggested that they should be 'interpreted as the remains of specialised activities taking place at the river location, rather than riverside settlement' (Nayling and Caseldine 1997, 278). Presumably, therefore, it is suggested that the boat parts are derived from riverside boatbuilding or repairing activities, as at Goldcliffe. It is more difficult, however, to imagine the activities that generated some of the other finds, including the coiled strip of tin, the two bronze chapes and the amber bead (Nayling and Caseldine 1997, 250–3). As well as these artifacts, there were animal bones and lithic remains: 'the fractured nature of much of this material, along with the associated stone, some of which exhibits heat damage, points to meat preparation and disposal of food refuse' (Nayling and Caseldine 1997, 278). The presence of bronze objects in a watery context, such as the old river channel, would normally suggest ritual deposition, and there is no reason to think otherwise here. Objects of tin are extremely rare in British prehistory, but the largest collection is from Flag Fen, where more than sixty were deposited in a similarly watery context (Pryor 2001, 255–91). The whole assemblage of bronzes, tin and amber is best understood as the result of deliberate deposition in the river, and the stone and animal bones could be the remains of feasting associated with such acts of deposition, or at least deposited with the other items. So too the fragments of the boat; it is not clear how or where the boat came to be broken up, but it seems probable that only plank-and-stitching fragments, such as those found, were originally deposited. Although it is possible that the boat had been dismantled for some other reason, perhaps for repair or recycling, it is also possible that it was broken up for the purpose of deposition. There are other probable boat parts from later phases of the palaeochannel system, as well as other finds of animal bones. Perhaps, therefore, we should indeed think of 'specialised activities taking place at the river location', and, in particular, of a long history of one such activity – ritual deposition.

Other boat finds are more substantial, but show similar signs of fragmentation before deposition. The Brigg boat (McGrail 1981) had certainly been dismantled, as the sides and ends had been removed before deposition. Given the circumstances of the 19th-century discovery of the Brigg boat, and the small-scale re-exploration in the 1970s, it is not surprising that there is no information about other possible finds in the river channel. The boat had been fixed in place by a post inserted vertically through a hole drilled in one of the bottom planks. This was interpreted as a secondary reuse of the boat, now reduced to a platform without its sides and ends, serving as a floating stage that would rise and fall with the tide. While it is impossible to disprove this functional explanation, it is unlikely that the water-logged oak platform would have floated sufficiently well to act in this fashion. Instead, it can be suggested that the boat was dismantled for deposition, and then held in place by a post to prevent its floating away. Perhaps the raft was 'killed' in this way by being prevented from doing the thing it was built to do – move in the water.

At north Ferriby, where remains of five boats have been found on the foreshore, the site is interpreted as one 'favourable for boat-working and [having] an accumulation of the debris typical of such activity coinciding in that stretch of the shore' (Wright 1990, 183). The three Bronze Age sewn-plank boats had been dismantled, and only small portions, including parts of their bottom planks, remained. Other finds (Wright 1990, 144–66) included parts of two other boats (one of Iron Age date), fragments of stitching, paddles, a wooden patch, oak axe chippings and other items possibly connected with boats. Two of the boats were associated with wooden structures, which may have been designed to support them during repair or dismantling. Although one of the boats had obviously been repaired, there was no sign that any one of them had reached the end of its useful life, and the explanation assumes that they were all abandoned in the middle of a process of repair. All of this may be consistent with the idea of boat repair, but there are some indications of other possibilities. Circumstances for observation and recovery were far from ideal, but other finds included pottery, and also a bronze blade – possibly a rapier fragment – found about 75m from the boats. There was also a fragment of a fired-clay weight, possibly a sinker, found close to the surface of the planks of Ferriby boat F2 (Wright 1990, 164 and fig 7.28). All of these, especially the bronze and the fragment of an artifact apparently placed inside one of the boats, suggest that other forms of deliberate deposition may have been taking place there.

No attempt has been made here to conduct a systematic analysis of the many other prehistoric boat finds, but some further examples can be quoted. The depositional context of the rather later Hasholme boat, dating to the 3rd century BC, is one of the most intensively investigated of all the prehistoric boat finds. The report (Millett and McGrail 1987, 145–7) considers possible reasons for the boat's final location, including abandonment and sinking or swamping during use. Of these, swamping is regarded as the most probable, and abandonment is considered unlikely because of the boat's location in the mudflats, presenting problems of access. The authors give careful consideration to the other finds associated with the boat – two pieces of timber and some animal bone, mainly two articulated cattle joints, representing prime beef (Millett and McGrail 1987, 137–9, 144). They argue that these items must have been on the boat at the time of deposition and might have been subsequently redistributed by tidal action, rather than being incidental later accretions. The argument is persuasive, but although referring to them as 'cargo' fits the preferred explanation of loss during use, it excludes consideration of other possibilities. The boat had been partly dismantled; the logboat construction meant that it could not be taken to pieces like a sewn-plank boat, but the bow had been broken up with sufficient force to rupture the treenails holding the two parts together. It was suggested that this might have been the result of attempts to rescue the boat or retrieve the cargo. An alternative reading of the evidence, however, is that the boat was deliberately deposited. The location of its deposition in tidal mudflats is similar to those of the other boats discussed here, while the partial dismantling of the bows, and the inclusion of unusual deposits in the boat, parallels the treatment of the Dover boat. (I am grateful to Professor Martin Millett for discussion of the question, though responsibility for this interpretation is mine.)

Other log boat finds cover a long period of prehistoric, early historic and medieval usage, and it is to be expected that deposition practices will vary greatly over that length of time. McGrail (1978) does not consider the circumstances of deposition, but the evidence he has assembled contains several interesting examples, although the records are often of poor quality. Log boats, by their very nature, cannot be so easily fragmented as can boats of sewn-plank construction. Nevertheless, in the case of those vessels with a separate fitted transom, which seem to be predominantly of prehistoric date, most were found with the transom missing or fragmentary; it seems likely that they had been dismantled before deposition (McGrail 1978, 317–8). Three log boats are recorded as having been found with significant artifacts placed inside them: at Chatteris it was a rapier-shaped bronze blade, probably of Middle Bronze Age date; at Erith a polished flint axe and a flint scraper, presumably Neolithic; and at Irlam a bronze spearhead of the Late Bronze Age (McGrail 1978, 175, 190, 220). If these 19th-century accounts can be trusted, it is clear that there was a well-established tradition of deposition involving the careful placing of selected artifacts within boats, and it is difficult to believe that this was anything other than an act of great ritual significance.

This brief review of the comparative evidence for the deposition of boats in prehistory reveals several striking patterns of activity. Although there are signs of use and repair, there are no indications that the boats were rotten or worn out. They were often dismantled or fragmented, sometimes quite violently, before or at the time of deposition. Objects were often placed on the bottom of the inside of the boats. Other material, including animal bones, is often found deposited around or near the boats.

Some of the objects deposited in or near the boats are of unusual material, such as tin, amber or shale, or are of types with important symbolic significance, such as a polished flint axe or bronze spearheads or rapiers. The sites where the boats were found often show evidence for a long period of deposition of boats and other objects.

In terms of its location and the treatment of the boat, the Dover find is comparable to many of these other boat finds. The placing of material in the boat and the deposition of other 'domestic' material in and around it also have good parallels. Perhaps Caldicot is the nearest such comparison, with a fragmented boat and the remains of animal bones and burnt stone. These boat deposits, their locations and the depositional practices documented, are also just part of a larger pattern of sites where deposition took place in the Bronze Age but did not include boats. Even if we exclude the boats, sites such as Caldicot or Dover would bear comparison with finds such as Flag Fen. The scale of the excavation has been much smaller, and the quantity of finds much less, but the nature of the sites and the social acts that took place there are similar.

Death of a boat

The Dover boat and the items found with it in fact represent the intersection of several recurrent themes in the range of deposition practices in the Bronze Age. First, they were deposited in a watery place, a practice that has been well documented for some time. Second, the deposition of worked flint, burnt flint and animal bones exemplifies the use of ordinary domestic waste, although the material may have come from social events directly linked to deposition, such as feasting, or have been specially manufactured for deposition, such as some of the flint artifacts. And, third, there is a very close parallel between the treatment of the boat and that of some structures on settlement sites. Brück (1999a, 154–5) discusses the final treatment of some Middle Bronze Age houses in terms of 'closure deposits' signalling their removal from usage. At Weir Bank Stud Farm, Berkshire (Barnes *et al* 1995) the house was completely dismantled, while at Down Farm, Dorset (Barrett *et al* 1991) various structures were partly demolished. At Trethellan Farm, Cornwall (Nowakowski 1991), houses were partly demolished and then covered in layers of rubble, earth and occupation debris to conceal them. These processes are well matched by the partial dismantling of the Dover boat and its deposition in an environment where it would gradually be reabsorbed back into the earth. There is a further similarity, too. At Black Patch, Sussex (Drewett 1982), a bronze blade and awl were placed on the floor of Hut 3 at its final abandonment. This is exactly the same as the placing of a shale fragment on the floor of the Dover boat; perhaps, too, the other examples cited above – including the clay weight at North Ferriby and the objects in the three log boats – played a similar role.

We can, therefore, attempt to reconstruct in outline something of the context of the deposition of the boat. It represents a 'closure deposit' signalling the end of the life of the boat. On one reading of the evidence, it would have been hauled into the shallows, outside the normal zone of its working life, and partly dismantled. A shale fragment was carefully placed on the floor, and it was surrounded by the remains of 'domestic' debris, perhaps derived from a feast and from deliberate acts of manufacture at the site. Thus it was symbolically entombed until the river reclaimed it. Alternatively, some of the other finds may have been deposited in earlier and separate acts. In this case, the boat would have been hauled to a place already invested with symbolic significance, to be dismantled there. We may never know the precise context for these last rites practised over the boat, but its passing represented a significant event in the lifecycle of a community or an individual. Perhaps, like the destruction and concealment of a house, the dismantling of the boat was a means of dealing with an event in the history of the local population, such as the death of an individual.

17
Conservation

by Jacqui Watson

When first discovered, and prior to being lifted, the Dover boat was examined by conservators from English Heritage. It had been fashioned in such a way that most of the vessels timbers have a tangential or oblique radial surface. It was also clear that the condition of the wood varied along its length and between its constituent parts. The boat was cut into some 32 pieces for its excavation and retrieval, each measuring between 0.63m by 0.15m and 2.45m by 0.58m (Chapter 3; *see* Figs 4.2; 17.1). Pieces were cut in such a way that the complex jointing between the main boat planks was preserved. At an early stage, it was decided that the boat should be conserved and displayed in Dover Museum. In spite of the overall length of the boat, the individual boat pieces were small enough to consider methods of conservation involving freeze-drying or polyethylene-glycol (PEG) replacement. Primary recording of the boat timbers was completed within eighteen months so that the active conservation programme could begin as soon as possible.

Figure 17.1
Articulated section of the boat on custom-made polyester and glass fibre cradle.

Condition assessment

In order to establish which conservation treatment was the most appropriate for this boat, a full condition assessment of the different wooden elements was undertaken. This involved calculating the water content and specific gravity, in addition to examining the cellular structure and noting the presence of minerals. It was originally intended to take samples using a standard 5mm coring tool, but this had to be abandoned as the surfaces of the boat have mainly a tangential section and were breaking up under the pressure. Instead, sections were cut from the sawn edges with a sharp blade. Areas that could not be sampled were tested by inserting a pin into the surface and comparing the depth it could penetrate with that of the sampled areas. This gave a general indication of the condition of the wood.

Water content

Both Umax and saturated wet weight (SWW) were calculated (based on Hoffmann 1981). Table 17.1 shows the range of water contents found in the different elements of the boat, based on the dry weight of the wood (Umax) and as a proportion of the wet weight.

Generally, the southern end of the boat appears to be in a better condition than the north. This cannot be shown numerically, as the end section did not have suitable breaks or sawn edges to take samples from, but it was clearly in better condition than the rest of the boat. Both sound and very degraded wood are present, and these would normally be treated with different

Table 17.1 Water content of different boat elements

boat element	*Umax*	*SWW*
withies	220–350%	68–77%
bottom planks	200–550%	67–85%
ile planks	400–650%	80–86%
laths and transverse timbers	400–850%	80–89%

ratios of mixed PEG in both freeze-drying and PEG replacement methods. It was possible to look at the water content profile across some sections, and, not surprisingly, the outer layers are more degraded than the core. Full details of the water content of individual elements of the boat and how they were obtained have been described elsewhere (Watson 1993).

Specific gravity

The specific gravity measurements were undertaken by Mark Jones of the Mary Rose Trust. The oak samples were found to have a specific gravity of between 0.13–0.26, as opposed to fresh oak, which is 0.55–0.64; the yew was 0.32. Using the specific gravity measurements it was possible to suggest the projected shrinkage rates of the oak on air-drying by comparison with similar material. This indicated that the Dover boat timbers were likely to shrink 10–15 per cent longitudinally, 14–16 per cent radially, and a dramatic 44–60 per cent tangentially.

Cellular structure

Samples were examined using both scanning and transmitted electron microscopy by Mark Jones. With these methods it was possible to see that the yew withes were still in good condition with most of the cell walls still intact (*see* Fig 17.2), but the oak had examples of all three types – good, transitional and highly degraded. In some of the highly degraded areas, the secondary wall layers were breaking away from the middle lamella, or were porous due to bacteria or fungal decay (*see* Fig 17.3). In all the oak samples the tyloses (bladder-like expansion of parenchyma cell wall) were intact, which means that the ingress of PEG and the egress of water would have to be through the tangential and radial surfaces, rather than the early-wood vessels.

Examination of the end grain of the cut edges revealed that some areas had been heavily compressed during burial, thereby distorting the medullary rays. During storage in water, some relaxation of the wood was noted, so that some parts of the boat were almost beginning to return to their original curvature.

Mineral content

When first excavated, the boat timbers were a pale brown colour, but over a short period they darkened to brown/black. This probably indicated the presence of iron in the form of ferrous ions that can react with any residual tannins in the wood to produce the black staining; this was later confirmed by X-ray fluorescence analysis. It is common for iron salts to accumulate in the wood as a result of bacterial activity during burial and high quantities of these can oxidise after conservation, causing further deterioration to the wood structure. Fortunately, the levels of iron salts in the Dover boat are probably not high, as there were no signs of the formation of reddish brown iron oxides on the wood surface.

Choice of method

The considerable size of the Dover boat limited the choice of conservation treatment to three methods: controlled air-drying, replacement of most of the water inside the wood with a solid-grade PEG, or removing the water by freeze-drying.

Controlled air-drying

Well-preserved wood can be dried by gradually reducing the relative humidity (RH) of the surrounding air inside a structure such as a polytunnel. From the projected shrinkage rates it was clear that the Dover boat timbers were not suitable for this system of drying. Most of the boat surface has a tangential section, which gave the most extreme projected shrinkage rates in the assessment, meaning that air-drying would almost certainly produce huge cracks along the grain.

PEG replacement

A twin PEG-replacement programme would be necessary to conserve the boat

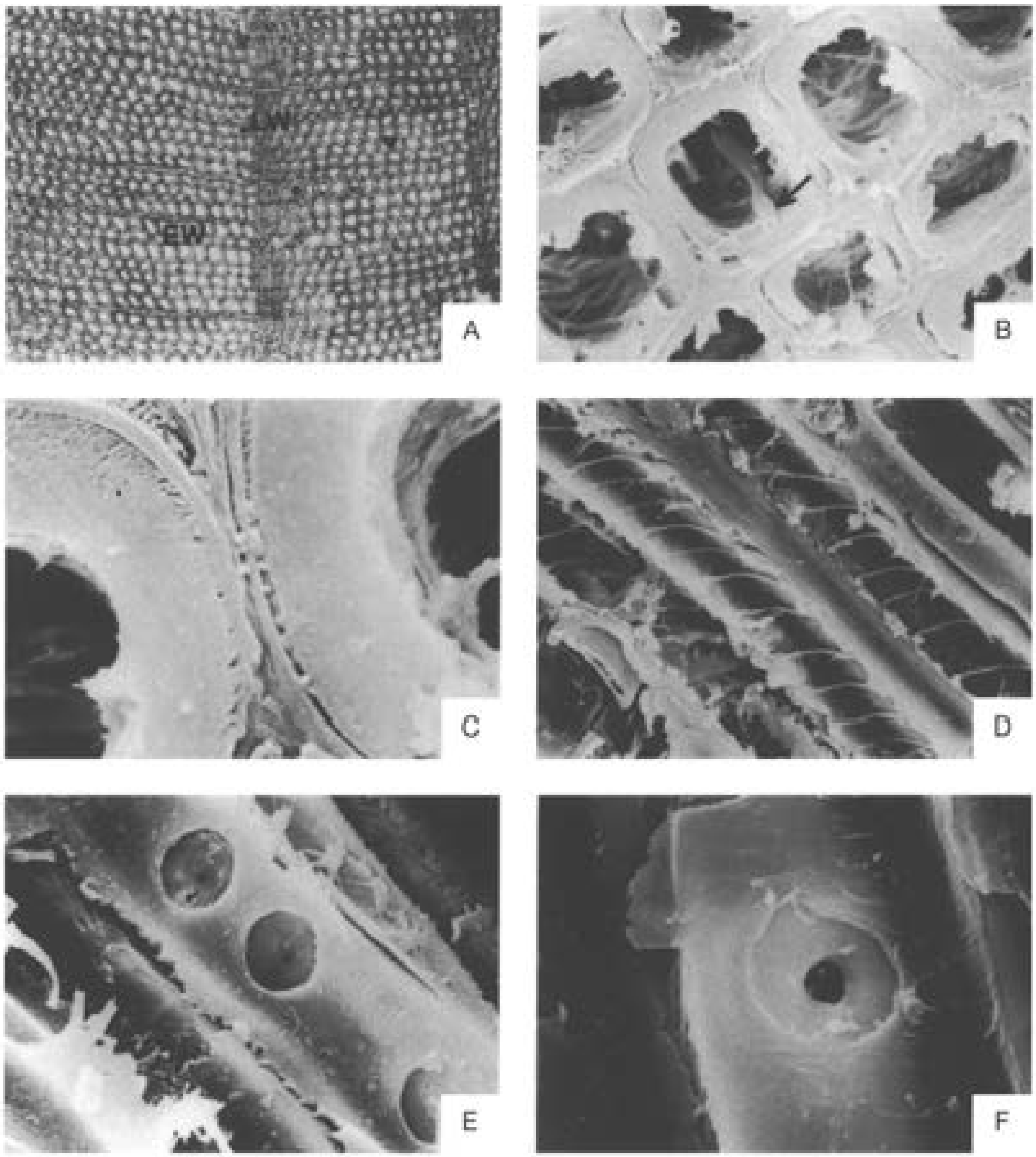


Figure 17.2
Scanning electron micrographs of a yew withy.
A: Sound early-wood (EW) and late-wood (LW) with most of the cell wall intact (mag. 320×).
B: Sound early-wood tracheids with fungal hyphae (arrowed) (mag. 3200×).
C: Tracheid cell wall with well-preserved secondary wall layers (mag. 12000×).
D: Longitudinal section showing spiral thickening (mag. 1600×).
E: Longitudinal section showing the arrangement of bordered pits; the S2 layer has become detached during sectioning (mag. 3200×).
F: Longitudinal section showing a degraded pit where the torus has disappeared (mag. 5600×).

timbers. This involves replacing nearly all the water in the waterlogged wood with two grades of PEG: a liquid grade of molecular weight 600 penetrates into the cell walls, and a solid grade of molecular weight 4,000 replaces the water in the cells (Hoffman 1984). PEG, especially the high-molecular-weight grade, penetrates very slowly into the wood structure (Dean *et al* 1997) and it is not unusual for it to take about ten years to reach an acceptable level of consolidation, during which time the progress needs to be regularly monitored. The consolidated timbers then need to be conditioned in the same way as in controlled air-drying, which could take a further two years.

Freeze-drying

The freeze-drying of waterlogged wood is a two-stage procedure. In the pretreatment phase, some of the water in the wood is exchanged for PEG, usually molecular weight grades of 400 and 4000. These are used to compensate for the stresses on the wood structure during freezing and chemically stabilise the wood to fluctuations in relative humidity after drying (Grattan 1981), as well as to provide a slight consolidation. The concentration of the combined PEG must be kept fairly low (under 40 per cent) to avoid problems during the freeze-drying phase (Watson 1997). This means that the immersion stage can be accom-

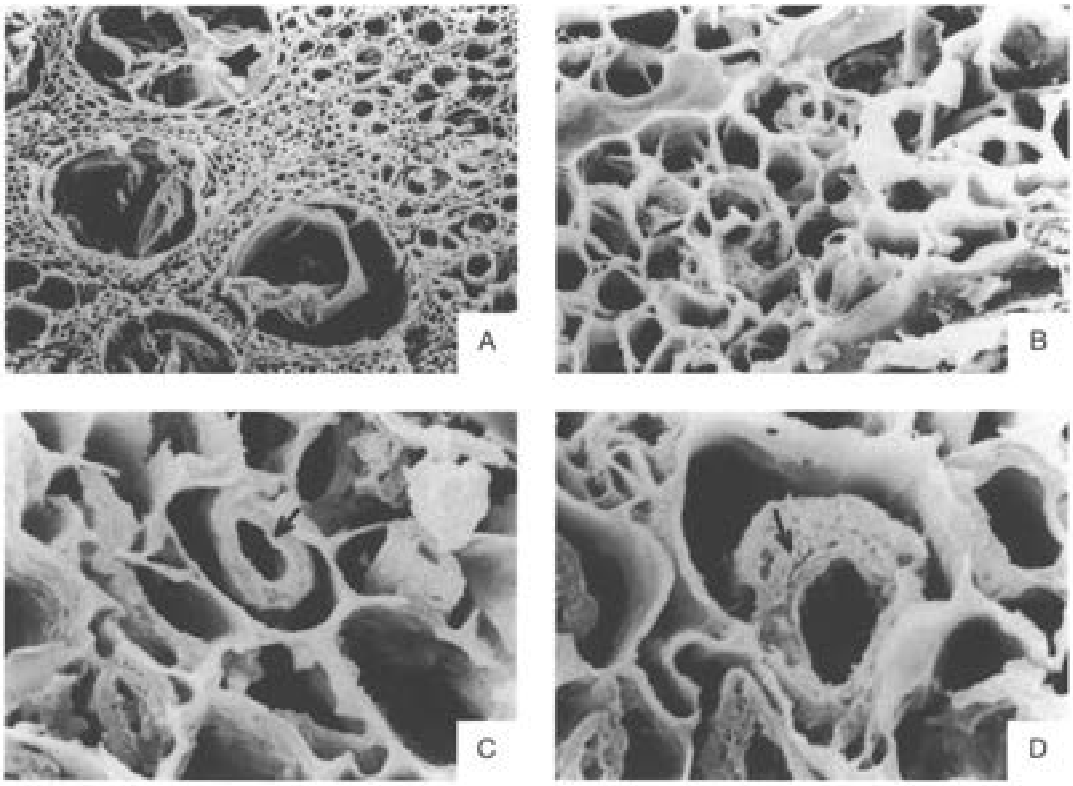


Figure 17.3
Scanning electron micrographs of a transverse section of one of the Ile timbers.
A: Outer surface showing advanced stage of decay. Tyloses in vessels showing selective degradation (mag. 160×).
B: Outer surface of timber and the secondary cell walls of most of the wood fibres are completely degraded with only the middle lamella remaining (mag. 1200×).
C: Porous appearance of the S2 layer (arrowed) of the fibre cell wall is probably due to decay by a combination of bacteria and fungi. Adjoining cells have lost their secondary wall layers leaving only the middle lamella intact (mag. 3200×).
D: Porous appearance of the S2 layer (arrowed) of the fibre cell wall is probably due to decay by a combination of bacteria and fungi. Adjoining cells have lost their secondary wall layers leaving only the middle lamella intact (mag. 5600×).

plished in just over a year. The timbers are then frozen, and, during freeze-drying, the remaining water in the wood is removed as a frozen vapour, so avoiding the normal drying stresses placed on the wood structure.

The condition of the wood indicated that the best results could be achieved only by freeze-drying or PEG-replacement methods. The freeze-drying option was eventually chosen, as the boat would be ready for display sooner and at approximately a tenth of the estimated costs of PEG-replacement by immersion. The freeze-dried sections are lighter in weight than they would be after PEG replacement, ensuring less of a problem for reassembly.

Pretreatment

Using the water contents of the different elements of the boat, we queried the PEG CON program (Cook and Grattan 1990). This indicated that we should use a combined solution of 18-per-cent PEG 400 and 25-per-cent PEG 4000 for the more well-preserved elements, and 8-per-cent PEG 400 with 36-per-cent 4000 for the more degraded elements. Taking the average water content as 400 per cent, and making adjustments for the PEG 400 coefficient, the recommended pretreatment solution came out as 18-per-cent PEG 400 and 35-per-cent 4000. The program indicated that this was very close to the eutectic concentration, and experience has shown that high concentrations of PEG can lead to problems during the freeze-drying phase. So, with this in mind, it was decided to use a pretreatment solution of 10-per-cent PEG 400 and 20-per-cent PEG 4000 for the boat.

Initially, the boat sections on their customised cradles were immersed in a solution of 10-per-cent PEG 400 for two months. Then PEG 4000 was added to this bath in two instalments of 5 per cent each, at two-week intervals, to get a combined concentration of 20 per cent, effectively killing off the bacterial slimes that form on the surface of the solution. The remaining 10-per-cent PEG 4000 was added in 2.5-per-cent increments, also at fortnightly intervals. It took about 4 months to reach the final concentration, and the boat sections were then left for a further year in the solution.

At the end of the pretreatment stage, all the sections were vacuum-sealed in barrier foil on their cradles for transporting to the Mary Rose Trust in Portsmouth (*see* Fig 17.4). With this method, all the component parts were held securely but gently in place, and stopping them being excessively shaken

Figure 17.4
Sections of the boat, including cradles, that have been vacuum-sealed in barrier foil in preparation for transport from Dover to Portsmouth.

during transit in the back of a refrigerated lorry. As this stage of the project had to be completed during one of the few hot spells in the English summer, it was essential that the pieces were moved from Dover to Portsmouth in a chilled container.

Freeze-drying

All the pieces of the boat were frozen at –25°C in their sealed packaging, and stored at these temperatures until space was available in the freeze-dryer. The freeze-drying of the sections was done by Mark Jones and Chris O'Shea at the Mary Rose Trust. Freeze-drying commenced with the chamber set at –25°C, and continued at this temperature until the sections (including their cradles) had lost about 25 per cent of their frozen weight. At this point, the rate of drying tailed off considerably so that the chamber conditions had to be adjusted to restore sublimation. The chamber temperature was slowly raised to –20°C in 1°C stages, and freeze-drying continued under these conditions to completion.

The freeze-drying was done in three batches, with each batch containing material of a similar thickness. The first batch began to be freeze-dried in September 1995 and the progress was monitored by regular weighing of the sections. The timbers were considered dry when the discernible weight-loss was less than 1 per cent of the original frozen weight. It was then returned to the chamber and the temperature was gradually increased to ambient temperatures while under vacuum, to prevent condensation forming on the cold wood surfaces. The timbers had lost between 12–40 per cent of their frozen weight during drying; the average being about 35 per cent. Each batch of timbers took between two and three months to freeze-dry. The drying details of batches 1 and 2 can be found in Table 17.2, and, from these adjusted figures, drying curves for different elements of the boat were produced for a varied selection of timbers (Fig 17.5). It was impossible to insert suitable thermocouples into the timbers, so it has not been possible to record the actual ice temperatures during the drying cycle.

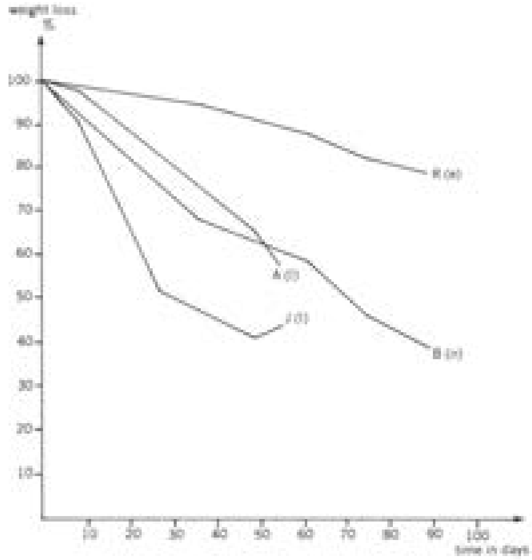


Figure 17.5
Drying curve of a selection of timbers from Batch I and II, with their percentage weight loss including the support cradles.

Table 17.2 Weight loss for batches 1 and 2 during freeze drying

batch 1

boat piece	*frozen weight (kg)*	*cradle weight (kg)*	*timber weight (kg)*	*day 8 (kg)*	*%*	*day 27 (kg)*	*%*	*day 49 (kg)*	*%*	*day 55 (kg)*	*%*	*total weight loss (kg)*	*%*
A (i)	20.5	7.75	12.75	20.3	98%	–	–	16.0	65%	15.0	57%	5.5	43%
A(iii)	17.0	8.75	8.25	16.5	94%	15.0	76%	14.5	70%	14.0	64%	3.0	36%
D (ii)	9.5	4.25	5.25	9.5	100%	8.5	81%	8.0	71%	9.0	90%	1.5	29%
H	22.0	6.0	16.0	21.7	98%	19.5	84%	18.0	75%	18.0	75%	4.0	25%
I	17.5	3.25	14.25	17.1	97%	15.0	82%	13.0	68%	13.5	72%	4.5	32%
J (i)	21.5	8.0	13.5	20.3	91%	15.0	52%	13.5	41%	14.0	44%	8.0	59%
J (iii)	21.0	5.75	15.25	20.6	97%	20.0	93%	18.0	80%	19.0	87%	3.0	20%
K	11.0	5.0	6.0	10.4	90%	9.5	75%	9.0	67%	10.0	83%	2.0	33%
L	24.5	7.6	16.9	24.0	97%	23.0	91%	19.0	67%	20.0	73%	4.5	33%
M	21.0	7.5	13.5	20.3	95%	19.0	85%	16.0	63%	17.5	74%	5.0	37%
N	33.5	6.0	27.5	32.5	96%	29.5	85%	25.0	69%	26.0	73%	8.5	31%
O	13.5	5.5	8.0	13.7	103%	13.0	94%	12.5	88%	12.5	88%	1.0	12%
W	24.5	6.5	18.0	24.0	97%	21.0	81%	19.0	69%	18.5	67%	6.0	33%

batch 2

boat piece	*frozen weight (kg)*	*cradle weight (kg)*	*timber weight (kg)*	*day 36 (kg)*	*%*	*day 61 (kg)*	*%*	*day 75 (kg)*	*%*	*day 89 (kg)*	*%*	*total weight loss (kg)*	*%*
A (ii)	37.0	8.5	28.5	33.0	86%	30.0	75%	28.5	70%	27.0	65%	10.0	35%
B (n)	37.0	9.25	27.75	28.0	68%	25.0	58%	22.0	46%	20.0	39%	17.0	61%
C	55.5	15.2	40.3	48.0	81%	43.5	70%	43.0	69%	40.0	62%	15.5	38%
D (i)	40.0	7.75	32.25	34.0	81%	31.0	72%	30.0	69%	28.0	63%	12.0	37%
G	44.5	10.5	34.0	39.5	85%	37.0	78%	35.0	72%	34.0	69%	10.5	31%
J (ii)	37.0	6.75	30.25	32.5	85%	29.5	76%	28.5	72%	27.0	67%	10.0	33%
P	42.0	9.0	33.0	39.0	91%	38.0	89%	36.5	83%	36.0	81%	6.0	18%
R (e)	46.0	7.5	38.5	44.0	95%	41.5	88%	39.0	82%	38.0	79%	8.0	21%
R (w)	46.0	6.75	39.25	40.0	85%	37.5	78%	36.0	75%	35.0	72%	11.0	28%
R (w) (ii)	17.5	6.75	10.75	10.0	30%	10.0	–	–	–	–	–	7.5	70%
V (e)	33.0	6.0	27.0	23.0	63%	19.0	48%	18.0	44%	17.0	41%	16.0	59%
V (w)	21.0	5.7	15.3	19.0	87%	18.0	80%	17.5	77%	17.0	74%	4.0	26%

Results

Once dried, the boat sections were checked against the original 1:1 drawings, which showed that there was little shrinkage in any direction, and the curvature had not altered substantially. This was a great relief, as it had been noticed that, during water storage, the wood structure had relaxed slightly in line with the original curvature of the boat. However, there was some surface cracking, which has been slightly exaggerated by the drying process. The surface of the wood looked dry, and on the upper surfaces was a faint yellow/green deposit (possibly sulphur), which had been precipitated in the treatment bath as a result of oxidising minerals in the wood. Unfortunately, the edges of some of the tangential cuts developed a wavy section during conservation, a problem that had not been encountered before with freeze-dried timbers.

The study of a sample taken from part of the keelboard, using a scanning electron microscope (SEM), revealed no obvious additional degradation after freeze-drying (*see* Fig 17.6); the cellular structure appears almost identical to the untreated material. PEG 4000 has been deposited in microscopic cracks in the wood rather than the vessels or fibres (*see* Fig. 17.7). This suggests that the wood was very degraded, with microfissures throughout the structure and already present at the immersion phase.

Post-drying treatment

All the post-drying conservation work was carried out by Sue Bickerton of the Mary Rose Trust. It was possible to brush off

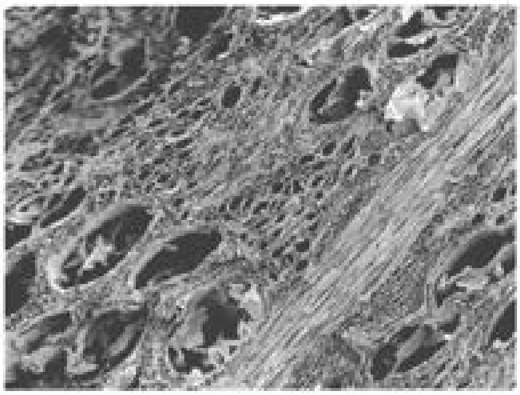


Figure 17.6
Scanning electron micrograph of the transverse section of the surface of a bottom plank that exhibits little additional distortion after freeze-drying.

Figure 17.7
Scanning electron micrographs of the surface of one of the boat timbers illustrating that the PEG 4000 has been deposited in microfissures within the wood structure rather than the wood vessels.

most of the excess PEG 4000 on the surface, and the yellow/green deposit was removed with swabs of IMS and distilled water. Broken fragments were repaired, the larger pieces occasionally being supported with wooden dowels. The surface of the wood was given a coating of PEG 6000 both to consolidate it and as a protection from dirt and dust. After this coating was applied, any visible surface cracks were consolidated with a mixture of PEG 6000 and wood pulp to tone in with the conserved wood (Fig 17.8).

Display

The boat has been reassembled and put on display in Dover Museum (Chapter 18). Conservation literature documents that PEG promotes the corrosion of most metals except for stainless steel. This posed problems in the choice of materials for the support cradle, ventilation ducts and archaeological metalwork exhibited nearby. Stainless steel is a very heavy metal, expensive and difficult to shape, and so it was not an ideal choice for the support cradle. All the studies on the corrosive action of PEG

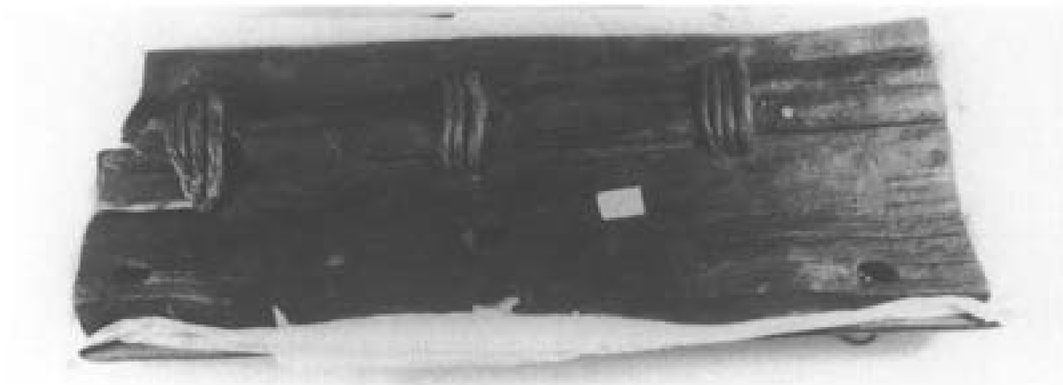


Figure 17.8
One of the completed ile sections after freeze-drying and surface consolidation.

Table 17.3 Oddy tests for support materials for use with the Dover boat

sample	*contents of flask*	*results*
A	anodised aluminium + distilled water	strange mid-grey deposit on edge
B	anodised aluminium + wood + distilled water	no visible change
C	anodised aluminium with exposed edge + distilled water	no visible change, even on exposed metal
D	lead + wood + distilled water	lead turned black
E	lead + distilled water	lead dulled to dark grey
F	zinc + wood + distilled water	zinc covered in white pustules of corrosion
G	zinc + distilled water	faint white deposit on the surface of the zinc
H	copper + distilled water	copper has tarnished to a crimson sheen
I	copper + wood + distilled water	copper turned black

were based on the chemical dissolved in water, and nothing was documented on the effects on wood treated with PEG in a relatively cool, dry environment. To try to find out the likely long-term corrosive effects of PEG freeze-dried wood, accelerated ageing tests were carried out on a variety of metals. Zinc, lead and copper were thought to be most at risk, and were tested along with anodised aluminium, which was the preferred choice of material for the cradle (Table 17.3).

On the basis of these stability tests, the cradle was made from anodised aluminium. Perspex 'tell-tales' were placed across selected cracks; these were engraved with fine lines in precise alignment across each crack. Any movement of the wood could be monitored by regularly checking if these lines had shifted out of alignment. A temperature- and humidity-controlled display case has been erected around the boat. The boat is to be displayed at 55% ± 2% RH, at a temperature of 18°C ± 2°C. The lighting has also been designed to avoid there being any local hot spots on the wood surface, minimising the risk of photodegradation.

18
Reassembly and display

by Peter Clark, Barry Corke and Christine Waterman

Introduction

The initial surprise, pleasure and excitement that accompanied the discovery of the boat was mixed – even in the first hours – with concern as to its ultimate future and care.

Ancient waterlogged wood is notoriously difficult and expensive to preserve and display. Once it became clear that the boat had to be lifted, and could not be preserved *in situ*, it was evident that an organisation with considerable resources would have to be found to take on the task of long-term care and also, it was hoped, public display of this internationally important find.

In the event, through the work of the Dover Bronze Age Boat Trust and its sponsors, the fully conserved boat and accompanying displays were opened to public view only seven years and fifty-two days after the first timbers were found – just 250m from where they had lain for 3,500 years.

This section describes how this part of the Dover-boat project was achieved to provide both a record of that work and an example to others who may be confronted with a similar challenge.

The Dover Bronze Age Boat Trust

Foundation

Most of the individuals and organisations that were to form the Dover Bronze Age Boat Trust (DBABT), which now owns the boat and its displays, were already present and active in the early days of excavation and recovery in September and October 1992.

There were five organisations from which the founding Trustees and advisers were drawn – Canterbury Archaeological Trust, Dover District Council, Dover Harbour Board, P&O European Ferries (now P&O Stena Line) and English Heritage. All were involved with the excavation process, as members of the field team, and/or in providing resources for them. The five original organisations represented were later complemented by the addition of a further Trustee from George Hammond PLC, an important shipping company in Dover.

The formation of the Trust, initially as a voluntary organisation seeking charitable status, did not take place until October 1993, a year after the boat's discovery, when the Director of Canterbury Archaeological Trust and the Curator of Dover District Council's Museum Service decided that this was the best possible vehicle for organising and fundraising for the preservation and display of the boat. The costs of the work, then estimated at £1 million, were beyond the resources of Dover District Council, who had only recently (1991) funded a new £13-million Museum and Heritage Centre. English Heritage, although generous with excavation, conservation and research grants for the boat, are, under their terms of reference, unable to fund displays. A charitable trust therefore seemed to offer the best solution.

The aims of the Trust

An extract from the DBABT's Memorandum of Association records its aims:

1 To protect, preserve and conserve for the public benefit the Dover Bronze Age Boat.
2 To advance the education of the public about all aspects relating to the boat, its design, construction, history, use and all other relevant matters, in particular by the provision of a museum concerned with the display of the boat.

To these could be added an important detail, that the Trust was concerned that the boat should be displayed in Dover, emphasising the context in which it was found – by the River Dour, close to the sea and at the shortest crossing point in the English Channel. Local residents, who already considered the find as 'their boat', were supportive of this view.

The work of the Trust 1993–1999

Below is a brief chronology of the work of the DBABT between 1993 and 1999, highlighting the most important project milestones. Throughout this period, the Trust was chaired by Dr F H Panton, CBE.

1993

- *October*: DBABT forms as a voluntary organisation seeking charitable status.
- *December*: Two open days, overseen by members of the excavation and recovery team, are held to allow the public to view the boat in temporary water tanks. Three thousand visitors attend.

1994

- *April*: Kent Archaeological Society provides a £4,000 grant to fund the printing of a leaflet and fundraising booklet about the boat. Dover Museum mounts an exhibition on the project.
- *May*: The Trust is launched at a reception on board the P&O ferry *Pride of Burgundy*, when a piece of the boat, in a water-filled tank, makes its first voyage for 3,500 years. At the launch, Sir Jocelyn Stevens (then Chairman of English Heritage) pledges £300,000 towards the cost of preserving the boat.
- *June*: The Department of Transport officially presents the boat as a gift to the DBABT.
- *November*: The Trust receives full charitable status.

1995

- *January*: Dover District Council agrees in principle to providing an exhibition space for the boat in an existing restaurant and shop adjacent to Dover Museum, and to providing free curatorial time to care for it once on display, thus relieving the Trust of the need to provide premises and staff for the proposed displays.
- *May*: Preparation of outline design work and the Heritage Lottery Fund application commences. (The cost of preparing the bid, including design and consultancy fees, was about £15,000.)
- *August*: End of the first phase of the conservation funded by English Heritage (the soaking of timbers in PEG) is achieved. Boat timbers are transported to the Mary Rose Trust laboratories in Portsmouth to commence the second stage of conservation (freeze-drying).
- *September*: The Rt Hon the Lord Brabourne CBE agrees to become patron of the Trust.

1996

- *January*: The Trust submits a £1.2 million bid to the Heritage Lottery Fund for the completion of conservation work, conversion and fitting-out of the proposed gallery, and for the provision of an endowment fund for the future care of the boat. By this stage, the Trust's fundraising activities had already secured donations totalling £343,736.
- *September*: The Heritage Lottery Fund agrees to provide a grant of up to £953,000 towards the project, representing 75 per cent of the eligible costs, but excluding the endowment, marketing and merchandising elements requested.

1997

- *February*: The Wolfson Foundation offers a grant of £25,000 towards the cost of the exhibition work.
- *March*: The European Regional Development Fund (KONVER Programme) offers £55,000 towards marketing and merchandising costs. Dover District Council agrees to fund the running costs of the gallery, estimated at £20,000 per annum over a twenty-five-year period.
- *August*: Contracts between the Trust, the Heritage Lottery Fund and Dover District Council are agreed and signed. A project manager, Mr Richard Sutch of the Bailey Partnership is appointed to begin the work in earnest. However, when all the costs originally prepared in 1995/6 are audited a shortfall is identified and further application is made to the Heritage Lottery Fund.
- *April*: The Heritage Lottery Fund agrees to a further grant of £159,300, bringing their total grant to £1,112,300. With all funding in place (*see* Table 18.1) the project's construction work can now begin. The main project contractors were Jenner (Contractors), a local, Kent-based company.
- *May*: Work begins with the conversion of the restaurant and shop into an exhibition gallery, including the construction of the boat case.

Table 18.1 Sponsors of the Bronze Age Boat project, January 1994 to December 1999

	£
Heritage Lottery Fund	1 200 000
English Heritage	300 000
Dover District Council	specialist services
Wolfson Foundation	25 000
European Regional Development Fund	55 000
Kent County Council	15 000
Sir James Colyer Fergusson Charitable Trust	10 000
George Hammond PLC	10 000
Carnegie UK Trust	5 000
Arjo Wiggins	4 000
Kent Archaeological Society	4 000
Dover Town Council	3 000
Tory Family Foundation	5 000
British Nuclear Fuels	10 000
Baltic Exchange	1 000
Dover Society	1 250
Swire Charitable Trust	1 250
Total	1 649 500

1998

- *August*: The thirty-two conserved boat pieces are returned to Dover for reassembly on a purpose-built cradle. A specially designed, enclosed, temporary air-conditioned working area with viewing panels allows the public to see the whole reassembly process. At the same time, Dover Museum staff, the gallery designer (Mike Whalley) and a team of exhibition specialists – including figure- and model-makers, computer-software, video and graphic-panel designers – continue to develop the detailed designs for the displays.

1999

- *July*: Reassembly of the boat pieces is completed by Canterbury Archaeological Trust. The boat case is glazed and the air conditioning for the case is commissioned. The fitting-out of the exhibition surrounding the boat case begins.
- *November*: Exhibition work is completed. The new Dover Bronze Age Boat Gallery and boat is handed over on loan to Dover District Council for twenty-five years. On 22 November, the gallery is opened to the public at Dover Museum by the Rt Hon Lord Kingsdown, Lord Lieutenant of Kent, in the presence of 120 guests, many of them members of the 150-plus boat project team.

Designing and building the Dover Bronze Age Boat Gallery

The Dover boat is a spectacular artefact that demands both a high standard of care and high-quality presentation.

The main challenges facing the design team were to provide a safe display environment for the boat and to provide displays that would interpret effectively not only the Bronze Age, but also the boat itself. Also, they needed to provide effective multi-layered displays to satisfy the needs and interests of a great range of visitors, from children to specialists in prehistory.

The brief

From 1993 to 1995, the museum staff had many opportunities to gauge visitor reaction to the boat at public open days and public lectures, and by observing and talking to visitors viewing a temporary exhibition on the project in the museum.

After a space for the gallery, adjacent to the museum's top floor, was allocated to the Trust by Dover District Council in 1995, a display brief was prepared and a designer, Mike Whalley of museum design practice Brennan & Whalley, was selected by a competitive interview and tender process.

Key points of the brief

The following quote is from the brief issued in 1995 to all proposed designers:

'We wish visitors to leave the gallery with a sense of awe engendered by the boat's age, construction and skills of its makers and of the remarkable state of its preservation; and with an understanding of its history, original setting, discovery, recovery, preservation and the continuing research programme.

All visitors will be able to understand the basic functions of a boat, but few will have prior knowledge of the Bronze Age and the time-scales involved. The full significance of the boat can be understood [only] if this period is clearly and imaginatively presented.

We also wish for a proportion of the displays to be interactive to enable visitors to participate and explore subjects for themselves.'

The outline design

The outline designs and costings for the gallery were submitted to the Heritage Lottery Fund in January 1996. Five themed display areas surrounding the boat were proposed for a gallery of about 425m^2, at an estimated cost of £550,000 (Fig 18.1).

These areas were:

1 The Bronze Age, including a replica hut and figures.
2 Boatbuilding technology, construction and use of the boat.
3 Real things: artefacts from the Bronze Age, to include material from the museum's own collection and loans.
4 Discovery, excavation and recovery of the boat, to include a video using archive film shot during the project.
5 A laboratory/research station containing microscopes and other interactives.

All areas were also to be supplied with touch-screen computer interactives, holding information on all aspects of the project.

Testing the designs: interviews with the public

Sketches and descriptions of the proposed displays were shown to 153 visitors to the museum in August 1996 by a postgraduate volunteer, Tricia Bourner, who discussed the items with them in one-to-one ten-minute interviews. Visitors' knowledge of the Bronze Age was also evaluated.

The most important findings were that only 8.5 per cent knew when the Bronze Age was and 38 per cent admitted they knew nothing about the period at all. The most-popular proposed exhibit was the Bronze Age hut and information on daily life in the period, closely followed by the boat itself and the proposed laboratory. It was also found that interactive displays were essential, especially for children.

These results largely confirmed that the designs were likely to appeal to a wide range of visitors, but they also highlighted the need for very clear explanation about the Bronze Age period. This is an important feature of the finished gallery.

Building the gallery

About 18 months elapsed after the preparation of the outline designs, during which time project funding was secured and contracts were agreed with sponsors.

Figure 18.1
An early draft for the gallery design.

In September 1997, with most funding in place, the preparation of detailed designs and the appointment of the many specialist exhibition manufacturers began. This continued throughout 1998 and the first half of 1999, while the gallery space was converted (involving demolition works, the fitting of air conditioning and a suspended floor) and the boat timbers were reassembled inside the frame of the case on a purpose-built cradle.

Reassembling the boat

Planning

The cutting of the boat into thirty-two pieces had been an essential requirement for its recovery, and had subsequently proved a boon for both the academic study and the conservation of the vessel. Five years on, however, we were faced with the task of reassembling these pieces to regain the original form of the boat. This was not to prove a straightforward assignment.

First, the boat pieces, while heavy, were also rather fragile and brittle. Although there had been only minor shrinkage or distortion of the pieces during conservation, what little there was had affected their relative shapes; this was particularly true with regard to the curvature of the ile planks. The pieces therefore represented the parts of a complex three-dimensional jigsaw, some of which had warped slightly in relation to one another. In addition, the boat had opened up and become deformed during its long burial; this was reflected in the shape of the boat timbers themselves. To make the pieces fit, we had to realise the exact shape of the boat as found, rather than the original form of the hull (although some flattening of the longitudinal profile was introduced at the breaks across the timbers made by the cofferdam wall). Crucially, no one knew the exact form of the outboard surface of the boat; this would be seen only after we had reassembled the pieces.

A plan for this process was drawn up and approved before the boat pieces were returned to Dover (Clark 1997). All concerned recognised that there would be a certain amount of experimentation and variation on our original plans, but quite how much trial and error lay before us was not fully appreciated at the time.

Essentially, the plan was to support the boat on a custom-built cradle. The pieces were not to be glued or pegged together, but individually supported in their correct positions. The cradle was designed to be adjustable so that it could take up the shape of the outboard face of the boat as it was put back together. A set of adjustable tables was commissioned that allowed the boat pieces to be offered up to the cradle and propped in their correct position relative to one another. They could be used singly or bolted together to accommodate the larger boat pieces. They were mounted on castors to ensure minimum handling of the timbers, and also to allow them to be moved easily away from the cradle to allow its adjustment.

The whole procedure needed to be undertaken in a controlled environment. It proved impossible to maintain the correct conditions in the gallery as a whole, so a temporary 'room within a room' was erected, allowing work to be carried out at the appropriate temperature and humidity. The reassembly team comprised Peter Clark, Barry Corke and Adrian Murphy of Canterbury Archaeological Trust. Specialist engineering support was provided by Dr Edwin Gifford, and final conservation treatment of the boat was carried out by Sue Bickerton and Mark Jones of the Mary Rose Trust.

The environmentally controlled workspace

Initially, a temporary scaffolding and timber framework was erected and covered in polythene, forming an enclosed work area around the skeleton of the final display case. Contractors had already installed the ducting for a makeshift system to regulate the temperature and humidity by redirecting the temperature and humidity intended for the final display case. This allowed the reassembly team unrestricted movement in and around the case area and maintained the boat timbers in the controlled climate required. For long-term stability, the boat needed an environment maintained at a constant 18°C and 55% ± 5% humidity.

The main floor of the gallery was suspended some 300mm above that of the original floor, with the gap between the two levels containing the air-conditioning ducting to the case, and the electrical conduits. The suspended floor was continued into the case, in order to conceal the base of the cradle structure, cables for the monitoring equipment and the ducting. Holes in the case floor would allow a free flow of conditioned air from under the floor to circulate around the case. This was to be extracted through vents in the ceiling of the structure.

The support cradle

The cradle to support the boat – designed by Dr Edwin Gifford and the reassembly team – was delivered in pieces ready for assembly. The cradle consisted of a central spine to which transverse 'ribs' were bolted (Fig 18.2). These were positioned to provide support to each of the boat pieces; longitudinal support was provided by metal 'trimmers' or struts between the ribs. The ribs were initially conceived as two-piece structures, with a primary, central piece designed to support the flat bottom planks, onto which a curved, secondary section could be bolted that would support the sides of the boat. This would avoid the need to lift the central sections over the supports for the sides, diminishing the possibility of damage to the boat pieces. The secondary rib sections could then be bolted in place once the side sections had been propped in the correct position. Set on the upper surfaces of the ribs were metal 'rib plates' which could be bent to follow the exact contour of the outboard surface of the boat. Grub screws set into the body of the ribs supported the rib plates. The boat timbers would be kept from contact with the metal rib plates by Volara, an archival-grade foam plastic strip.

Made of black, anodised aluminium, the cradle consisted of four main elements:

- a square-sectioned base with additional L-shaped sections for weight distribution;

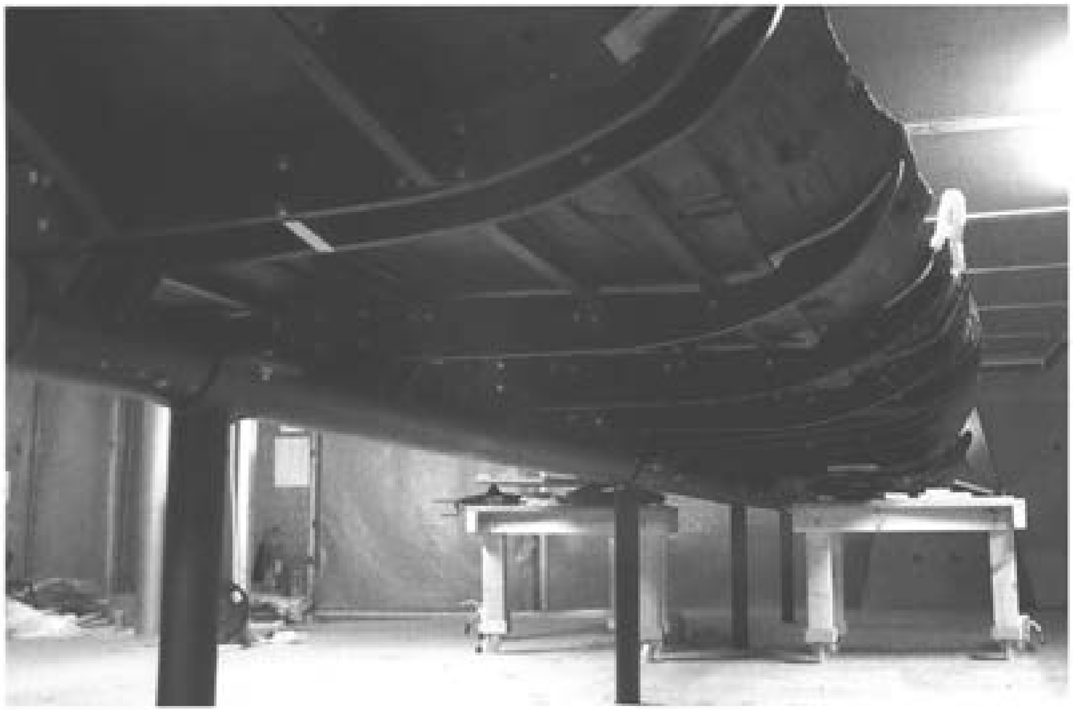


Figure 18.2
The support cradle, showing the cradle spine, transverse ribs and rib plates, and the longitudinal 'trimmers', which together supported each boat piece individually.

- four 750mm-long tubular legs, with a cup at the top of each;
- a three-section tubular spine, 9.50m long, onto which were welded vertical plates at pre-determined positions; and
- a number of shaped half ribs, fitted with grub-screws to take subsequent fittings.

Under the guidance of Dr Gifford, the components forming the base were laid out and bolted together. The legs were fitted and the spine sections assembled and laid in the cups. Semicircular aluminium clamping plates, along with bolts on the underside, held the spine in place. Once assembled, the entire structure was bolted securely to steel joists lying under the gallery floor.

Support tables

Six adjustable, wheeled tables were commissioned (to a design by Dr Gifford) for use in positioning the fragile boat pieces (Fig 18.3). These were roughly triangular in plan and consisted of a baseboard on wheeled legs, surmounted by three car scissor jacks, one at each corner, onto which was bolted the tabletop. By adjusting the height of the jacks, variations could be achieved for individual pieces as they were being positioned. Unfortunately, a glazing flange, welded to the base of the display case, meant that the tables could not be wheeled directly into the case, and a temporary raised wooden floor had to be constructed over this flange. Girder section spacers, bolted to the base and surmounted by the cradle legs, were fitted to compensate for the raised floor.

Reassembly

The main reassembly project could now begin. The sections of boat were stored in the temporary workspace, stacked on shelving around the boat cradle.

It was clear from the excavation data and the detailed study that the two halves of the boat were slightly different in terms of shape and their relative position to each other; the western half survived more intact and lay slightly higher than its counterpart. The main rib positions were determined at a fairly early stage but, on reviewing the situation, especially around the cofferdam

Figure 18.3
The reassembly team placing one of the boat pieces onto the support tables. The tables could be bolted together to provide support for timbers of different sizes, allowing them to be offered up to the boat cradle without fear of damage.

cut, it was felt that additional ribs might well be required. Welding these extra plates on would not be an option, so bolt-on plates were designed and fabricated. These did have the obvious advantage over the fixed positions – they were moveable and could be installed at an optimum location simply by drilling two holes, tapping threads and bolting them up. Trimmers, square-sectioned lengths of anodised aluminium with bolting flanges at each end, were prefabricated to fit between the ribs supporting the timbers along their length. The exposed end of the rib came to a sharp end, tapering to a point. The outer part of the rib, to be formed *in situ* for the iles, was to be bolted to the end of the primary rib sections after the bottom of the boat was in place.

The bottom planks

The first pieces to undergo assembly were the main base planks from the Cofferdam II (S, T and U; *see* Fig 4.2). These pieces were in a better condition than were some of the others, and it was felt that they would enable the team to get a feel for the boat and its requirements before some of the more fragmentary pieces were tackled. One half of piece T was taken from its fibreglass conservation support and placed on foam on the adjustable tables. This half was in three pieces, which made the task slightly easier. Alongside was placed piece S, roughly in its correct position. The three tables, all bolted together, were wheeled towards the cradle, with the beds high enough to clear the ribs. For ease of manufacture, the ribs were all fabricated to the same length, although the boat varied in width. Their original length was correct for the centre of the boat but, as the widths diminished towards either end, the ribs required shortening (at the spine end) to compensate.

On top of each rib, resting on the grub screws, an aluminium rib plate, about 40mm wide and cut to the same length as the rib, offered most of the support that the boat required (Fig 18.4). This was covered with Volara. The rib plates could be bent to follow the curvature of the boat's outboard surface. As the boat timbers were gradually lowered towards the rib plates, it became clear where each plate needed bending. The original rib plates delivered were made of pre-tensile aluminium, whose strength was such that they required several hundred pounds of pressure just to make a slight kink, and these were unsuitable for the detailed bending that was required here. Further rib plates of a softer aluminium were ordered; these could be bent 'over the knee' for gentle curves, or in a vice for more demanding angle changes. The bending of the rib plates was more of a visual application, shaping and reforming, noting and accommodating all of the subtle deviations until the correct contour was achieved. On completion of the four plates, the grub screws were raised or lowered accordingly and the boat timbers were gently lowered almost into their final position, but still supported on the tables. The exact trimmer positions were decided at this stage and, once placed exactly where support was required, were drilled and bolted between the ribs. As the trimmers were solid structures and the outboard surfaces of the boat undulated to differing degrees, the variations were filled with Volara. A similar procedure was used for the other half of piece T, and for the adjacent piece U (Fig 18.5). Using the 1:1 drawn profiles and plans from the study phase, adjustments to the levels and attitude of the pieces were made until the correct position was attained.

The pieces C, E and F from the first cofferdam were assembled in the same way. The fragmented sections of piece J were temporarily laid onto the cradle and acted as spacers to indicate the gap between S/T/U and C/E/F. Piece J was fitted at a slightly later stage. Pieces D(i) and D(ii) were then added. It was soon realised that the thickness of piece C varied – some areas were approximately 25mm thick; others compressed down to 5mm – and these variations were affected by the conservation process. Shrinkage of up to 15 per cent, and some distortion of the ancient timbers during the freeze-drying phase was anticipated. Most of the pieces handled up until this stage had been substantial, and of a fairly consistent thickness, so any shrinkage or distortion had been minimal. The cut lines did not match quite as well as they

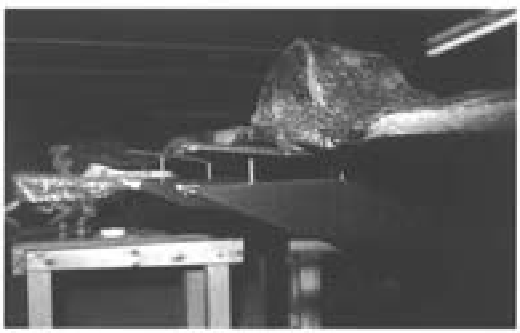


Figure 18.4
Detail of a rib plate supported on grub screws set into one of the main support ribs. As the boat was pieced together, it became apparent that the outboard surface of the boat was more distorted than originally thought, resulting in the rib plates being bent much more than planned; the result was the boat timbers were supported on long lengths of grub screw, a potentially unstable arrangement.

could have done, but this was expected. However, the thin portion of piece C, near the machine bite, had shrunk by as much as 5mm across its width. This would eventually cause some problems when the ile planks were offered up, as their relationship was directly bound up and affected by the small section of base plank still attached to the iles.

The northernmost pieces proved more problematic, as they were divorced from piece D around the machine bite and cofferdam cut, and their correct alignment could not easily be gauged via the central rails. It was decided that they should be fitted roughly into position, and adjusted later, following the line of the iles shown on the original site plan.

Figure 18.5
The first boat pieces placed on the cradle; the bottom of the boat was reassembled first, with the more complex side pieces and southern end added subsequently.

The ile planks

The ile timber sections were to provide an assortment of problems not previously encountered and to which solutions had to be found, although the responses varied from technical design changes to simple manual adjustments. Not only did the iles have to match with the adjacent ile timbers, but the small section of base plank, attached by the stitches on each one, had to align with the relative cut of the base plank already on the cradle. In addition, the ile had to sit at the correct angle, or as close as possible, to keep the strake line consistent. It was, therefore, decided that the complete side should be offered up at the same time, so that each piece could be directly related *in situ* (Fig 18.6).

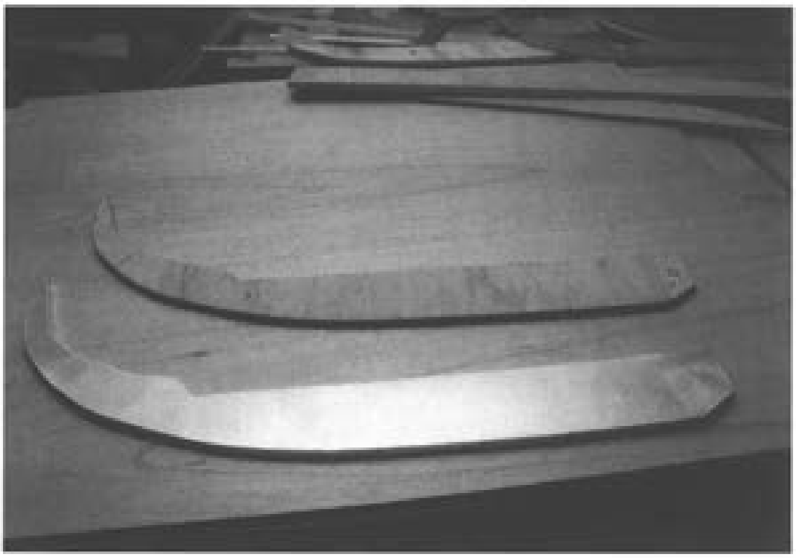
Similar curved supports to those used during the inversion process were made (two pieces of ply with a curved cutout and a piece of flexi-ply or hardboard on the curve). In principle, if the curve is scribed from the outboard of the boat piece, the angle should be near perfect. The flexi-ply was covered with foam or bubble wrap to protect the timbers. The ile sections were propped in pairs; B(n) and B(s) first, then W and N. Pieces B(n) and B(s), two of the more substantial elements, were relatively easy to prop together to form a reasonable butt joint, but the problem with the mating

Figure 18.6
The pieces constituting the eastern ile plank propped in position; borne on the adjustable support tables and a series of curved plywood supports, a great deal of trial and adjustment was required to obtain a satisfactory fit.

of the base plank C was to prove more difficult to overcome. A good joint was impossible to achieve because of the shrinkage in the base plank. A compromise position and axis was the only answer. By adjusting the angle of the iles slightly, the gap in the base planks was reduced somewhat, but could never be eliminated.

Once the likely best position was attained, the emphasis moved to pieces N and W, both of which were formed from the same piece of wood. When viewed from above, both these timbers had a scalloped effect. Both pieces had suffered in the same way – shrinkage of the centre sections had pulled the outer edges inwards. When placed together, they looked like a flattened 'w'. Again, nothing could be done about this condition. The base-plank sections proved to be more complicated. As with all of these ile sections, many of the base-plank portions had cracked and split in the area of the stitch holes. Many of these would have been present when found, but, during conservation, they had opened up. Shrinkage of the timbers, movement of the stitch packing, and repairs undertaken during the conservation period, meant that the joints with the main base planks were unsatisfactory. The shrinkage was uncontrollable, but, by heating the wax and pulling conserved joints apart and re-adjusting the stitch packing, along with some alteration to the alignment of the ile plank, the look of the base-plank sections could be improved. By inserting the small section of piece J as a spacer, B(s) and W could be checked for position. Piece J had suffered significant damage from the cofferdam, splitting in several places, while also suffering some compression.

Figure 18.7
Final design for support ribs. The unevenness of the outboard surface of the boat meant that individual customised ribs had to be cut for each station along the cradle spine. A plywood former (above) was cut for each rib, which was used as a pattern for cutting the aluminium rib (below). These were anodised before bolted onto the cradle spine.



Once the probable best alignment had been achieved, the final support strategy could be considered. The original theory was to bolt the secondary rib sections onto the primary ribs, to form a single element with one joint. An 18mm plywood ile support was cut to the correct shape and temporarily clamped to the base-plank rib. In order to fix the two together, two holes, drilled at the correct angle and fitted with helicoils, would be needed. This could be achieved, but the joint would not be invisible and, in fact, any error in the bolt positions or alignments would render the joint poor at best, and possibly ineffective. Indeed, it became clear that we had significantly underestimated the degree of variation of the outboard surface of the boat. The rib plates, intended to allow fairly minor adjustments, were, in places, bent 100mm or more above their supporting ribs. The intended secondary rib sections would have to be extremely broad and bulky to make the transformation from the horizontal, primary rib section up and around the ile. Fitting the trimmers also proved troublesome, as the bolting flange was not long enough to cover this variance; large packs of Volara made up the difference. After reviewing the situation with the ile pieces *in situ*, the decision was made to abandon the idea of the two-section rib and fabricate a set of single piece ribs, individually tailored to the appropriate outboard contour of the hull. These would simply require bolting to the spine in a position that had already been defined.

This would address the unsatisfactory gap between the ribs and the rib plates, unsteadily supported on long grub screws. Some clearance for the grub-screw adjustment (as originally intended) would be included. It was then a matter of scribing the outboard shape and creating a plywood former on a band saw, complete with additional grub-screw positions for the required ile support. These could then be sent to the fabricators along with a pattern for new ile rib plates (Fig 18.7). They would need to be shorter than those used previously, and, to prevent an excess coverage of the ile's outboard surface, cutouts either side of the top were added (similar in shape to that of a cricket bat).

Time did not allow for this whole process to be completed before moving on to the other side of the boat. Plywood copies of the ile sections had to be cut and were bolted to the main rib. Fixings were not that strong through the ply, so supporting legs were screwed on to maintain their position. Temporary plywood trimmers were also added. The first set of formers was sent for fabrication along with measurements for trimmers of the same form as used previously. With the pieces well supported, the tables could be removed and taken around to the opposite side. The pieces here were in a much poorer condition and required considerably more work to realign the correct shape. Piece P had an ancient horizontal split along its complete length; during the freeze drying the upper and lower sections twisted and distorted differently from one another and did not mate very well. A compromise position between P and Q was adopted to attain the best-looking finish, but further adjustment was necessary with the addition of the end section. Pieces A(i)–(iii) were also reassembled. Again, the rib formers and measurements for trimmers were sent for fabrication.

Supporting the southern end

Time soon became increasingly short; the reassembly process was but one part of the programme to establish the gallery, whose opening ceremony had already been organised. The complex southern end section had still not been put into place. The final mechanism for supporting the piece was a subject of much discussion. Ultimately, a one-piece welded support, bolted to the existing spine plates, seemed to be the most suitable answer (Fig 18.8). Struts extending back to the first available rib would help to offset the weight distribution. A wooden mock-up was prepared to form the template for this complex support.

As the newly fabricated pieces were returned, each rib was bolted into position with relatively few problems, and trimmers were added. All the temporary wooden formers and legs were gradually removed to leave the boat supported solely on the cradle. The end of the spine had to be cut off, as the design of the cradle had changed. A cap, made of the same material, was fabricated and fitted to conceal the alteration, and the new end section was bolted into place. The reassembly of the main boat pieces was complete.

Lowering the boat

It now remained to lower the boat to its display level. The height of cradle suitable for the reassembly process was clearly unsuitable for presenting it to the public; many people, particularly children, would be unable to see the inboard surfaces of the boat. The entire reassembled boat needed to be lowered by 0.5m. This was an intensely nerve-racking procedure; the reassembly team had spent ten months positioning the boat pieces and customising the cradle support. Any mistake, even if the timbers

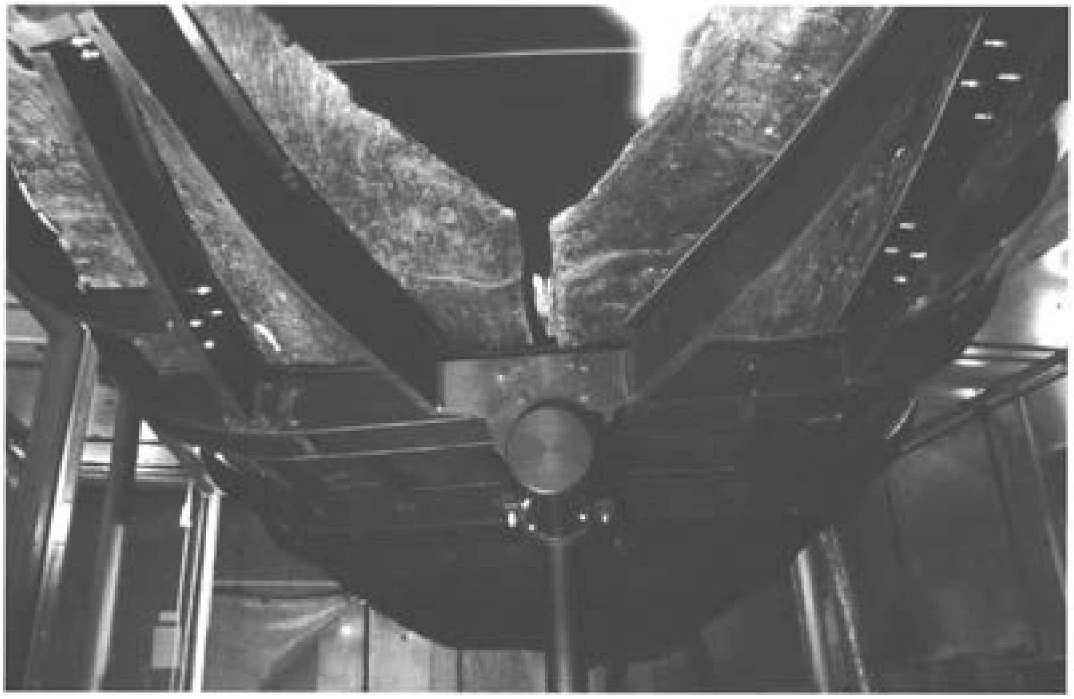


Figure 18.8
The support for the southern end; a complex one-piece welded support bolted onto the main spine plates.

themselves escaped damage, would require the procedure to be gone through again.

The method adopted was essentially quite simple. Four steel girders were manufactured with a bracket welded onto their upper surface that allowed them to be bolted to the cradle spine adjacent to the main support columns. These were supported on stacks of timber, themselves screwed to wooden battens and supported by diagonal steel struts bolted to the cradle base (Fig 18.9). Simple scissor jacks were bolted to either end of each girder, which were then set atop further stacks of smaller timber blocks. When all was in place, the cradle spine was unbolted from its supportive columns.

It was essential that the boat was lowered very slowly, being kept absolutely level at all times. A trial run was carried out prior to the reassembly to evaluate the method, the cradle weighed down with steel plates and scaffold boards to simulate the weight of the boat. This proved highly successful, and many useful lessons were learnt. It was a very different exercise lowering the boat itself. A team of eight volunteers was assembled, each charged with looking after one of the jacks. The cradle was plastered with spirit levels along the spine and on the transverse ribs, so that any change in angle of the boat cradle could be monitored as it was lowered. (During the trial run, teacups were filled with water and placed atop paper napkins in saucers at various points along the cradle. Any jolting or tipping would result in water spilling and dampening the napkins. They stayed dry.)

On a chant from the project manager (Peter Clark), each of the volunteers raised the jacks one turn (clockwise). The boat was now freed from its supportive columns, resting on only the eight jacks atop their stacks of timber. The reassembly team now replaced the supportive columns with new ones, only 0.5m high. They then unscrewed and removed the topmost timber block from the main stacks. Then, again following a chant, the jacks were lowered, one turn at a time (anticlockwise) until the steel girders rested on top of the next main timber block. The jacks were slackened off, a timber block removed from each of the small timber stacks, and the strain taken up once more. This process was repeated until the main spine rested on the new, shorter supportive columns.

The reassembly team continually monitored the cradle as the boat was lowered to ensure everything remained perfectly horizontal. Even with minor differences of extension, one turn represented a slightly different amount of vertical movement for each jack. Cumulatively, these minor differences could tip or buckle the cradle. The entire lowering process was punctuated by continual monitoring of levels and fine-tuning at individual jacking points.

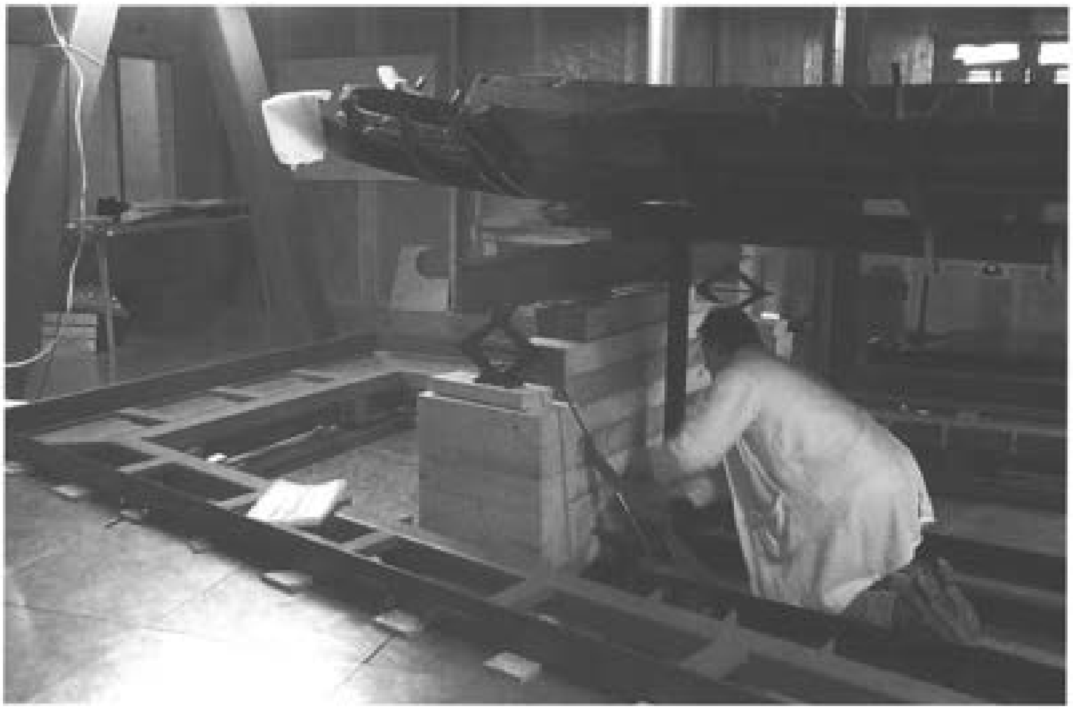


Figure 18.9
Lowering the boat; the southern end of the boat cradle has been bolted onto a steel girder, set atop stacks of timber and two scissor jacks.

At last, the boat reached its final position. The cradle spine was bolted to the new supportive columns, and the steel girders, wooden blocks and jacks were removed. It is difficult to describe the feeling of relief felt by the reassembly team as we stood back from the display case; in spite of all our fears, everything had gone well. The entire process only took seventy minutes to carry out.

Completing the case

Next, we could address the final stages of reassembly; fitting small pieces of timber – such as sections of laths, wedges and transverse timbers – and reconstituting stitches that had become separated from the boat pieces. We tried very hard to bring the boat back to the condition in which it was found. In this we were most fortunate that the staff of Dover Museum had made available a digital record of the entire photographic archive. This meant we could quickly review all available photographs and enlarge or crop shots of particular details, which could then be printed out as a guide for the conservator, Sue Bickerton, to complete this final stage. It is difficult to conceive how this could have been achieved with traditional photographic techniques. After a final surface treatment of the reassembled timbers, the job was complete (Fig 18.10).

The next stage required the completion of the case to allow time for checking of the air-conditioning unit. Several sensors were added to the case and cradle to monitor the air circulating with the case. Fibre-optic lighting stems were installed with all the relevant cables laid under the suspended floor outside the case, for ease of access. The pierced floor, its joists and the walkway around the boat (all within the case) were all fixed in place. The contractors glazed the case with a series of toughened glass panels, 19mm thick and sealed with clear mastic. This allowed a check of the environmental control system to be undertaken, after which the case was sealed behind a protective timber hoarding as the rest of the gallery was fitted out.

Figure 18.10
The reassembled boat. After completion, the case was glazed and the temporary environmentally controlled workspace dismantled before the rest of the gallery could be fitted out.

The finished displays

The final fitting of the gallery took five months, culminating in the opening of the gallery on 22 November 1999. The museum team, led by Christine Waterman, included Mike Whalley, Jon Iveson, Mark Frost and Elizabeth Owen, who all worked with many specialist contractors to produce the finished gallery.

The boat case

The boat has been reassembled on a 9.5m-long steel cradle inside a 10.5m steel case fitted with eighteen toughened-glass panels (Fig 18.11). The absence of glazing bars allows an uninterrupted view of the boat from either side of the gallery. A steel-framed glass door allows access for inspection and maintaining the monitoring devices in the case.

These devices consist of a recording thermohygrograph with a paper roll recording a week's readings, and an 'instant view' hair hygrometer. Both are calibrated regularly.

Filtered, air-conditioned air is provided from a sealed system operated in a dedicated plant room. It is brought to the case by a duct running underneath the gallery's false floor. The air is drawn up through perforations in the case base, and is taken back to the plant room through a second air duct running along the top of the case and through an A-frame at the end of the case.

The case lighting consists of forty-eight fibre optic spotlights supported on eight steel columns, and four roof-mounted spotlights. These provide light without heat, avoiding hot spots that would damage the timbers. The light sources are in boxes, outside the case. The specification for the case environment is strictly controlled and monitored and is required to achieve a temperature of 18°C ± 2°C and a relative humidity of 55% ± 5%. Pairs of stainless-steel pins have been inserted into the timbers at various points, and these can be monitored precisely to assess any movement or distortion of the timbers.

Figure 18.11
The completed gallery, with the reassembled boat as its centrepiece. The gallery has proved extremely popular, and has won many awards since it opened.

Bronze Age life and artefact areas

The centrepiece of this area is a full-scale section of a hut, constructed by the late Peter Reynolds from the Butser Ancient Farm project (Fig 18.12). Inside the hut are three human figures, a man, woman and child dressed in hand-woven woollen clothes based on actual Bronze Age Danish costume and a pig, based on prehistoric evidence. A 'talking label' has been provided, with earphones – in four languages plus English – to explain the different aspects of Bronze Age life.

Bronze Age artefacts

Five cases have been provided covering the themes of pottery, metalwork, farming and Bronze Age ritual and religion.

The underlying purpose of these displays is to present as wide a range as possible of actual Bronze Age material, but also to explain the technological aspects of bronze working and pottery manufacture. For the latter, a Bronze Age pottery firing was specially organised and filmed in April 1999 with Alex Gibson providing specialist advice and supervision. The resulting pots, photographs and video have been used in the displays.

A further advantage of the long lead-in period of the project has been that the museum has been able actively to collect Bronze Age material with the clear intention of displaying it in the new gallery. As a result, local people have donated a number of important hoards and individual pieces they have located using metal detectors. A number of local burial groups, such as those from the Ringwould Barrow have also been put on permanent display.

Boatbuilding technology and construction

These displays are centred on the mid-section replica, whose construction is described elsewhere (Chapter 9). Once again, photos taken, and video recordings made at the time have been incorporated into the displays, as have the replica tools used in the construction.

The replica itself, an effective visual aid for understanding the boat's construction, is a good example of how the research project and display work have combined to produce something neither could have achieved alone.

Figure 18.12
One of the life-size figures in the reconstructed Bronze Age house in the gallery. The reconstructions have proved to be very successful in helping explain life in the Bronze Age to visitors.

The boat lab

During the public open days to view the timbers in 1993, one of the most popular exhibits, especially with children, was an area devoted to the environmental evidence found around the boat. Different samples were provided for viewing by eye and through microscopes.

At an early stage in the design it was decided to incorporate a laboratory exhibit in the gallery to act as the focus for information on the excavation and preservation of the boat, as well as environmental and dating evidence.

The design of this area mirrors a real lab with brighter lighting and metallic surfaces. Three manual microscopes and a video microscope have been provided, as well as an interactive dendrochronology game and pull-out sample tubes. These latter contain larger samples from the excavation, such as wood, flint and bone.

The computer interactives

There are three touch-screen computers in the gallery, running software comprising over 14,000 words in four languages plus English, dealing with the whole range of boat-project topics. This sounds a daunting prospect for a visitor, and it was certainly a major task to prepare, but each screen has been designed with plenty of illustrations, video clips and fewer than seventy words of text (with the exception of a text-only section for those who are really keen).

The purpose of these interactives has been to provide visitors with the chance to find out about the boat at their own pace. A *Load the Boat* game – where visitors choose from various combinations of weather, boat size, paddlers, cargo and bailers – is popular with many, and surreptitiously shows the reason behind the favoured reconstruction method.

The original appearance and use of the boat

One wall of the gallery is devoted to explaining how the boat might originally have looked and what it might have been used for. Three scale models and large colour drawings have been used to show possible reconstructions, and a number of sample cargo types are shown.

The Langdon Bay hoard, on loan from the British Museum, provides impressive evidence for cross-Channel trade in this period. The scrap hoard, discovered on the seabed off Dover in 1974 – by Dover Sub Aqua Club – includes many French examples and is thought to have been the cargo from a shipwrecked Bronze Age boat.

The boat project video

An eleven-minute video runs continuously in a mini audio-visual theatre at the rear of the gallery. It features footage taken at critical points in the project, from the first day of discovery to the completion of the displays, and interviews with a number of the project team. This is also available in English and four other languages, through headphones.

Figure 18.13
A visitor to the gallery.

Public response to the gallery: December 1999 to March 2000

The original aims of the gallery design have been achieved. In February 1999 visitor research was undertaken in the gallery on the feedback received informally from visitors' comments to the museum custodians, and also on the comments recorded in our gallery visitors' book.

The key findings were:

- 100% would recommend a visit to the gallery to friends.
- The most popular exhibits judged from 'very good to excellent' were:
  1 The boat (91%)
  2 The hut and Bronze Age life displays (84%)
  3 The interactive computers (77%)
  4 The laboratory (75%)
  5 Other interactives (75%)

The gallery also seems to have succeeded in appealing to all age ranges and levels of interest (Fig 18.13). The average visit is about an hour, but many people are making repeat visits.

Children as young as 3 or 4 love the low-tech, pull-out interactives, but there is also plenty for the specialist archaeologist. Everyone is surprised and intrigued by the boat. Most are leaving with a far clearer idea of what the Bronze Age was.

Some of our visitors' book comments are reproduced below:

- 'I'm very proud of what has been achieved.' (Dover resident)
- 'Wonderful. Hope you get the rest of it some day.' (Australian visitor)
- 'It proves we were smart.' (Australian child)
- 'Very well set up and all age appealing display.' (Turkish visitor)
- 'Stunning. The children got a lot from it.' (Local primary school teacher).

These comments – and many more made in the same vein – have delighted the whole boat team.

19
Discussion

by Peter Clark

This section aims to develop some of the themes that have emerged from our study of the boat, to highlight the contradictions and disagreements remaining in our understanding of the vessel and to speculate on future avenues of enquiry. It makes no attempt to summarise the contents of the preceding chapters.

The discovery and excavation of the Dover boat has undoubtedly provided a major contribution to our understanding of prehistoric water transport in Western Europe. Finds of Bronze Age sewn-plank boats are extremely rare; to date (2004), only three substantial parts of vessels have been found, as well as smaller fragments of another six, in spite of extensive surveys of the wetland zone in Britain (van de Noort and Davies 1993; Hall and Coles 1994; Bell 1993b; Bell and Neumann 1996). There seems to be a common technological repertoire to these craft, characterised by hewn planks stitched together by twisted stems of vegetable fibre and smaller timbers inserted through upstanding cleats hewn out of the solid wood. The examples recovered thus far have been found in the Humber estuary, the Severn estuary and at the mouth of the Dour valley. None has been found in western continental Europe, despite a number of archaeological surveys. This need not lead us to postulate a solely British origin for this sort of vessel. Despite a long tradition of archaeological fieldwork, the three major finds were separated by roughly half a century from one another; Brigg in 1888; Ferriby 1 in 1937 and Dover in 1992. The other smaller fragments were found during the course of extensive field survey programmes, including the late Ted Wright's monitoring of the Humber foreshore over many years. So few examples have survived (or at least been discovered) that it would be premature to propose that they suggest the full geographical distribution of such boats in the Bronze Age.

It is self evident that boats must have been commonplace during this period; the overwhelming evidence for the exchange of goods across the seas and along river systems demands the availability of suitable transport (Champion *et al* 1984; Scarre and Healey 1993). In addition, there is a substantial body of iconographic evidence, particularly from Northern Europe, that attests to the familiarity of Bronze Age communities with boats. And this evidence could also suggest the many roles of such vessels in society: economic, social, symbolic and religious (Gelling and Davidson 1969, 43–67; J Coles 1993; Kaul 1995; 1998).

It must surely be a matter of time before another substantial part of a complex prehistoric boat is found. Given such paucity of evidence, each new discovery will be of fundamental importance for some time to come.

Building the boat

The size and type of oak trees used in the manufacture of the Dover boat is very impressive to the modern eye. At least four massive trunks were needed, each up to 11m long and weighing about 10 tonnes. Such tall, straight-grained trees, with no lower side branches, are now rare in Western Europe. The felling, transport and preparation of these logs would appear a substantial task, over and above the woodworking skill and effort evident in the manufacture of the boat itself. Richard Darrah suggests the trees used were 'dominant trees', particularly tall examples in the native wildwood (Chapter 7), implying that substantial areas of dense oak forest were still in existence in southern Britain. However, massive clearance of the indigenous forests of Britain had been going on for many centuries by the time the Dover boat was built. The construction of the huge 800m long timber palisade at Mount Pleasant in Dorset in about 2100 Cal BC (*c* 3700 BP) is thought to have required 1600 large oak trees (Wainwright 1979). Large areas of Britain were deforested by the

Middle Bronze Age (Godwin 1962), and it might be assumed that communities at the time were well accustomed to the felling and working of large trees.

Nevertheless, there is clearly a substantial investment of time and expertise in the construction of a wooden boat like that found at Dover. Some have suggested that skin or hide boats were in use from the Palaeolithic (Johnstone 1988, 102–6; McGrail 1987, 185). It is clear that people had access to some form of water transport from a very early period. For example, obsidian found in the Francthi cave near Porto Cheli in Greece – dated to the 10th millennium Cal BC – has been shown to have originated in the isle of Melos, some 120km away by sea (Jacobsen 1969; Perles 1979; Bass 1980; Durrani *et al.* 1971). Indeed, the colonisation of the Mediterranean islands, Australia and possibly the Americas shows that some form of sea transport was available much earlier (Bednarik 1997; McGrail 1991). Unfortunately, there is no unequivocal evidence for hide boats in the archaeological record; the rock carvings, models and other iconographic representations are open to various interpretations (Hale 1980). A fragment of reindeer antler (about 0.2m long) excavated at Husum in Schleswig-Holstein has been interpreted as a fragment of a hide boat frame, and dated to the 9th millennium Cal BC (Ellmers 1984). A great deal has been made of this single and, at best, ambiguous find; its interpretation has not won universal acceptance (McGrail 1987, 185). There have been a few finds of possible coracle-type vessels, for example at Dalgety in Fife, Scotland (dated to around 1700 Cal BC (*c* 3450 BP); Watkins 1980), but these are very small affairs without substantial framing.

These finds have led many to rely on the technological possibility of hide boats when considering their use in early prehistory; it is clear from the abundance of flint scrapers that animal hides were routinely used, and finds of needles and awls show the potential for sewing hides together. A hide boat of any size would require a frame of some kind to give strength to the vessel and provide something to attach the skins to. The concept of such a framework (at least on land) might be suggested from the Palaeolithic onwards. The 'huts' made from mammoth bones found at Krakow in Poland are presumed to represent a framework for a weatherproof covering (Kozlowski 1974), but whether they supported animal skins, turf or some other material is unknown. It is interesting in this respect that Peter Marsden ponders on the function of the transverse timbers in the Dover boat as 'embryonic frames' (Chapter 5). It might be thought that, if hide boats were a long-established form of boat construction, the use of frames in a boat would be commonplace. The complex and ingenious solutions adopted in making the Dover boat do appear unnecessary within a tradition of framed hide boats, though of course there are fundamental differences in their function and in the manner of construction. What advantage was there in building a wooden vessel over a hide boat? Why, if framed hide boats were being made, were frames not used in its construction? Even allowing for the preparation of animal skins, it might appear that greater material and human resources were required for a timber vessel. Theoretically, seaworthy hide boats of a comparable size with the Dover boat would have been perfectly possible with the technologies available in the Middle Bronze Age. In Arctic waters, the Inuit people have long constructed large hide boats – the 'Umiaks' or 'Baydars', about 9–10m long, 2m broad and about 1m deep. They were made with a wooden frame and a covering of bearded seal or walrus hide sewn together with sinew, lashed to the timber frame and waterproofed with seal oil (Morrison and Germain 1995). These vessels could transport up to thirty people and several tonnes of cargo, and were exceptionally seaworthy (Stefansson 1942, 37–9), well within – if not exceeding – the hypothetical capabilities suggested for the Dover boat (Chapter 10). The requirement for frames in a large hide boat, and their absence in the Dover boat, might be related to the concept of the technological 'evolution' of boats discussed below. If large hide boats were being made during the same period as wooden sewn-plank boats, perhaps they were used for different functions, or were perceived in different ways. Maybe wooden boats had technical advantages for different uses, though this might not necessarily have included strength, cargo capacity or seaworthiness (Johnstone 1988, 27). Alternatively, perhaps framed hide boats were unknown in southern Britain at this time; there seems to be very little (if any) indisputable European evidence for such things until the later Iron Age, and only then because of the survival of documentary evidence.

The bottom of the boat

Richard Darrah has presented compelling evidence that the two bottom planks were not only each hewn from half a tree trunk, but that the two planks were made from different trees (Chapter 7). When we undertook the reconstruction experiment (Chapter 9), a trunk was split in two and each half used for the manufacture of a section of bottom plank. This would seem a sensible and economical way to use the raw material, presumably harvested and transported to the construction site with some effort (Chapter 8). Why was the same tree not used for both bottom planks? One possibility is that more than one boat was built, and the two 'missing' half-logs were used for another vessel. This, however, would have necessitated a substantial amount of manhandling of the split half-logs into position, with no readily apparent benefit. Alternatively, it might have emerged on splitting the log that one half had flaws, or was otherwise of unsuitable quality for making a bottom plank. It might have been discarded and another tree harvested. Given the deep knowledge of woodland and woodworking apparent in the construction of the boat, it seems unlikely such fundamental flaws would not have been identified prior to the felling of the tree – although, of course, the trunk might have been damaged during felling. Peter Marsden (Chapter 5) has drawn attention to the contrast in wear patterns on the outboard face of the southern western ile plank (301) and the adjacent part of the western bottom plank (300). He suggests that perhaps the bottom plank had been replaced after a period of use, possibly explaining the different origin of the two bottom planks. Another possibility is that one half-log was damaged beyond repair during the reduction and fashioning of a bottom plank. This is conceivable; during the reconstruction experiment there was always a danger that rails or cleats could be broken off, and the possibility of something similar happening over an 11m length of timber is not unlikely. If, say, a cleat were broken off by accident, the whole plank would be unusable. In this respect, it is interesting to note the asymmetry of the two bottom planks outboard, where they form the junction with the missing end board 306. The western bottom plank (300) is some 300mm shorter than the eastern (303; *see* Fig 5.18). It is also interesting to look at the southern end of the western bottom plank (300), between the seam rail 371 and the yoke rail 363. Here the bottom plank thins markedly, suggesting that the seam rail had accidentally been broken off and the plank hewn down to leave sufficient upstanding timber to continue the line of the rail. Perhaps a similar, but more serious, accident rendered one half-log unusable, necessitating its replacement during construction.

Grounding the boat

The Dover boat was flat bottomed, though its outboard surfaces showed clear signs of wear, presumably indicating that it was grounded (Chapter 5). The pattern of this wear suggests that the underside of the boat was transversely slightly concave when afloat; tool marks survive immediately adjacent to the centre seam outboard. It is not clear if this concavity would have helped reduce leeway in the absence of a keel. Nevertheless, the evidence for grounding seems clear – although whether this represents rubbing along the bottom in shallow water or beaching cannot be ascertained. The care and effort that went into protecting the lower stitches shows that beaching was a regular occurrence, anticipated in the design of the vessel. The stitches were passed through the thickness of the bottom planks in such a way that the stitches would not be damaged by grounding (on the Inuit Umiaks mentioned above, sinew lashings passed through the thickness of the covering hides in a similar way). The evidence for the nature of the Dour valley in the Bronze Age suggests that it was unsuitable for a vessel of the size of the Dover boat (Chapter 12); it seems more likely that the boat operated in coastal waters or at sea and that it was driven up onto a beach. It is suggested that the boat weighed around 2.3 tonnes, excluding crew and cargo (Chapter 10). It would be practically impossible to push the loaded boat back into the water; the assistance of the tide would have been needed in order to free it. In addition, the fragile 'shelf' at the southern end of the bottom planks would surely have been damaged when beaching unless there was a rocker that raised it above the point of contact. The boat must, therefore, have been brought to shore on a falling tide, and the incoming tide would have helped the boat float free. If the boat were to make long journeys (such as that to Dorset; Chapter 11) this would imply its crew possessed a detailed knowledge of local tides along the route. Peter Marsden has suggested that there were also patterns of wear on the side of the boat, suggesting it had rubbed against a waterfront, either running against a natural foreshore or moored against an artificial quay (Chapter 5). The evidence for artificial jetties in the Middle Bronze Age is somewhat inconclusive (Thomas *et al* 1986; Nayling and Caseldine 1997, 49–55; O'Sullivan 1995a, 16; 1995b). At the timber alignment recently excavated at Testwood Lakes, near Southampton, a possible cleat fragment was recovered from the debris lying among the base of the timber piles (Wessex Archaeology 1996, 20). It seems more likely that boats were beached in this period (McGrail 1985), sometimes on timber 'hards' of poles and other light timbers placed on the foreshore (Wright 1990, 160). Later examples of gravel have been suggested at Hengistbury Head (Cunliffe 1990).

Joining the bottom planks

The exact sequence for joining the two bottom planks is still a matter of debate. A common view is that the two bottom planks were brought together, the moss and central laths placed in position and then the transverse timbers and wedges hammered into place. This was the sequence used in the reconstruction experiment (Chapter 9). One difficulty of this approach was hammering the transverse timbers through the cleats but over the seam rail, requiring the timbers to be bent and increasing the upward pressure on the cleats, increasing the risk of their breaking. However, this was achieved in the reconstruction experiment without mishap and, with more practice, this approach would become somewhat easier. Peter Marsden has offered another possibility (Chapter 5). He suggests that the transverse timbers were pushed through the central rails and under the cleats from the centre line as the bottom planks were brought together. The wide eastern end of transverse timber 341, however, does not immediately suggest it was inserted in this way; it would be impossible to insert the timber through the slots cut through the central rails. The advantage of this method would be that the timbers would not have to be bent over the seam rails. The moss and central laths could then be positioned, presumably hammered under the transverse timbers, and then the wedges could be inserted through the central rails, holding the laths in place and perhaps locking the two bottom planks together. Both these sequences view each element of the central seam (wedges, laths, etc) as being installed along the whole length of the bottom planks, albeit in a different order.

A third possibility is that the different components of the central seam were positioned together and were worked in short sections along the length of the bottom planks. Thus, the moss and one central lath might be put in position, and the overlying wedges and transverse timber hammered in before moving on to the next lath. It is frustrating that we are not sure how many central laths originally existed. During excavation, conditions did not allow for a detailed study of the central seam, which was part of the boat most susceptible to damage during lifting operations. There were at least three central laths (Chapter 5) or, more probably, as many as five or six (*see* Fig 5.46). The end of each lath either underlay or overlay the ends of its neighbours. If the laths were simply laid in position, this might suggest an order of insertion (Chapter 5, p 71; *see* Fig 5.52). If this is correct, it implies that the boatbuilders did not start at one end of the boat and work along; rather it appears that the first lath laid was in the middle of the boat, under transverse timber 342. However, the superposition of the various central laths is not unequivocal evidence of sequence; one lath end might have been driven under the end of a lath already in place.

The mechanism by which the two bottom planks were held together is also imperfectly understood. To modern eyes the central seam of the Dover boat appears strange; today we would expect a solid keel plank (as existed in the Ferriby examples), but here we have a simple butt joint, with no obvious technique to stop the seam opening up. Perhaps the wedges – crossing the centre line at an angle –provided sufficient friction to hold the bottom together. Of the twelve surviving wedges crossing the centre line, five crossed at an angle of *c* 90 degrees, six between 80 and 85 degrees, and one between 75 and 80 degrees (*see* Fig 5.1). It has proved difficult to calculate the effect these wedges would have had in holding the central seam closed; perhaps further experimental work would help in exploring this issue. It appears certain that the central seam was prone to opening up and leaking;

there was evidence both of patching with extra stopping and moss (Chapter 5), and of tightening one of the transverse timbers (342) with a flint wedge. (The suggestion that these large timbers could be tightened by the insertion of moss packing, however, remains more dubious.) The putative bailer found at Caldicot (McGrail 1997, 215) could be an example of an essential piece of equipment for such a boat. It has been suggested that such a wedge could be inserted only when the boat was out of the water, relieving the force of buoyancy acting on the timber; similarly, the repair stitching, inserted from outboard (Chapter 5), would best be carried out when the boat was beached.

Fitting the ile planks

The ile planks were held closely against the bottom planks by twisted yew withy stitches, spaced about 380mm apart. The ile seams appeared to have very little moss actually inserted between the planks. Most moss wadding was placed on top of the seam, in some places overlying a 'stopping' material that had been pressed down on the junction between the planks after the ile had been offered up. It seems likely that this stopping was inserted after the planks had been stitched together; unfortunately, analysis of its composition was not conclusive (Evans 1999). Peter Marsden has argued that, in the case of the iles, the laths were hammered under the stitches, pressing down on the moss wadding and also tightening the stitches themselves (Chapter 5). This is in contrast to ethnographic evidence for sewn-plank boats with laths, where the laths are not driven under the stitches, but placed in position prior to stitching. During the reconstruction experiment, it was shown that pads of moss placed under a lath could be dragged under the stitches as the lath was driven home. It is not clear whether all the stitches along one side of the boat were inserted before the laths and moss were put in position. This would have helped establish the strength of the side during the construction process, but would also complicate the insertion of the laths. The laths would have to be bent up over the stitches as they were hammered in; in the case of a long lath, such as 751, this would mean hammering in the lath over the top of about nine other stitches. The reconstruction experiment showed there was no real problem in bending the laths in this way, and the moss wadding could be fed into place as the lath was hammered in. However, this procedure would expose the *in situ* stitches to potential damage from hammering. To avoid this, it might be that the boatbuilders worked along the seam, inserting each lath under its related set of stitches before moving on to the next. Thus, only the stitches relating to a single lath would be inserted at one time. It is interesting to note that the northernmost lath on the western ile seam (752) is of hazel rather than oak. It seems extremely unlikely that there would have been insufficient oak available at the time of construction to fabricate all the laths from this material. Probably, this lath was a later replacement, inserted for repair or refurbishment.

The tops of the iles have a right-angled rebate cut into the outboard corner, presumably for receiving an upper side plank. On the inboard corner is a carefully shaped bevel about 20–5mm wide. This might indicate that the upper side plank was somewhat thinner than the ile planks (it would have lain above the waterline and presumably not been subject to the same stresses). The bevel might be to thin the upper edge of the ile planks to match the thickness of the upper side planks. Alternatively, the bevel might be intended as a seating for moss wadding along the seam between the ile and upper side planks, particularly if mirrored by a similar bevel on the inboard lower edge of the now missing upper planks. The general principle might be reflected in the seam caulking of the 7th century BC Phoenician ship found at Playa de la Isla, off the east coast of Mazarrón, Spain (Negueruela *et al* 1995; Navis I, Ship Nr. 58). The moss might have been twisted into a rope to aid its insertion into the seam. A moss rope was used for waterproofing Ferriby 3, where it underlay further moss wadding and a wooden lath (Wright 1990, 78, fig 4.19). No such moss rope was found at Dover, however, and its use must remain speculative.

The upper side planks

There is clear and unequivocal evidence for the original existence of one further plank on either side of the boat (Chapter 5). Slivers of oak adhering to the tops of the ile planks suggest that these planks were also of oak. Beyond this we have no data, and, to avoid unwarranted speculation, a 'minimum solution' has been sought to understand the original vessel form, with only one side strake above the iles (Chapter 10). However, the possibility of there being a third strake should not be ignored, although we shall not explore this in detail here. Sean McGrail (1997) has argued that the large oak plank found at Caldicot, Gwent (6001/20684), is the upper (second) side strake of a sewn-plank boat, perhaps similar to Ferriby 1. What is relevant here is that the piece possesses a cleat (postulated for the upper side planks of the Dover boat; Chapter 5; Chapter 10) and stitch holes on both lower and upper edges, implying the existence of a further upper strake (even if this was a simple rail). If McGrail's interpretation is correct, the plank does not appear to be part of exactly the same type of boat as the Dover find, as the cleats, for example, are quite different to those proposed for Dover. Nevertheless, the possibility of a further strake to the Dover boat (as proposed in the Ferriby reconstruction) is an intriguing one; it would make the vessel deeper, with an increased freeboard, and would have significant implications for its stability and performance. This theoretical possibility might be a suitable subject for future study.

The end board

There was good evidence for the nature of the missing timber that originally fitted into the Y-shaped scarf at the southern end of the boat (Chapter 5), and the proposed reconstruction is convincing (*see* Fig 5.17). If correct, to describe this timber as a 'board' is somewhat slightly misleading; it was a large, complex, sculpted timber that was hewn in three dimensions to remarkable tolerances. The northern end of the timber had to fit snugly against the southern ends of the two bottom planks; the yoke rail had to mirror the extensions to the central rails; the piece had to curve upwards to meet the line of the ile planks; and, on the bottom, a rebate had to be cut just a few millimetres deep to fit against the thin shelf at the southern end of the bottom planks. The timber would be difficult to make, and heavy and awkward to manoeuvre into position.

Where it fitted against the bottom planks, a particularly elaborate method of securing it and making the joints watertight was adopted. Six wedges, three on each side, were hammered through the extensions to the central rail, presumably into wedge holes cut through similar rails on the end board. Between these upstanding rails was a gap similar to that on the central seam; moss wadding was laid on the joint and three small laths held this down. The small cross-lath (790) had rebates cut into its upper surface to receive the north ends of the two side laths (800 and 810) and the southern end of the central lath (740); these all overlay 790. Lath 790 appears to have been held down simply by these three lath ends; it did not underlie a wedge. It is difficult to see how cross-lath 790 could have been inserted after the insertion of the end board if the central lath 740 was already in place. The southern end of 740 extends over the gap between the rails, and there is no room to insert cross-lath 790 from the sides. However, the northern end of 740 overlies the southern end of lath 741 and is blunt, suggesting it had been hammered in from north to south. Perhaps it was not hammered into its final position until cross-lath 790 had been put into place.

The southern ends of the side laths (800 and 810) are cut diagonally; we do not yet understand how these ends relate to the construction of the boat. It might be that they were intended to sit flush against the curved inboard surface of the ile planks, or were perhaps cut to form a junction with the laths covering the seam between the ile planks and the end board (although this seems less likely, considering the laths elsewhere on the boat).

The ile planks were sewn to the end board with withies, presumably with moss wadding and oak laths similar to the other seams on the boat. The stitch holes in the end board are likely to have passed through the thickness of the timber, as did those on the outer edges of the bottom planks.

If we are correct in our interpretation of the end board as a single timber (Chapter 5), it is clear that it could not have been removed intact. The eastern wedges had been cut through vertically, presumably following the outer face of the end board rail. This is particularly difficult to do with an axe, and indicates that some care must have been taken cutting these wedges. However, two of the wedges on the western side are not cut through and appear to be *in situ*. This means that the end board as envisaged could not be removed as a single piece, as these wedges would have to be cut through or removed to do this. The end board could not have been levered up and removed to the east, as this would entail removal of the western wedges, and, in any case, the eastern lath is also *in situ*. Either the interpretation of the end board as a single timber is incorrect, or it was broken up when removed. It is perhaps relevant that, while the eastern lath (810) is in place, the western lath (800) has been slightly dislodged, as though part of the end board had been pulled away to the south-east, leaving the wedges in place (*see* Fig 5.1).

The northern end

Owain Roberts has proposed a flat transom stern, attached by a system of wedges passing through transverse rails on the bottom planks, iles and upper side planks (Chapter 10; *see* Fig 10.1). As drawn, the end board sits in a slot created by leaving upstanding transverse rails on the bottom and ile planks, held in place by wedges. However, the laths covering the ile and central seams appear to go through the transverse rails and end board, as did – presumably –the laths between the ile and upper side plank. If this were the case, then slots for the laths would have to be cut through the transverse rails, and rebates would have to be cut into the transom board to allow it to fit snugly over the laths. This seems a lot of effort, and could create weak points at the stern, increasing the boat's natural propensity to leak. Of course, abaft the transom, the laths would not serve any waterproofing function; perhaps a simpler solution would be to butt the laths against the forward transverse rail. The sternmost wedge across the central lath might provide sufficient pressure to keep the central joint waterproof, and the transverse rails on the bottom planks could then be brought together as a butt joint in the centre line of the boat. The transom stern would pull the bottom and sides of the boat together, possibly obviating the need for stitches at the extreme end of the boat.

The concept of a flat transom stern is convincing, though it has been the subject of some debate; some have preferred a symmetrical, lenticular shape to the boat with identically shaped ends. However, there is indirect evidence for Bronze Age boats with a flat transom end. The Bronze Age ship-settings of northern Europe (of which there are around thirty-five examples) are normally laid out as a double-pointed oval, where it is impossible to distinguish between bow and stern (Capelle 1995, 71). However, in three examples (Liffride and Stora Bjers in Gotland, and Thumby in Schleswig-Holstein), the stern is laid out straight across, in exactly the same way as in Robert's reconstruction (eg Capelle 1995, fig 7).

Repairs to the boat

The ile planks were split in three places; the splits having been repaired by cutting lines of stitch holes above and below the split, and lashing down timber laths holding moss wadding in place. The laths did not serve as 'patches' as found at Ferriby (Wright 1990, 145–7) and on the Hasholme log boat (Millett and McGrail 1987, 119); their sole function was to hold the waterproofing moss against the split and to help tighten the yew withy stitches.

These splits might have occurred when the boat was being built (splitting was a problem even on the short lengths of tree trunk used in the reconstruction experiment), but the scars on the ile and bottom planks suggest that they resulted from a collision of some kind (Chapter 5). In addition, the general direction of stitch insertion in the boat (ie from north to south) is not reflected in the repair stitches (some of which are inserted from south to north), which might also suggest the repairs were carried out some time later than the initial construction.

The split on western ile plank 301 was repaired with two separate laths (780 and 781; *see* Fig 5.46). The southernmost lath (780) is about 1.3m long; its northern end has been deliberately shaped to a feather edge, presumably to form a scarf with the southern end of lath 781 (now missing; *see* Fig 5.60). The exact length of lath 781 cannot now be ascertained, as both its southern and northern ends are missing; however, it cannot have extended much further north, as there are no more repair stitches to hold it in position. It was probably about 0.8m long. Peter Marsden has suggested that this split was repaired with a single lath – about 2m long – that had been broken in antiquity (Chapter 5).

There are two splits on eastern ile plank 304 – an upper one at least 1.8m long, and the other, lower split perhaps 5.2m long (Chapter 5). The upper split had been repaired with two laths – 792, about 1.05m long with feathered scarfs at each end (*see* Fig 5.62), and 793, about 0.6m long, broken at either end (though the original site plan shows its southern end overlying the northern end of 792). Elsewhere it has been suggested these two laths were originally a single piece approximately 1.7m long (Chapter 5).

Below this was another split, running for about 1.6m to the damage caused by the cofferdam. This was overlain by two laths, 790 and 791. The northernmost of these, (791), was a particularly small lath, only 0.65m long and 0.04m wide. Its southern end was overlain by the northern end of lath 790 (*see* Fig 5.62), which was about 0.07m wide and 1.1m long, its southern end being broken at the line of cofferdam damage. It has been suggested that these two laths were originally a single piece approximately 1.6m long (Chapter 5). It might be that this split (and its associated repair) extended south of the cofferdam break. There is a pair of damaged repair stitch holes immediately on the line of the break that appear to continue the line and spacing of the stitches associated with lath 790.

South of this, the situation becomes less clear. The upper part of the ile is badly damaged; the southern 2.5m has broken away and is missing. North of this, a mid-section is also missing, although the upper part of the ile was *in situ* when excavated. There is a line of repair stitch holes running below this damage, but this appears to be on a slightly different alignment to that relating to lath 790. These stitches might relate to a repair of a split that eventually led to the upper part of the ile breaking away. They do not appear to be matched by upper repair stitch holes, although it is conceivable that these were present in the piece that is now missing. However, cut into the surface of the line of breakage in the southern part of the ile is a number of cut holes directly above the lower stitch holes. If this line of breakage follows the line of the split that was repaired, they presumably cannot represent the upper repair stitch holes, as they cut through the split and could not function to hold a repair lath over the split. Their status and function, therefore, remain unclear.

Seagoing, coastal or rivercraft?

There is no direct evidence for the conditions the boat operated in. It was a narrow, flat-bottomed vessel, superficially reminiscent of a modern river punt (Chapter 5); it was abandoned at the side of a river valley, seemingly in entirely freshwater conditions (Chapter 12). There are no signs of infestation or damage to the hull from marine organisms such as *teredo*. At first sight, therefore, there seems to be a case for suggesting that the Dover boat was intended as a river-craft. However, this possibility has generally been rejected; the boat is seen as a coastal or sea-going craft.

The reasons for this are circumstantial but compelling. In essence, the Dour valley is too small for a boat of this size, even allowing for coastal erosion and sea-level change (Chapter 15). Furthermore, the environmental evidence (Chapter 12) suggests the nature of the Dour at the time of the boat's abandonment was not that of a broad, deep river channel (which might have suggested the need for a ferry), but rather a braided network of shallow streams running down to the sea. This study also demonstrated the presence of marine sand on the inboard surface of the boat that did not originate from Dover (Chapter 12). Today the Dour is a narrow and rather shallow river running through the heart of the modern town. It is difficult to conceive that a vessel the size and complexity of the Dover boat would have been created to operate on the shallow waters of this modest valley. Surely the boat must have ventured into the uncertain waters of the English Channel under the towering chalk cliffs stretching to the east and west (*see* Fig 19.1).

The cliffs must have existed in the Middle Bronze Age; our prehistoric mariners, when setting forth from what is now Dover would have had no easy passage in shallow and relatively safe coastal waters. At once, they would have been exposed to conditions similar to those in the open sea, and their boat would have had to have been able to cope (*see* Fig 19.2). This is not to say that they would set forth in bad weather; although great storms might rage against the White Cliffs at any time of the year, at other times the sea can be as flat as a millpond, with the coast of France clearly visible on the horizon. Waiting for the right weather and tide would be vital to make a safe journey. However, this author's experience of sailing off the north coast of Kent has emphasised how changeable the weather can be in this area, and how powerful the effect of tide and current. One can assume the crew of the Dover boat had deep knowledge of the environment they operated in, and were very familiar with the capabilities of their vessel.

Much has been made of the possibility that the Dover boat travelled to France; the concept of the first cross-Channel ferry has excited popular imagination. Sadly, this cannot be demonstrated one way or the other. There is, of course, overwhelming evidence that there was extensive contact between Britain and the Continent during prehistoric times (Muckelroy 1981), and the large hoard of bronze implements found on the seabed just east of Dover is thought to be of Continental origin, possibly from a shipwreck (Needham and Dean 1987; Muckelroy 1980). However, in the absence of a cargo in the Dover boat, we cannot prove that it made the crossing to France. Nevertheless, as intimated above, on leaving the haven of the Dour valley one must negotiate the open sea below the cliffs of Dover. In recent times the Channel has been crossed in a motley assemblage of unlikely vessels, from bathtubs to simple wooden pallets. The coast of France is clearly visible from Dover; it would not be a journey into the unknown, and there seems to be no technical reason why such a journey could not be undertaken.

It is probable that the boat plied up and down the south coast of Britain, in addition to any putative Channel crossings. The single fragment of Kimmeridge shale recovered from the northern end of the boat (Chapter 11) might offer a clue to the kinds of distances travelled (although we must recognise this is a substantial inference drawn from little evidence). A large Trevisker urn (around 600mm high with a rim diameter of about 275mm) was recently found in an excavation on the Isle of Thanet (Gibson *et al* 1997); this had been imported from Cornwall in south-west Britain, and the most obvious method of transport of this large and cumbersome object would have been by sea. It has been dated to 1530–1320 Cal BC (OxA-6141; 3175±50 BP), potentially within the period of the working life of the Dover boat.

The function of the boat

If we accept that the boat was working along the coast of southern Britain, perhaps also crossing the Channel to what is now France, it is pertinent to ask what the purpose was of such journeys. Again, the absence of a cargo makes it hard to be definitive, but there are a number of aspects of the boat that can help inform such speculation. First, we might consider the surface treatment of the boat's timbers. Ted Wright has drawn attention to the rough surfaces of the Dover boat in contrast to those of the Ferriby examples (Chapter 14). During the reconstruction experiment, it was noted that even woodworkers unfamiliar with Bronze Age type tools left a smoother finish to the timbers than that found on the Dover boat (Chapter 9). It would appear that the original boatbuilders, though clearly capable of a high standard of work, did not feel moved to expend the effort to fair the surfaces of the vessel. To modern eyes, it might appear that the boat was not intended for display; function was more important than appearance. Although Damian Goodburn has suggested that the fluting on the outboard surfaces was intended as a semi-decorative finish, why this should be desired on the bottom of the boat is unclear (Chapter 8). The roughness of the finish suggests that the boat was a working vessel, rather than a specifically ritual or high-status display craft. If we leave aside esoteric roles (at least as the primary function of the boat), we might suggest functions such as a war craft, a cargo boat, a fishing boat or a ferry or personnel carrier. Of course, a boat might be used in more ways than one, but here we are concerned with the primary intended function of the vessel suggested by its design and manufacture. We might be aided in this by considering the 'comparison of coefficients' of the hypothetical reconstruction of the Dover boat with those of other vessels (Chapter 10). Here we can see that shape of the Dover hull is not conducive to high speeds (unlike the Iron-Age war boat excavated at Hjortspring; Randsborg 1995), but is better suited to carrying relatively large cargoes at moderate speeds. This might suggest that the boat was not intended for combat, and had a rather more prosaic role.

The evidence for offshore fishing in the Middle Bronze Age is somewhat circumstantial in north-west Europe, though better documented for the Eastern Mediterranean (Powell 1994). A Bronze Age rock carving from Kville, in Bohuslän, Sweden appears to show two people fishing from a boat with hook and line (Clark 1952). Finds of fish bone from terrestrial sites suggest that some large fish were being caught offshore – including cod, dogfish and haddock – but it appears that they could be caught from fairly small boats operating relatively close to shore (Ryder 1969; Clark 1948).

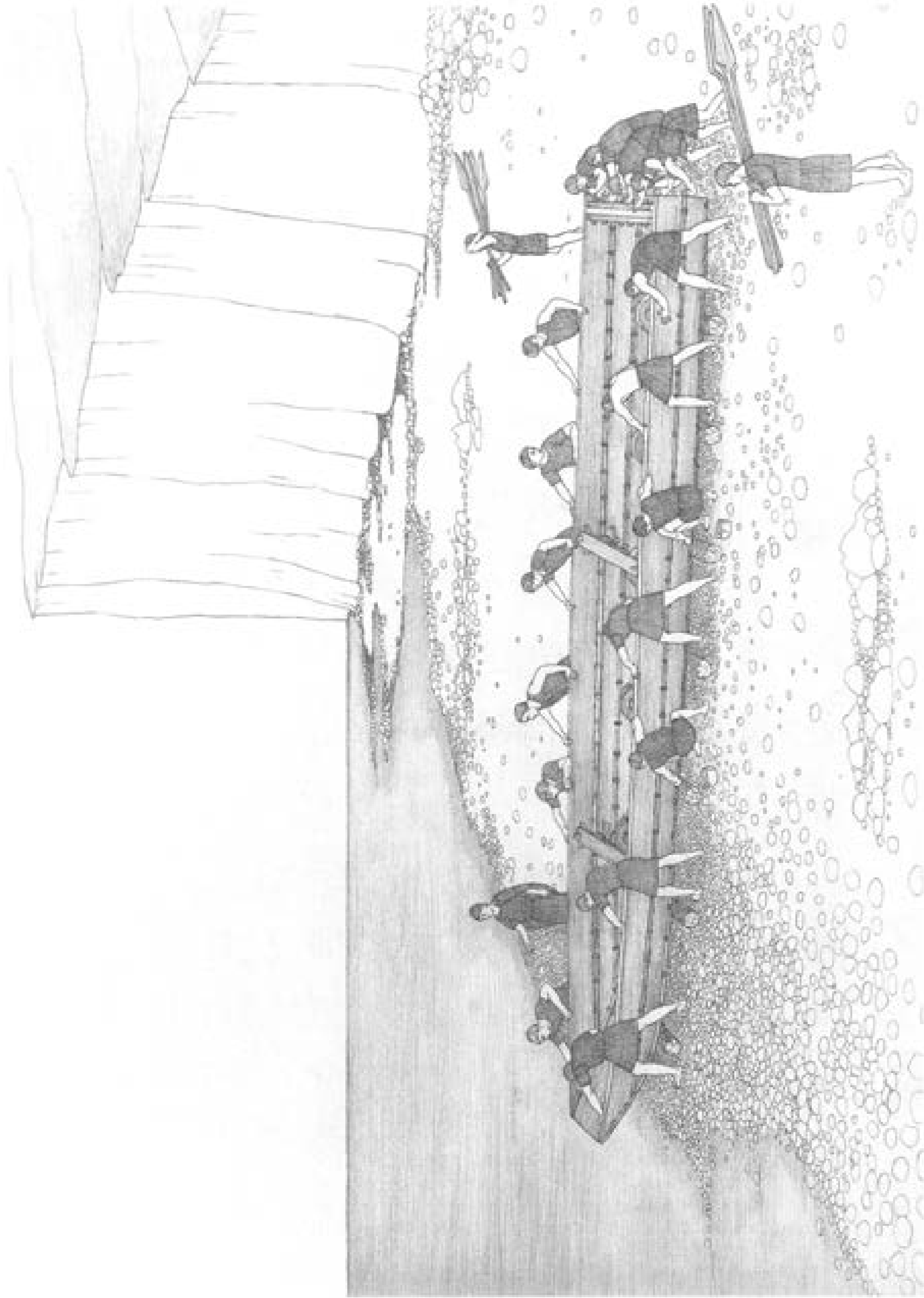


Figure 19.1
Launching the boat. Because of the great weight of the boat, rollers may have been required to get the boat into the water.

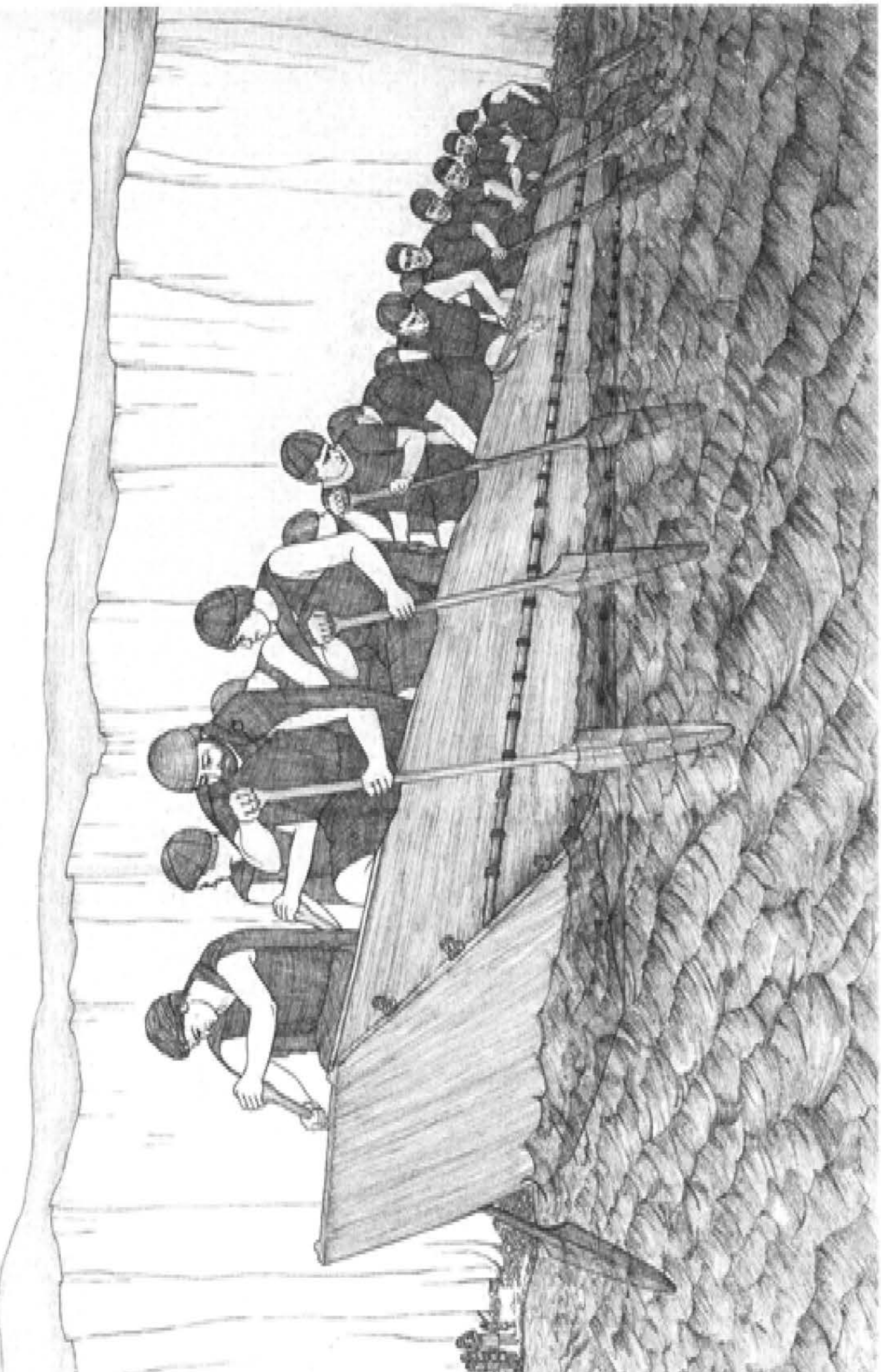


Figure 19.2
The boat at sea. Nobody knows what voyages the boat undertook, but technologically it would have been capable of travelling great distances in moderately rough seas.

There seems to be little evidence for suggesting large fishing vessels operated in deep waters (herring, for example, does not seem to have been exploited until historic times; Ryder 1969, 385). In the absence of better evidence, our current understanding of the exploitation of offshore fishing stocks suggests the Dover boat is too large and too complex to be interpreted primarily as a fishing boat, although this possibility cannot be excluded.

More attractive, however, is the idea that the boat was originally intended to transport people or other cargoes. As has been suggested above, it appears that the River Dour itself would not warrant a purpose-built ferry to cross its waters (unlike the Humber, for example). Moving further afield, one must consider the nature of a society that would warrant a vessel built specifically for transporting people. Harding has emphasised the 'village life' of societies north of the Alps in Bronze Age Europe, 'revolving around a local or at most regional operation' (1996, 254), in contrast to the more developed and extensive social systems in the Mediterranean. Whilst there is good evidence of intra- and inter-regional exchange, there seems little to suggest the need for dedicated personnel transports at this period.

On balance, therefore, this author suggests that the Dover boat was primarily intended as a cargo vessel, plying the coasts of southern Britain and possibly crossing to the Continent. The qualities of its hull form, the apparent disregard for a fine finish or cosmetic effects, and the many signs of wear, damage and repair on its hull suggest it had a long and hard-working life. Set against this, however, is the puzzling lack of wear on the inboard surfaces of the boat (Chapter 8). If the boat had been regularly carrying cargoes, then one might expect these to have left traces or perhaps damage the bottom of the boat, particularly to the upstanding elements such as the cleats and central rails. Perhaps the boat was not very old when abandoned; the lack of variation in stitching direction might suggest that the original stitches remained and had not been replaced. The lack of internal wear might also suggest that the boat was of no great age. Alternatively, Damian Goodburn has suggested that dunnage might have protected the bottom of the boat (Chapter 8); brushwood dunnage was recovered from the Bronze Age wreck at Cape Gelidonya, off the coast of southern Turkey (dated to *c* 1200 Cal BC (*c* 3000 BP); Bass 1967, 49). This brushwood underlay the heavy bronze ingots that formed its cargo; at Uluburun (*c* 1300 Cal BC (*c* 3050 BP)), thorny burnet (*Sarcopeterium spinosum*) was used in the same way (Wachsmann 1998, 305; Pulak 1998, 197). Perhaps a similar material would help explain the lack of wear or damage on the bottom of the Dover boat.

It is also pertinent to ask what cargoes the boat might have carried; the single fragment of shale found at the north end of the boat is suggestive of material having been brought into Kent from south-west England – perhaps, as has been suggested, as raw material for the manufacture of jewellery (Chapter 11). Of course, we should not suggest that the boat carried only one type of cargo, or that the cargo was not mixed; it seems likely that a variety of goods would be carried on any one voyage. Cargoes from Bronze Age ships in the Mediterranean show that they carried many different wares, including raw materials in the form of ingots of bronze and glass (some apparently stored in bags or baskets), unworked ivory, metal tools and weapons, pottery, together with organic goods such as resin, pomegranates, olive oil and timber (Bass 1967; Wachsmann 1998, 303–14; Haldane 1993).

A different range of goods would have been carried by boats in north-west Europe, no doubt including organic material that has left little trace in the archaeological record. The Iron Age log boat discovered at Hasholme in Yorkshire is thought to have been carrying a cargo of joints of prime beef when it sank (Stallibrass 1987, 144; however, a different view of the nature of this find is now thought likely (Chapter 16)). However, as with the Mediterranean examples, it seems very likely that a major component of many cargoes would be bronze, either in the form of ingots, scrap metal or finished implements. The retrieval of over 350 Middle Bronze Age bronze objects from the seabed at Langdon Bay is evocative of the scale of sea transport of bronze during the Middle Bronze Age (Coombes 1976; Muckelroy 1980; 1981; Needham and Dean 1987). For many thousands of years, stone was the primary raw material for toolmaking, although organic materials such as wood were no doubt also important. Stone implements and waste – usually of some form of flint – are ubiquitous on early prehistoric sites, but, during the Bronze Age, across Europe the relative sophistication of stone tools seems to decrease, and their prominence in the archaeological record lessens. It would appear that communities became less dependent on stone-tool technology, so that manufacturing skills were lost and this ancient tradition faded into a reactive, ad hoc response over just a few hundred years (Saville 1981b). The implication of this could be that metal tools became ubiquitous throughout European society, their advantages being such that the developed stone-tool industry was largely abandoned within a few generations. By the 12th century Cal BC, for example, a metal workshop was set up amid the abandoned workings of the huge flint mines at Grimes Graves in Norfolk (Darvill 1987, 121). Of course, we need not propose simple technological determinism here; metal tools had been available for a long time before their widespread adoption. However, when the socio-economic climate was appropriate, the use of bronze tools was quickly and widely embraced; their implied ubiquity required large amounts of raw material to be transported across Europe, often over large distances. The effect on contemporary social and economic relationships must have been revolutionary; the distribution networks for stone tools were quite different for those of bronze (Clark 1965; Clough and Cummins 1979; Darvill 1987, 71–3; Le Roux and Courdier 1974; Smith 1974, 122; Tabaczynski 1972; Wickham-Jones 1990). In Kent, for example, where good quality flint is commonplace, there are no raw materials available for the manufacture of bronze. The nearest source of tin is in Cornwall in south-west Britain; on the Continent, tin deposits can be found in Brittany and south of the Loire. Copper deposits can be found in Wales, northern Britain and southern Ireland, but on the continent, one must venture south of the Pyrenees or into central Europe before suitable sources are found (Kristiansen 1998, fig 11). The decline of the stone-tool industry and the implications of a widespread move to metal tools is a subject that might well repay further study.

While the phraseology might be inappropriate for the Middle Bronze Age, there was a 'demand' for bronze that could be satisfied only by exploiting resources hundreds of kilometres away; bronze had to be imported into south-east Britain over long distances. The amount of material required is difficult to ascertain; unlike stone, bronze can be melted down and reused. Much of our knowledge of Bronze Age metalwork is derived from hoards probably intended for recycling, as well as votive deposits that might not always be representative of everyday items (Bradley 1985; 1987; 1990). However, it is clear that substantial amounts of bronze were being imported, and this must have been carried in some kind of transport. Perhaps the Dover boat is one example of the kind of vessel that supplied this demand for bronze in the Middle Bronze Age.

The cargoes carried by the boat had much more significance than simple trading goods. The people of Bronze Age Europe lived in small communities, modest villages or isolated farmsteads (Harding 2000; Pare 1996). The boat brought in essential goods, but was also a vehicle for social and political intercourse with other communities, both nearby and far away. It carried gifts, news, dowries, tributes, emissaries, brides, stories and religion. With its ability to travel long distances over the alien and sometimes turbulent environment of the sea, the boat was a powerful talisman for the people it served. It was a potent symbol, touching on all aspects of their lives: economic, social, political and spiritual.

Boats in the Bronze Age

This author suggests, therefore, that the Dover boat was essentially a cargo boat, primarily intended for the transport of bronze, whether as ingots, scrap metal or finished objects. It would probably have carried a mixed load, possibly including shale, pottery, perhaps livestock and other organic produce; its cargo would have rested on brushwood dunnage to protect the timbers of the boat from damage. Of course, it could have been used in other ways, additional to its primary function; it could have carried passengers, or been employed as a fishing boat – indeed, any function that required a boat of some kind.

However, this is not to suggest that the Dover find was the only kind of vessel used by Bronze Age communities in south-east Britain. In spite of the technological similarities of the construction details, there are quite marked differences between the design and possible primary function of the Bronze Age sewn-plank boats discovered so far. While

Ted Wright has suggested the existence of a 'Ferriby–Dover' class of vessel (Chapter 14), this might be a premature suggestion, given how few examples have been found; indeed, one might ponder what shared set of attributes would be appropriate to identify a vessel 'class'. Nevertheless, the relative scarcity of boat discoveries should not be taken to imply that boats themselves were rare in the Middle Bronze Age; it is a remarkable fact that, in a relatively small area of the Humber estuary, the remains of no fewer than five different vessels have been found (Wright 1990; Wright and Switsur 1993).

It might be there was a range of different vessels available to Middle Bronze Age communities, with different properties and abilities, suitable for different functions. Log boats appear to have been in use across Europe from at least the Mesolithic up until the present day (Arnold 1995; Mowat 1996); their ubiquity is testament to their utility in certain operating conditions. We would certainly expect the builders and users of the Dover boat to be familiar with such craft. It has also been suggested that plank boats were constructed with stems and keels during the Bronze Age (McGrail 1988, xvii). A boat-shaped log-coffin from Loose Howe in Yorkshire, dated to the Early Bronze Age, appears to have the shapes of both stem and keel carved into the log (Elgee 1949).

Elsewhere, the representations of boats on rock carvings in Scandinavia (Malmer 1981), Iberia (Alonso 1994) and on portable metalwork in central and northern Europe (Gelling and Davidson 1969, 117–35; Kaul 1995; 1998) seem to show a type of vessel very different from either Ferriby or Dover. Unfortunately, the type of vessel represented on these carvings is still a matter of debate (Hale 1980; Barrosso Rúiz 1980). John Coles (1993) has suggested the rock carvings indeed show a wide range of different vessel types, including log boats, hide boats and plank boats. Many of these carvings show a number of similarities to the much later planked boat from the bog at Hjortspring Kobbel, on the island of Als in northern Denmark; this is undoubtedly a vessel built for speed (Randsborg 1995), quite different to that from Dover. A carving from the decorated slabs lining the burial chamber of the great coastal grave at Kivik, in Skåne, Sweden, shows a very similar vessel. This site has been dated to around 1300 Cal BC (*c* 3050 BP; Randsborg 1993), which might suggest that such light, fast vessels were also in use around the time of the Dover boat.

We should perhaps be more circumspect when discussing the nature of water transport in the Middle Bronze Age; it seems quite likely that boats of many different types and capabilities were relatively common. We have just a handful of wonderful survivals from this period; archaeology will no doubt bring forth new and unexpected discoveries in the years to come, illuminating the range of vessels in use at the time.

The evolution of boats?

In many studies of the technological development of boats, the concept of 'evolution' is an important model for explanation; Paul Johnstone refers explicitly to the 'evolution' of various types of vessel (eg 1988, 45); Ted Wright speaks of the 'parentage' of the Ferriby boats (1994, 32); Béat Arnold seeks the 'ancestor' of Romano-Celtic boats (1999, 40). This theoretical approach is also echoed in some contributions to this volume (eg Chapter 5; Chapter 14). It is perhaps pertinent to ask if this biological model is appropriate in discussing the development of boatbuilding technology.

Although technological development does occur over time (a nuclear submarine is very different from an Athenian trireme), we need not assume that boatbuilders in the Bronze Age were seeking technical optimisation in the same way we do today. This way of thinking is very much a post-Renaissance phenomenon in Europe (albeit with its roots in the Classical world). We should also recognise that the technology of constructional techniques is fundamentally different from the shape of the vessel created; the technology of construction is the means by which a boat shape is realised (though of course these two concepts are intimately related). In over-emphasising the concept of technological evolution in boat technology, we strip these craft from their human, cultural context and seem to present them almost as living things, subject to the vicissitudes of Darwinian selection and the 'survival of the fittest'.

This subject has been explored in some depth by David Conlin (1998). In the context of the Dover boat, it might be appropriate to develop some of the themes he has presented. First, we might examine the temporal context of models of explanation; over long periods of time (many centuries or millennia), the demands of the marine environment are paramount in prompting particular developments in boatbuilding technology. Over shorter periods of time (a few generations or centuries) social and perceptual constraints might be more important: 'There are countless examples of the willingness of human beings to ignore the deleterious effects of their decisions for perceived benefits. In the case of ships it is easy to conceive of a culture willing to accept less than maximal sailing characteristics due either to extenuating social or economic processes at work, or a perceived benefit greater than that which can be achieved from a maximum efficiency of ship form' (Conlin 1998, 12). Attention has been drawn, for example, to the fact that no nails were used in the construction of the Dover boat (Chapter 5); the 'invention' of the nail has been suggested as a major breakthrough in the development of boatbuilding technology. However, the concept of nails or pegs was well known centuries before the Dover boat was built. Coles has pointed out the use of 'pegs and pins' in the Neolithic (J Coles 1993, 29); simple riveted knives and daggers are known from the Early Bronze Age (Burgess 1974, 193; Piggott 1963, 82–4, fig 18). Arnold also refers to the use of treenails in the Neolithic: 'North of the Alps, the use of treenails and treenail-wedges (the latter used to insert pegs firmly into a mortise or drilled hole) during the Neolithic is an established fact...' (Arnold 1999, 42). It would appear that, while the general principle of nails was widely known, there was no impetus to apply this technology to boatbuilding, in spite of the technological benefits.

One should also consider that the marine environment, while admittedly difficult for human society to transform in the same way as they could the terrestrial environment, is not a single, independent variable. The nature of the world's seas is almost infinitely variable, from quiet inshore waters to the open ocean, with all the complications of tide, current and weather (Muckelroy 1981, 279). The impetus for technological advance must surely be dependent on the conditions that a boat must operate in. If a boat worked perfectly well within the waters of a large estuary, for example, there would appear little reason to change its design; only the need to operate in new environmental conditions would necessitate change (though it can be argued that economy and technological ability might determine the perception of 'transport zones' in which vessels might operate; Westerdahl 1995). Indeed, given the natural conservatism of boatbuilders, it is pertinent to explore what circumstances would provide the impetus for technological innovation, creating the variability in boat design that would allow natural environmental forces to operate selectively (Conlin 1998, fig 1). Here we are reminded that boats and ships are not special, separate things; they are intimately bound up in the lives and histories of the communities that built and used them.

The people who built the boat

Keith Parfitt and Tim Champion have reviewed the cultural background of the Dover find (Chapter 15). Throughout this volume, various authors have referred to the 'boatbuilders', but we have not really considered who these people might be, or what position they held in contemporary society. It is clear that those who built the boat were highly skilled woodworkers, in possession of a clear vision of the final product of their labours. The intricacy of the boat's construction – including the complex scarf at the southern end, the mirroring of cleats and other features on the bottom planks, and the elaborate waterproofing systems – suggests people operating within a long tradition of boatbuilding and having an intimate knowledge of the materials available. While it may be inappropriate to refer to the 'design' of the boat, its overall symmetry and the requirement for these huge sculpted planks to fit together closely shows that, from the outset, there was a general knowledge of how the various elements of the boat were to be fashioned. There is no need to postulate some kind of 'blueprint' or master plan; the knowledge of building boats such as these was probably contained in an oral tradition. Even as late as AD 1804, shipbuilders in the north of England relied almost exclusively on oral knowledge for designing their vessels (Pollard and Robertson 1979, 131). Peter Marsden has drawn attention to the possibility of regularised units of measurement in the construction of the Dover boat (Chapter 5), and the dimensions (or at least proportions) of the boat would be an important part of this oral tradition.

Similarly, the sequence of construction, which has been the subject of much discussion in this volume (Chapter 5; Chapter 8 and above), is of fundamental importance in constructing a complex boat or ship (Conlin 1998, 8; Maarleveld 1994). The apparent decision-making process underpinning the sequence of construction has implications that might well repay further study.

It is unknown, however, whether this boatbuilding tradition and the ability to carry out the work, were part of the spectrum of skills generally available to a small coastal community in the Middle Bronze Age. We have noted above the likelihood that people at this time were accustomed to felling large trees and working with timber, constructing their homes, animal enclosures and other structures – not forgetting portable objects such as bowls, ladles, troughs and shafts for metal tools (Earwood 1993). It would appear that woodworking skills would be available to such a community, but, even allowing that a range of different types of boat might be required, would the oral tradition of building such sophisticated vessels be present in every settlement that required a boat? The small fishing communities on the northern and western Norwegian coast built their own boats during winter, all using clinker types but showing slight variations in style (Owain Roberts, pers comm). Perhaps, for coastal Bronze Age communities, boatbuilding was just another communal skill, certain technological aspects being transmitted between them, but leading to individual expression in the final boat form. Westerdahl has drawn attention to the individual adaptation of boat types in different river systems in Poland and France, even as late as the 20th century AD (Westerdahl 1995, 214).

Alternatively, it might be that there were 'specialist' boatbuilders who travelled from site to site, advising and supervising local communities in the construction of boats suitable for their needs. In support of this, it might be relevant to note the remarkable technological similarity of the boatbuilding techniques from Bronze Age boat finds from around Britain. The use of cleats, withy stitching, moss waterproofing under timber laths, etc, is all typical of boat construction, even in boats of quite different form. These elements do not seem to appear in the repertoire of woodworking techniques for other kinds of construction (eg Taylor 1992). Perhaps there was a separate technological tradition for boatbuilding, finding expression in different vessels separated by hundreds of kilometres – this at a time when the evidence from metal hoards suggests that exchange was highly localised, with little evidence of long-distance trade (Rowlands 1976). The transmission of this tradition by word of mouth from community to community might have taken place, but looking at the complexity and sophistication of the Dover boat it seems unlikely that it had been made by local people turning from forest clearance or house-building to boatbuilding. Perhaps a simpler solution is to postulate a group with appropriate experience and expertise that could work with a community to create a boat when needed.

How this service was negotiated remains unknown, but it seems likely that such boatbuilders would be people of some social status, perhaps akin to the bronze-smiths that in later years became closely associated with the ruling elite (Megaw and Simpson 1979, 298). Indeed, one might speculate that the building of boats had magical aspects and that the boatbuilders themselves were seen in this light, as has been suggested for prehistoric metalworkers (Budd and Taylor 1995). Certainly we might expect all aspects of the boat's construction to be accompanied by ritual and ceremony.

The people who used the boat

Throughout this volume there has been reference not just to the boatbuilders, but also to the community using the vessel. Here it might be pertinent to consider the nature of that community; who 'owned' the boat? Recent studies of Middle Bronze Age settlement in Britain have painted a picture, in the main, of relatively isolated small settlements, perhaps comprising a single extended family group (Brück 1999a; 1999b; 2000; 2001a; 2001b). Where 'villages' of this period do appear in the archaeological record, it is clear that the buildings within these settlements had very different histories of use and abandonment (Nowakowski 1991; 2001). Larger, nucleated settlements appear to be a development of the later Bronze Age, although they do appear in Continental Europe from the early Bronze Age (Harding 2000, 58). Other archaeological phenomena suggest that these small settlements were organised into higher social groups, with the manpower, skills and expertise to create monuments and extensive field systems in the landscape (Bradley 1998, 132–46; Brück 2000, 290–1) and the redistribution networks implied by the movement of large quantities of metal. The creation of a large and complex artefact such as the Dover boat, to modern eyes at least, would seem to be the product of more than one household. Perhaps it was a shared resource, crewed by people drawn from several households, providing a communal resource for a scattered society. Understanding the social hierarchies of Middle Bronze Age Britain, suggested by objects such as the boat, could well be a fruitful focus for further research.

Pragmatism and symbolism

In discussing the social status of the boatbuilders, we should also consider how boats themselves were perceived by the societies that created and used them. While the demands of seaworthiness stipulate that a boat must be a practical construction, made at some expense for pragmatic purposes, such vessels figure prominently in the symbolic repertoire of Bronze Age Europe (J Coles 1993; Gelling and Davidson 1969; Crumlin-Pedersen and Thye 1995). Even today, the vessels that negotiate the dangerous and alien sea away from the security of land can still excite a relationship that transcends the rational.

This is an enormous subject that we cannot explore in depth here. There might, of course, be a difference between the perception of boats used as symbols and the perception of boats themselves. Westerdahl has pointed out that maritime symbolism is not the exclusive domain of 'maritime cultures' (1994, 265). It is clear that the depiction of boats as symbols – whether on rock carvings, bronze objects, as grave settings, on pottery vessels or as ceramic models – encompasses a multiplicity of roles and meanings. These meanings, and the way in which such symbols were utilised in contemporary ritual and social life, are difficult for us to approach today, although the subject has been a matter of great debate and speculation (Almgren 1926; Almgren 1962; Bertilsson 1987; Crumlin-Pedersen and Thye 1995; Ekholm 1916; Ellmers 1973; Helskog 1985; Schjøldt 1986).

Perhaps our best source of information on this subject comes from northern Europe and Scandinavia. Here, during the Bronze Age, boats figure significantly in symbolic expression; many thousands of rock carvings, over 500 depictions of ships on bronze objects and at least 35 'ship-settings'. During the Early Bronze Age, boats appear to contain a symbolic message in themselves; in the Middle and Late Bronze Age they are vehicles for other kinds of symbol – such as the aquatic bird, the 'sun-horse' and the enigmatic mushroom-shaped symbol – perhaps inspired by the symbolic repertoire of central Europe (Kaul 1995, 64–8). In Britain, perhaps the best-known example is the boat model and associated figures from Roos Carr (B Coles 1990; 1993, 21–2). Such symbology has been seen by some to be an arbitrary assigning of meaning to form, with nothing intrinsic in the form of a symbol to limit it to any particular referent (Binford 1971, 16). Others see such expressions as structured in relation to the social construction of reality, and in relation to social strategies of interest and power (Shanks and Tilley 1987, 98). As the nature of the symbolic expression of boats changes over time in the northern European Bronze Age (as described above), it might be that the choice of symbol is not an arbitrary process, but reflects aspects of ideology rooted in society and, ultimately, the politics of power and control.

Kaul (1995) has pointed out that one phase of the use of boats as symbols begins and ends with the Bronze Age; it is not until the Late Iron Age that we again find it occupying a marked position as a religious and political symbol. He suggests that this represents the importance of such vessels in supplying the raw materials from sources that, as we have seen above, are sparsely and widely scattered across the continent. As iron technology was adopted, the relative ubiquity of raw materials lessened the socio-economic importance of transport vessels as well as, therefore, their symbolic importance in social expression.

Moving away from the boat as a symbol, we might consider how boats themselves were perceived by contemporary society. We should be aware that their adoption as symbols of power and meaning might of course have influenced their perception in everyday life. Nevertheless, it has been argued that the symbolic representations of boats, particularly in the Early Bronze Age, reflect with reasonably accuracy the technological form of contemporary vessels (J Coles 1993; Kaul 1995). Although this author knows of no Bronze Age examples (apart from the possible burial at Loose Howe; Elgee 1949), boats themselves were also used in burials during the preceding Neolithic period, and later, during the Iron Age (Skaarup 1995; Crumlin-Pedersen 1995). This suggests that the vessels themselves were viewed with ritual significance.

Abandonment

The concept of the boat itself being imbued with ritual or symbolic significance could be pertinent when we consider the final abandonment of the boat. This subject has been discussed by Timothy Champion (Chapter 16) and above.

It has been suggested that the boat was brought upstream and dismantled for 'recycling' certain parts of the vessel, particularly the upper side planks. It was not unknown for parts of boats to be re-used in new vessels in antiquity; this was found to be the case in the 2,000-year-old boat found on the shores of the sea of Galilee in Israel (Wachsmann 1988; 1995). However given the difficulty of working even partly seasoned oak (which would have been the case with the boat at the time of its abandonment), this seems extremely unlikely here. A number of things suggest a series of actions designed to mark the end of the boat's 'life' – the removal of the upper side planks; the way the end board had been deliberately destroyed; the central rails above transverse timber 342 cut through for no obvious reason and the damage to the eastern ile (possibly to remove a side cleat). Its abandonment and ritual 'killing' at this liminal spot, where earth, sea and sky come together, perhaps accompanied by feasting and other ceremonies, might have also marked the passing of a person, perhaps a senior member of the boat's crew. Similar suggestions have been made for the abandonment and destruction of domestic structures (Brück 1999b). Hard though it is to visualise now, the place where the boat came to rest for millennia was truly dramatic; the narrow valley – flanked by steep hills and towering cliffs framing the sky and beaten by the sea – must surely have been redolent with meaning and power to our Bronze Age ancestors. Wherever the boat was built, whatever shores it visited and whatever communities it served, the Dover boat was given back to the earth and sea in a very special place.

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Figure 3.11 Plan of the excavation area, showing the location of artefacts and other features in relation to the boat.

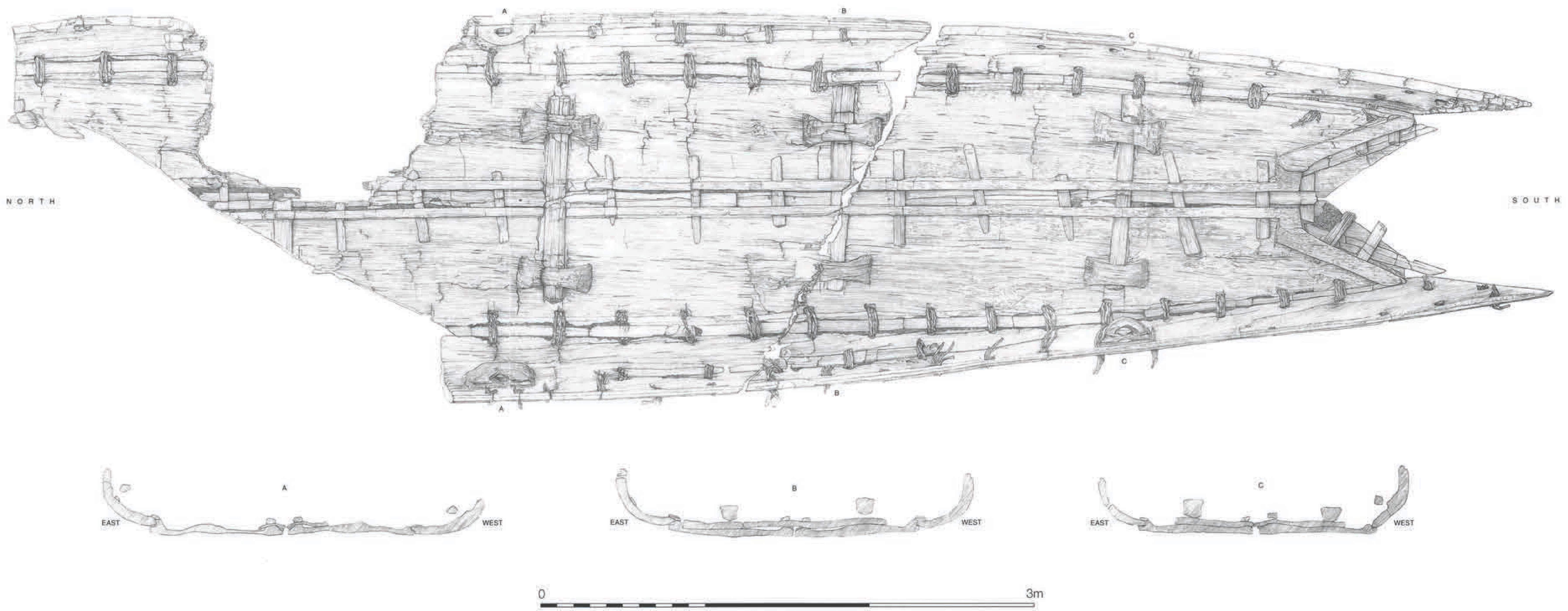

Figure 5.1 The inboard surface of the boat, together with three cross sections through the hull.

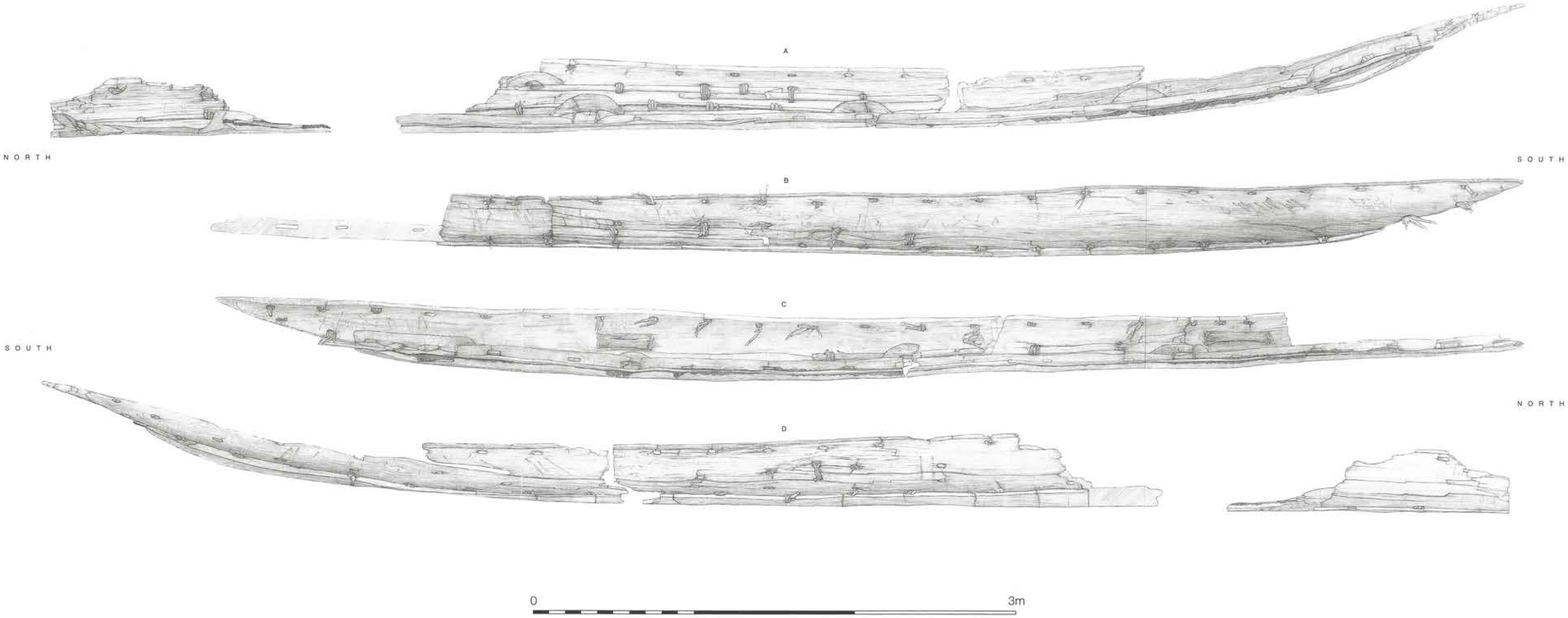

Figure 5.6 Inboard and outboard elevations of the boat as found.

Figure 5.18 The outboard surface of the boat.

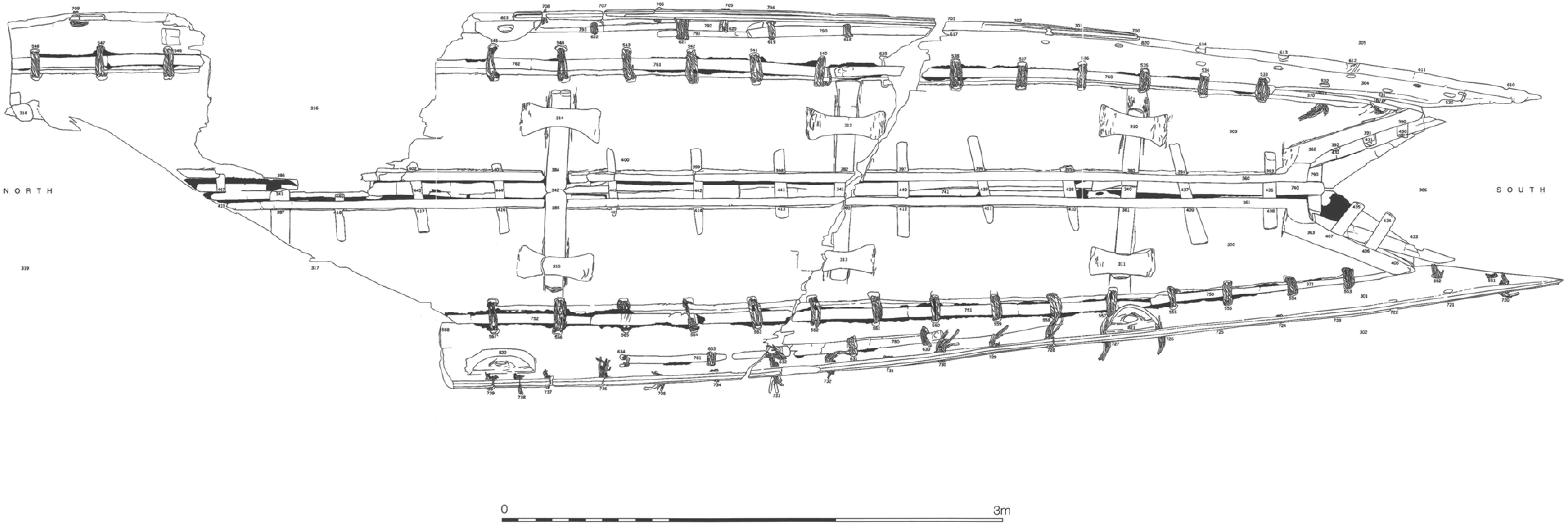

Figure 5.19 Schematic plan of the inboard surface of the boat showing all major numbered features.

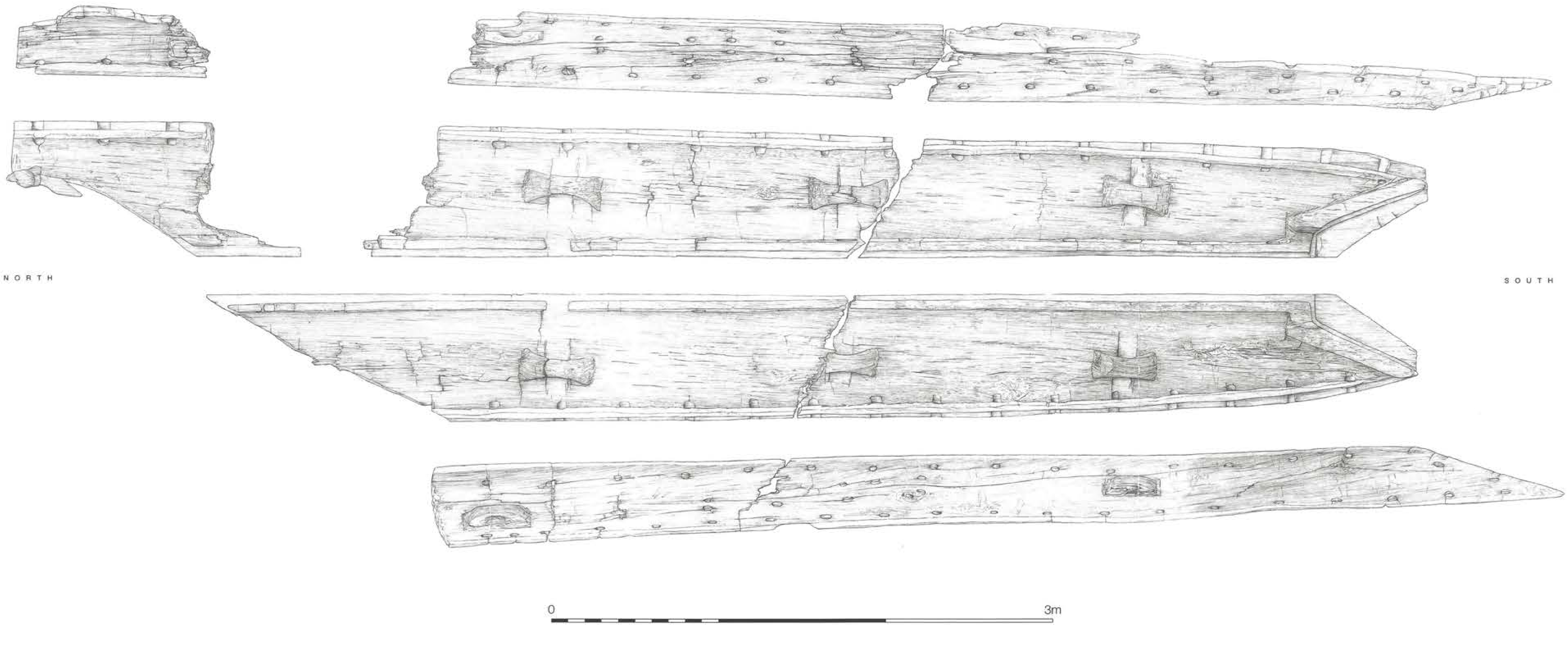

Figure 5.20 Plans of the inboard surfaces of the major component timbers of the boat.

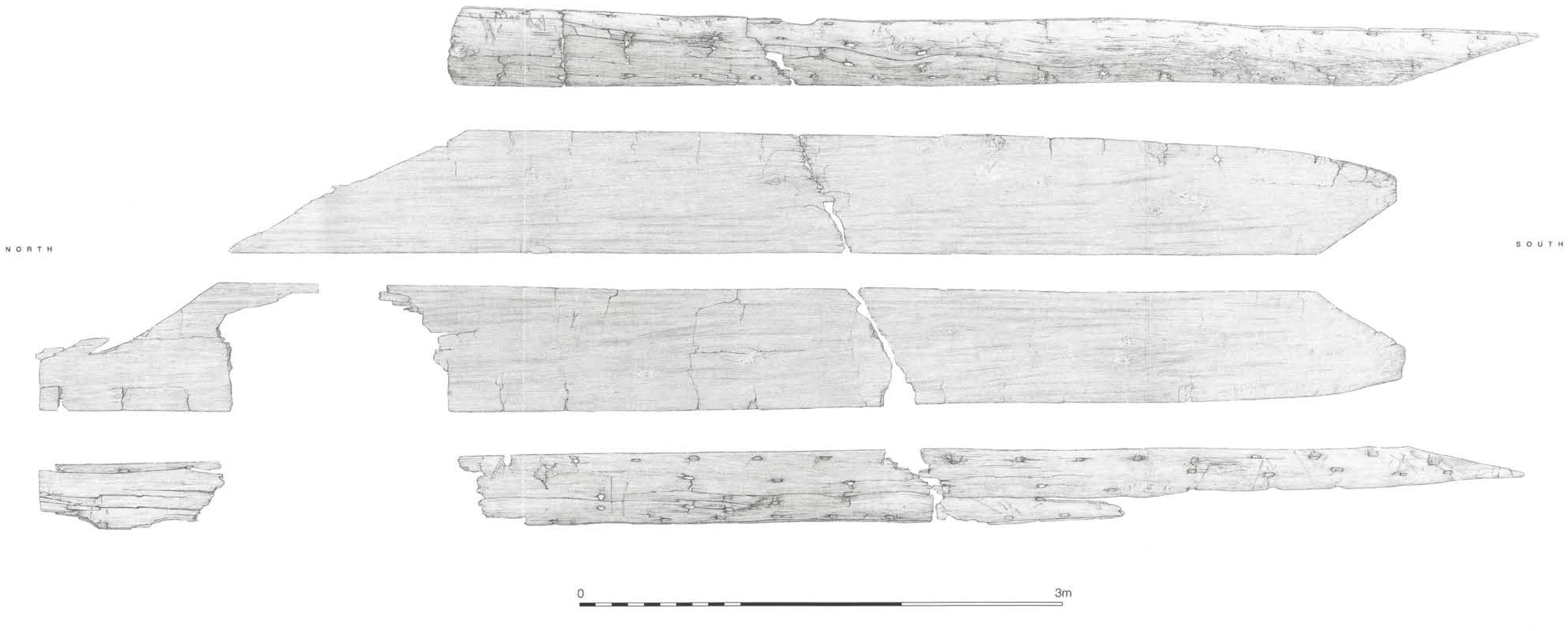

Figure 5.24 Plans of the outboard surfaces of the major component timbers of the boat.

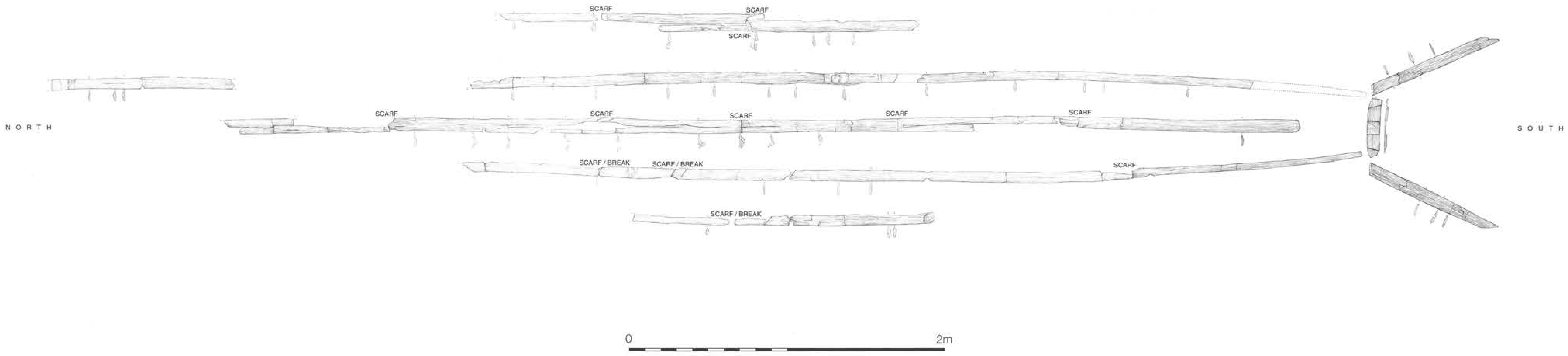

Figure 5.46 Plans and cross sections of the laths fitted along the seams and repairs to the boat. They were held in place by stitches or wedges and transverse timbers, overlying and compressing pads of moss to help make the boat watertight.

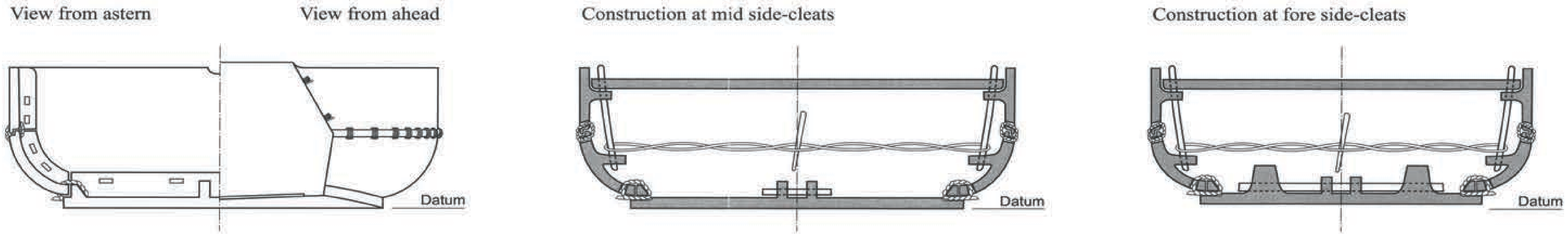

Figure 10.1 Hypothetical boat reconstruction: view from astern and ahead, and cross sections at mid and fore side-cleats.

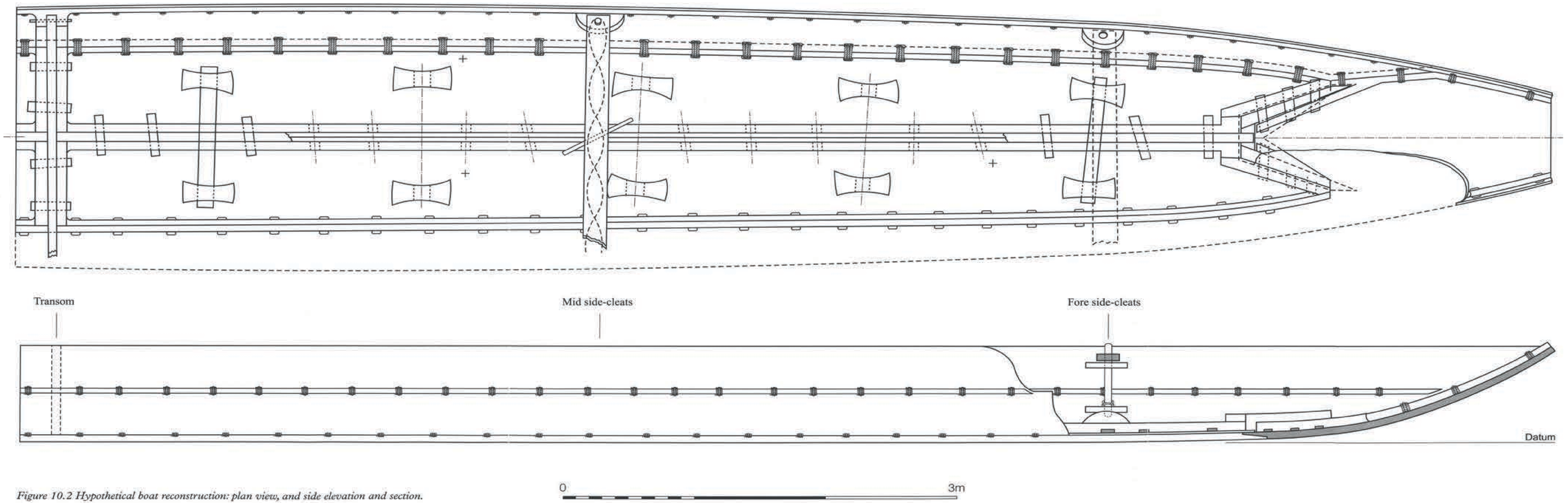

Figure 10.2 Hypothetical boat reconstruction: plan view, and side elevation and section.

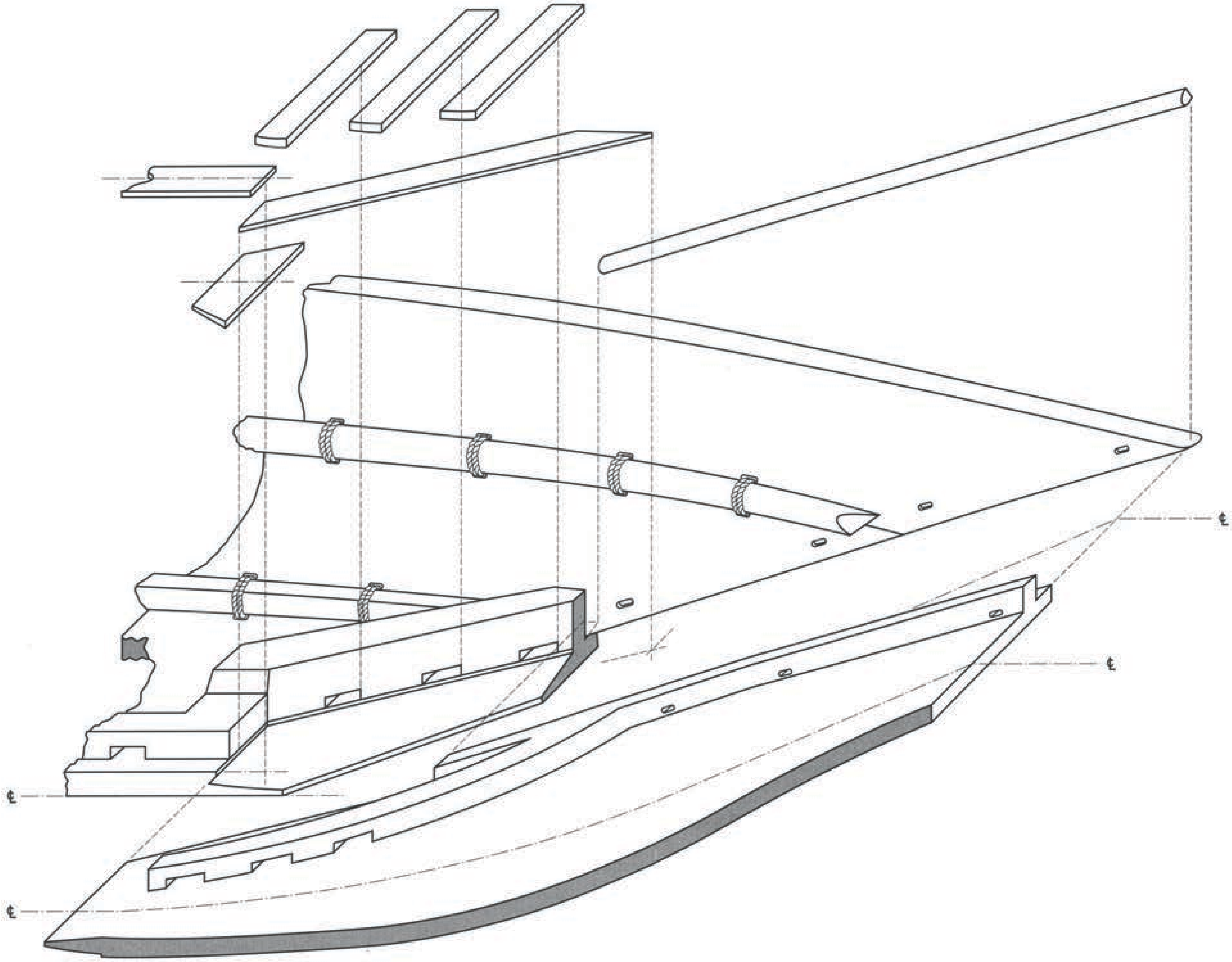

Figure 10.3 Hypothetical boat reconstruction: exploded view of components of the scow-form bows structure.

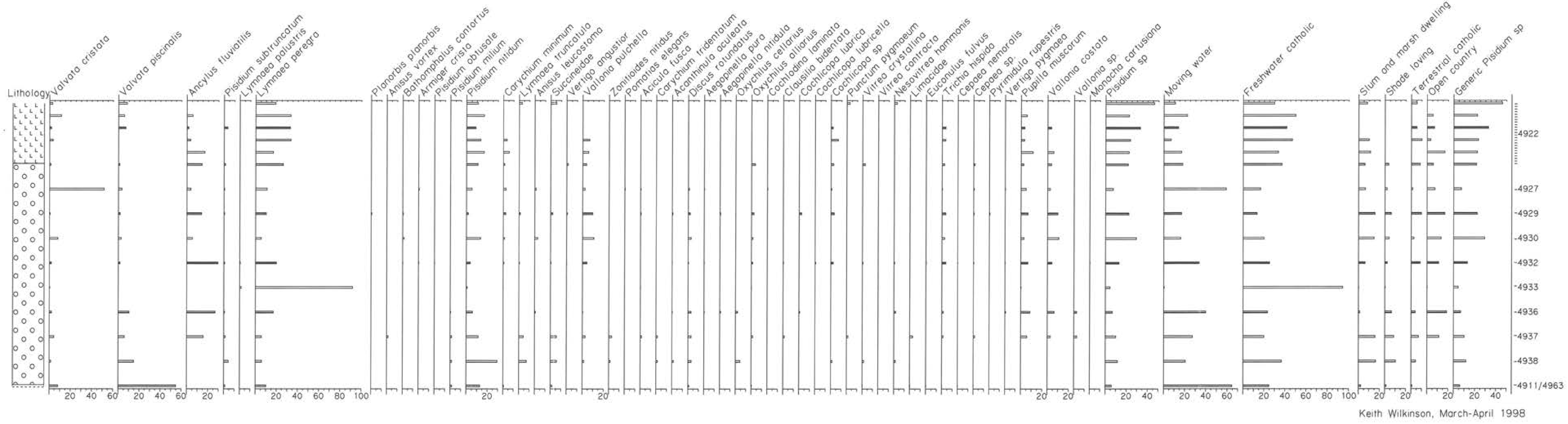

Figure 12.6 Histogram of molluscs from western side of boat, trench 1.

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Front cover
The boat in situ.