

# THE GRAVENEY BOAT

edited by  
Valerie Fenwick

National Maritime Museum, Greenwich  
Archaeological Series No. 3

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1978

# The Graveney Boat: a Tenth-Century Find from Kent

Excavation and recording; interpretation  
of the boat remains and the environment;  
reconstruction and other research;  
conservation and display

Edited by  
**Valerie Fenwick**

Prepared for publication by Ann Morley

National Maritime Museum, Greenwich,  
Archaeological Series No. 3

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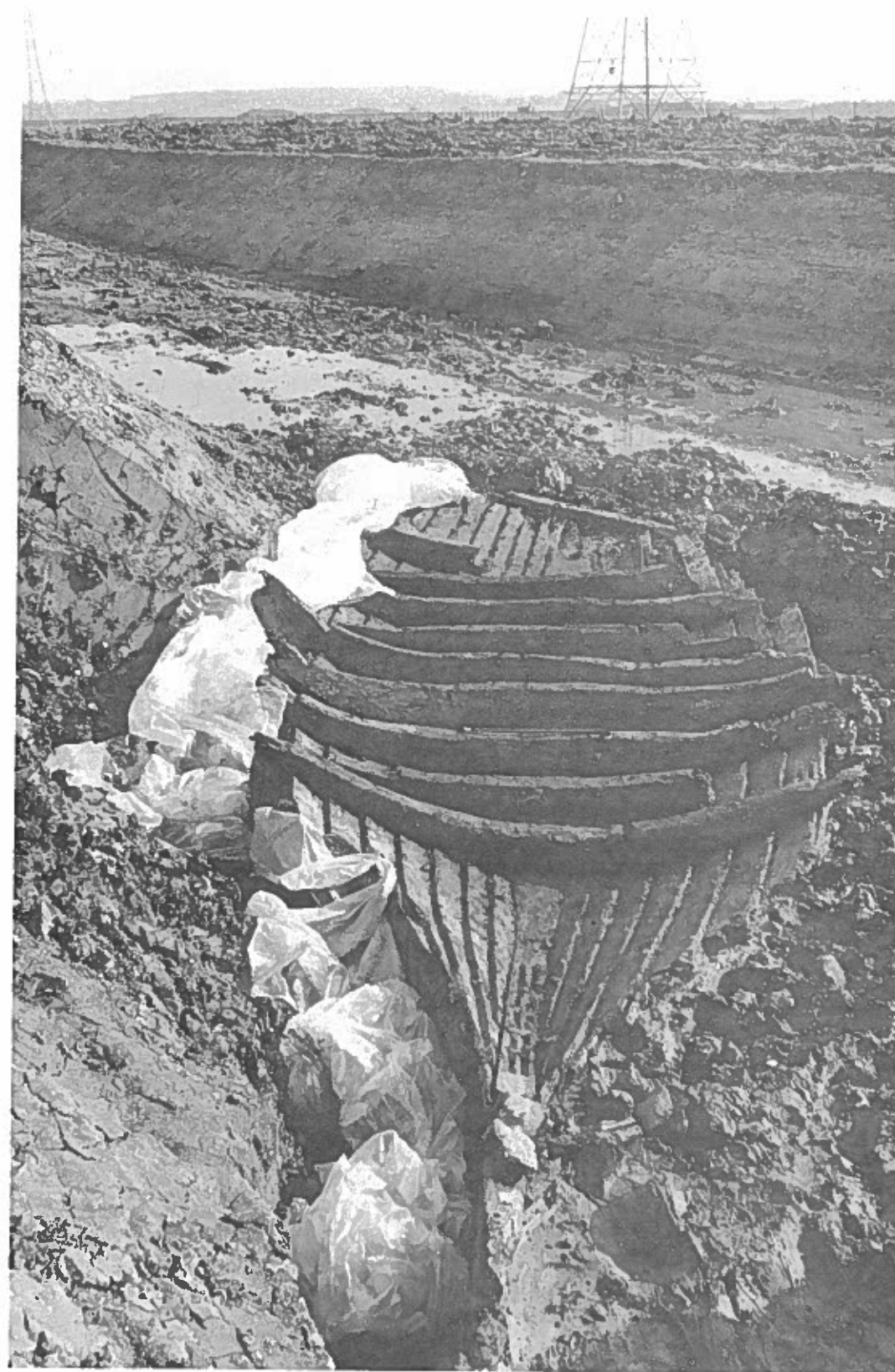
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Frontispiece THE GRAVENEY BOAT BEFORE THE RESCUE OPERATION

The Seasalter Level and medieval mounds can be seen beyond the upcast of the Hammond Drain.

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## FOREWORD

by Basil Greenhill, Director, National Maritime Museum

The chapters which follow comprise between them one of the most comprehensive and thorough reports yet written on the discovery, excavation, and subsequent examination of the remains of an ancient boat. The care with which the boat was excavated and with which it, and the allied finds, were subsequently examined and recorded, and the thoroughness of the reporting, provide a model for future work in this branch of archaeology. The obligation to publish fully has been met. This obligation is on all who undertake or sponsor excavations, and without the fulfilment of it the work is virtually useless. The significant excavation material and the original records of the work are preserved at the National Maritime Museum for reference by future scholars. Thus the requirements laid down in the Department of the Environment's excellent report, *Principles of Publication in Rescue Archaeology* of October 1975, for publication at Level IV have been met.

But the Graveney find has had greater consequences than this publication and its supporting material and records. It provided the occasion for the development at the National Maritime Museum of a research function new in Britain, the full-time professional study of the archaeology of boats and ships and the encouragement and support of relevant research activities, and for the construction and staffing of a Research Centre where this work is being developed. There had previously been no professional staff working full-time in this particular field of archaeology in this country, and very few people working in the field anywhere in the world.

The excavation, examination, recording and publishing of a find like that made on the Graveney Marshes in the bleak autumn of 1970 requires, as this report shows, considerable resources of human effort, of professional skills, and of materials. The deployment of these resources requires a decision-making machinery, management, and money, as does the development of a new specialist department in a National Museum. The chapters which follow invite questions. How did it all happen? Many finds of remains of ancient boats have been made in many countries, but until recently they have usually been inadequately recorded and published. Why did the find made at Graveney get quite different treatment? Why did the study of the archaeology of the boat in Britain take a new turn with this particular discovery? What were the circumstances which made it all possible and how were the decisions taken?

The happy chain of circumstance is quite simple. The discovery of the boat by Mr Roy Botting led to an approach to the Royal Museum at Canterbury and the local Archaeological Society, and to consultation with the Department of Medieval and Later Antiquities at the British Museum. This department, heavily committed to the preparation of the report on the Sutton Hoo excavations,

was not able to take on the Graveney vessel, nor had the British Museum any long-term commitment to build up the study of the archaeology of the boat. On the other hand the Department had in its team some of the very few archaeologists in Britain with first-hand knowledge of the problems of recording ancient boat structures. Bearing in mind possible parallels between the Graveney find and the evidence for the structure of the Sutton Hoo vessel, the then Keeper of the Department, Dr Rupert Bruce-Mitford, made available the services of two members of his staff, Mrs Fenwick and Miss Evans, who were at the site from a very early stage.

At that time, the autumn of 1970, almost the only institution in Europe to devote substantial resources to the full-time study of boat archaeology was the National Museum of Denmark. It had been clear to me from my appointment to Greenwich three years before, that the time was rapidly approaching when a similar programme of study could and should be developed in Britain. The National Maritime Museum was clearly the appropriate institution to take this initiative and we had already decided to add a first archaeologist to the professional staff. By 1970 the planning and execution of the reconstruction and expansion of the Museum had reached the stage when, bearing in mind that the commitment would involve heavy investment of money and resources, recruitment and prolonged training of staff, it needed only the occasion to move from this decision in principle into action. I had just returned from a visit to Denmark where I had discussed these matters with Ole Crumlin Pedersen of the Danish National Museum, one of the two or three leading authorities in the world on the archaeology of the boat, when I heard from the late Paul Johnstone, Executive Producer of the BBC 'Chronicle' archaeological programmes, that the Graveney find had been made and was being excavated by the Canterbury Archaeological Society. A quick visit showed her to be a very likely candidate for the beginning of the National Maritime Museum's practical involvement with the new study. Mr Crumlin Pedersen responded immediately to a telephoned request to visit the site, and his expert opinion confirmed that a full-scale excavation and recovery would be justified. The members of the Canterbury Archaeological Society already working on the site agreed willingly that the National Maritime Museum should take the lead. There was at that time no element in the National Maritime Museum's vote for archaeological work and so the necessary funds were provided initially quickly and generously by the Trustees of the Caird Fund.

Dr Bruce-Mitford agreed to spare the services of other members of his staff, in addition to Mrs Fenwick and Miss Evans, to supply, as well as archaeological direction, conservation and practical excavation skills; the National Maritime Museum agreed to provide manpower, photographic recording, services of technicians to prepare recovered material for transport, finance and general management of the operation. The Cory Barge Works, and in particular its vigorous and resourceful General Manager, Mr Charles Blakey, of whose imaginative approach to problems we already had much experience, made the whole job possible by the speed and efficiency with which they provided the covering for the site, the duck boards from which the recording and extraction of the timbers were carried out, and the headquarters marquee. They also provided us with transport, tools, and many hundreds of feet of timber, and other materials. They constructed, in a week, at the request

of the Department of the Environment, a temporary plastic lined steel conservation tank, some 30 metres by 3 metres, on the site adjacent to the National Maritime Museum where the Archaeological Research Centre has since been built. As the urgency grew with every day, members of the administrative staff of the National Maritime Museum, as well as curatorial staff of many disciplines, volunteered to struggle in the mud, and were released from their normal duties to do so, and in the end thirty-five members of the staff took part in the recovery of the boat.

The boat was found on property of the Trustees of Lord Sondes and the problem of ownership had to be resolved at an early stage. Lord Sondes visited the site himself and agreed orally with me that the Museum should proceed with the recovery and conservation with a view to the eventual display to the public, of what was obtained from the excavation. In due course, however, it became clear that the situation was complicated by the position of the estate. The legal ownership of the timbers rested with the executors of the late Lord Sondes and, although most sympathetic to the Museum's wishes, they were not in a position to give away an asset which they held in trusteeship. The executors were, however, satisfied, after consultation, that an option given to the Museum to purchase the boat at a market price, less the cost of recovery and preservation, would be a proper discharge of their duty to realize the asset on the best possible terms.

An approach was made to the Estate Duty Office in an attempt to seek the acquisition of the boat by the Government as acceptance in part payment by the executors of Estate Duty, but unfortunately this proposal failed on the grounds that the late Lord Sondes was not aware that he possessed the boat, although it was an object of national, scientific, and historical interest. It remained therefore to establish a market value for the boat which would represent a fair realization by the Trustees of their unexpected asset.

In establishing the value of the remains, the then Director of the Science Museum, Sir David Follett, kindly acted as an impartial arbiter and, in negotiation with representatives of the Trustees of the estate, agreed the sum of £3,000 as being the fair market value of these important archaeological remains. The timber was therefore acquired by the National Maritime Museum for this sum.

Once the remains of the boat and associated material had been placed in the tank at Greenwich the problems of recording and publishing presented themselves. Recording required an archaeologist and a trained draughtsman with very considerable knowledge of boat structures to work together and with the photographers for many months. Mrs Fenwick was released from the British Museum and became an employee of the Trustees of the Caird Fund and was in turn seconded by them to the National Maritime Museum to perform the archaeologist's functions. We were extremely fortunate in obtaining the services of an outstanding authority on the development of boat structures, Commander Eric McKee, O.B.E., R.N., as the draughtsman, on similar terms. These two, together with Mr Christopher Gregson, Conservation Officer, constituted the Graveney Boat Unit. In due course other staff were recruited to begin to build up a new archaeological department. With the completion of the research and conservation facilities and a staff of eight or nine the organization is now known as the National Maritime Museum Archaeo-

logical Research Centre and is directed by the Chief Archaeologist, Dr Sean McGrail. Meanwhile Mrs Fenwick, appointed for the purpose as a Caird Research Fellow of the Museum, has completed the editing of this report.

There remains one major part of the Graveney research programme to complete and this is the construction of a replica of the vessel. While the recording of the structure of the Graveney boat herself has been going forward, a parallel study has been made of the problems of building copies of ancient boats. A full-size copy of the four-oared boat found in the Gokstad ship in Norway in 1880 has been built by Harold Kimber, a boat-builder of great experience, who entered the Museum's employ for the purpose. He was assisted by Sean McGrail, and worked in close association with the University Museum of National Antiquities in Oslo, who hold and display the original boat, and in particular with Mr Arne Emil Christensen, Jr, of that Museum, whose expertise in the field of Scandinavian Iron Age boat structures has been invaluable.

This copy has been subjected to comprehensive rowing trials under the supervision of Commander McKee and at the time of writing has just completed sailing trials. The building of the copy and the rowing trials have already been the subject of reports published by the Museum, and the experience gained has been an invaluable preparation for the much larger undertaking of building a full-sized copy of the Graveney vessel. Eric McKee's replica plans reproduced in this volume, and the alternative proposals made by Valerie Fenwick in Chapter 8 will form the basis of a research programme, in which different hypothetical reconstructions of the Graveney boat, all based on the surviving remains, will be investigated. These variants will be evaluated in a variety of ways before selecting the version considered to be closest to the original. It is then hoped to proceed to building a full-size replica, in the course of which a great deal more may be learned about the original boat, and as a result, the replica may be modified as building progresses. This is all part of the continuing research process.

A full-size model in fibre glass of the Graveney vessel as she was found will be on display in the new archaeological gallery of the National Maritime Museum from late 1978. In due course when the conservation process is complete it is hoped that the original material will be substituted for the model.

There remains one final comment. The vessel discovered at Graveney was a boat in the sense that she was almost certainly an undecked vessel, not capable of sustaining human life for long periods, even at a time when human life was more resistant to exposure than it now is. She was a ship in the sense that she was a big vessel for her time. Other ancient vessels of comparable size and structure have been described as ships in earlier archaeological reporting, notably those found at Skuldelev in Denmark and now on show to the public at Roskilde, which are roughly contemporary with the Graveney vessel. Valerie Fenwick has followed the Danish precedent in referring to the Graveney vessel as a ship. But most of those who have contributed to this volume have considered the term boat more appropriate, as do the Museum's Chief Archaeologist and his staff. My own view is perhaps novel — and I am not prepared to defend it too far — that the term 'ship' should be reserved for vessels dating after the revolution which appears to have taken place in the 1400s, when the edge-joined shell-constructed single-masted sailing boat in various forms gave

place to the non-edge-joined fully skeleton-built three-masted sailing ship. This technical revolution, about which very little is known, marked the birth of the sailing ship and is now the subject of full-time study at Greenwich.

June 1978

problem arises when there seems to be no word in current use for a particular feature, and the options are three:

1. to borrow a word from a foreign language;
2. to use an ancient term;
3. to coin a new word.

In this report the vocabulary used is principally that distilled by Cdr McKee for his study of British clinker-boat construction, Clenched Lap or Clinker. The Glossary contains additional terms, together with references to Old Norse and Old English equivalents. These are derived from Sandahl's Middle English Sea Terms and from Toller's Anglo-Saxon Dictionary. Kerchove's International Maritime Dictionary has also been consulted.

The attention which has subsequently been given to the recovered timber, the construction of a new building and plant in which to conserve it and now the setting up of a well-equipped Archaeological Research Centre at the National Maritime Museum tend to obscure the fact that Graveney was an improvised rescue-excavation. 'How did it happen?' people invariably ask, and perhaps what is written in this book makes too formal and official what was in fact a separate determination on the part of many people that this particular find should be saved. Some toiled on the site in the mud with a bonhomie such that, at the time of writing, the third Graveney reunion party is about to be held. Others, colleagues, wives and husbands, were off-stage, coping at home or at work so that the operation could continue smoothly.

In the final analysis the most important, the one irreplaceable person in the whole sequence of events was the finder. Without the Roy Bottings of this world the chance discoveries that are made continue to go unrecognized and unrecorded. Thereafter the pattern was one of official notification followed by individual participation and museum involvement. This ship was initially excavated by volunteers because it mattered enough to them to make the effort to get to a bitterly cold remote marsh and to work long hours in the bottom of a muddy ditch. It was saved because, to the museum professionals called in, it was important enough to be given top priority and more time and effort than official duties required.

There are many contributions to this report and collaboration with the authors, particularly Eric McKee, has been a stimulating experience. I am most grateful to Mrs Ann Morley for her work on the preparation of the texts for publication, and for spotting numerous inconsistencies. To the contributors specifically and to all those not mentioned in this book by name, who have helped the Graveney project thus far, I would like here to say 'Thank you'.

Valerie Fenwick, March 1977

## INTRODUCTION

Graveney is described variously as a boat or a ship: boat out of habit (she was affectionately dubbed 'the Gravy Boat'); ship from study of her construction and seagoing role. This study has shown that she was a merchant-man, in size and function comparable with other ancient finds termed ships by their excavators, for instance: Gelidonya; Kyrenia; Blackfriars I; Skuldelev 3; Kalmar I.

This report shows that Graveney was originally about 14 m long with a beam of 3.9 m. She seems to have been designed to carry a heavy cargo, such as stone. A conservative reconstruction gives her a capacity of seven tons. Residues of hop plants and unfinished millstones found on board point to sailings across the North Sea; perhaps up the Rhine, or to an entrepôt, such as Haithabu in Schleswig-Holstein. Radiocarbon and dendrochronological study of the oak from which she was built can probably provide a date for her construction of A.D. 927 ± 2. At some point in her career the keel was badly cracked and had to be repaired. She was finally abandoned more than 1 km from the sea beside a creek where she had been beached on an improvised 'hard' of sticks dated by radiocarbon to c. 947.

In 10th-century England she would undoubtedly have been given the generic term skip or scyp. In Scandinavian usage skip was the general term for an independent vessel, batr being a ship's boat. Graveney would have been in the category kaupskip, 'trade vessel'. The Anglo-Saxons spoke of both a sea-going and a river craft as a scyp, using bat to describe a small undecked vessel. The specific contemporary name for the Graveney ship-type is not known.

Precise terminology is an essential tool for any discipline; its absence in nautical archaeology is a reflection on the infancy of the subject. Until recently, the men who built boats with such a sure eye did so without the use of plans and measured drawings. The terms they used were not written down, and thus a variety of names for the same thing and of spelling and pronunciation of the same word can be found in different parts of the country. Standardizing the vocabulary is no easy matter, for many distinct boatbuilding traditions have evolved and the construction of even small vessels is complex and varied. Simplification can cause confusion if terms derived from one tradition are applied to vessels constructed in a different way — the use of the word 'carvel' to describe Greek and Roman edge-joined planking is an obvious instance.

The nautical archaeologist writes about an ancient hull with some difficulty. Intent on informing colleagues with a minimum use of technical words (tolerated in other disciplines but liable to be dismissed as jargon in his), he is aware that his terminology may prove to be inappropriate to the boat-building traditions which he is trying to identify. Worse still, it may contain wrong implications with regard to the function or construction of parts of the hull. An additional

## CHAPTER 1: DISCOVERY, EXCAVATION AND RECOVERY OF THE REMAINS

### PART 1. DISCOVERY AND EXCAVATION, PHASE I

by Frank Jenkins, Canterbury Archaeological Society

In September 1970 an improved drainage scheme for Graveney Marshes (Kent) was nearing completion. This project, for which the Kent River Authority was responsible, included the deepening and widening of Hammond Drain, which followed the line of a stream forming part of a much earlier drainage pattern (Fig. 1.1.1). During this work the driver of a mechanical excavator, Mr Roy Botting, noticed that his machine had encountered an obstruction at a low level and with commendable foresight stopped work and investigated the cause. He found that a large timber had been shifted out of position (Fig. 1.1.2), whereupon he reported the discovery to the site engineer in charge of the project who in turn informed his headquarters at Maidstone. Within a few hours Miss Louise Millard, Curator of the Royal Museum at Canterbury, was notified of the find with a view to it being further investigated.

On the following Saturday, September 26, I visited the site (in the parish of Seasalter, NE. of the village of Graveney, N.G.R. TR065638) with Miss Millard and Mr Cecil Hogarth. After preliminary examination it was realized that part of a boat had been uncovered and that, as much of it still lay in the side of the widened channel beneath more than 2 m of marsh clay, it must be of considerable antiquity. Mr Peter Marsden, then the of the Guildhall museum, was informed and recommended total excavation. The following Monday permission was granted by the Kent River Authority for the work to proceed as an archaeological rescue project with their full co-operation. A volunteer task force was assembled consisting of members of the Canterbury Archaeological Society, the Ashford Archaeological Society, Chatham House School, Ramsgate, Archaeological Society, and the University of Kent. The excavation was carried out under the joint supervision of Miss Millard and the writer.<sup>1</sup>

The Authority proposed to flood the new channel in about two weeks when it was expected to be completed. In view of this time limit we decided to remove the overburden of marsh clay with a mechanical excavator. When approximately the 2 m level was reached, controlled archaeological excavation took over. Removal of the marsh clay was difficult because of its sticky, heavy character, but eventually the tops of the surviving uppermost strakes on each side of the boat and the sternpost were revealed to establish the full surviving length.

The next process was to remove the filling of marsh clay which had drifted into the boat. This showed no signs of stratification until at c. 0.1

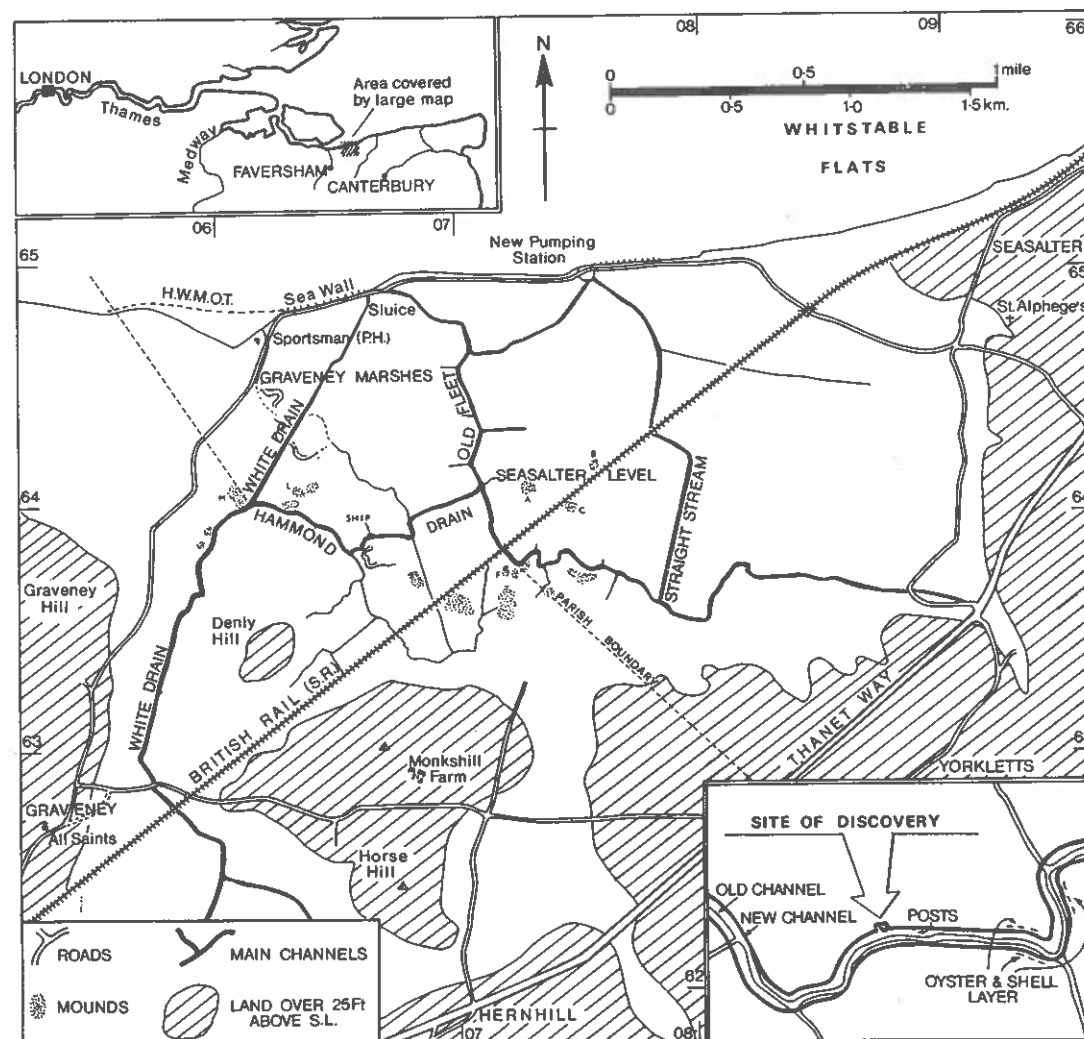


Fig. 1.1.1 Map to show location of the boat found on Graveney Marshes, Kent. Drawn by Eric Eden © V.H. Fenwick

to 0.15 m above the keel it became much darker and had a somewhat gritty texture. This primary deposit was removed in two stages from top to bottom and in two sections to the port and starboard respectively of a central line along the length of the hull. Unlike the marsh clay above it, which was archaeologically sterile, this primary deposit yielded an assemblage of objects, including animal bones, fragments of lava and of Roman tiles, pieces of Kentish ragstone with mortar adhering, and several beach pebbles. A rim sherd of grey pottery was found aft of frame R8.<sup>2</sup> A few fragments evidently from the same pot were resting on the keel between frames R9 and 10 and were sealed by the primary deposit. It is noteworthy that the edges of these sherds were not abraded as would be likely had they been subjected to movement in the water for a long time. This suggests that they were already in the boat before the primary deposit drifted in to cover and protect them. Their origin is obscure, for no more were found in the area around the boat.<sup>3</sup>

The accumulation of marsh clay, which had built up around the boat after it had been abandoned, proved extremely difficult to excavate. When the clay was finally removed, it was seen that the boat was supported by substantial pointed stakes driven into the ground at intervals along both sides, and that it rested on a single layer of sticks. It is virtually certain that these sticks had been deliberately placed, presumably to counteract suction of the mud under the hull, and did not represent debris which had drifted in on the tidal flow to be trapped in that position as the vessel settled down. Eventually more pieces of Roman tile, pebbles, Kentish ragstone and mortar were found under strakes 6 and 7 on the port side. When the boat was first uncovered the 'painter' attached to the sternpost appeared to be intact (Fig. 1.1.3), but, although it was provided with a protective cover, an unauthorised person visited the site during our absence, and, judging by the deep imprint of a large boot, in getting down into the boat had jumped on to the place where the rope lay and had cracked it into several pieces. An interim plan of the boat was made and expert opinion was sought on the fully uncovered vessel. As a result a large-scale operation was undertaken to plan and record the boat *in situ*, to examine the organic material in its immediate vicinity, and finally to dismantle it expertly and take it to the National Maritime Museum, where a special unit was speedily set up to study and conserve the vessel. At this stage the team of amateur archaeologists gladly relinquished its responsibilities in the knowledge that it had been instrumental in preserving this unique vessel for posterity.

#### NOTES

1. I wish to thank the Kent River Authority for help and co-operation at all stages of the investigation and for the loan of a mechanical excavator; and all those who assisted in the excavation (C. Hogarth, F. Wall, N. MacPherson-Grant, J. Bradshaw, A. Bruce, D. Harrington, and members of the societies mentioned above). It was due to their enthusiastic efforts that the work was brought to a successful conclusion in conditions which at times were not ideal for comfort. Finally the expenses of the excavation team were covered by a grant from the Department of the Environment.

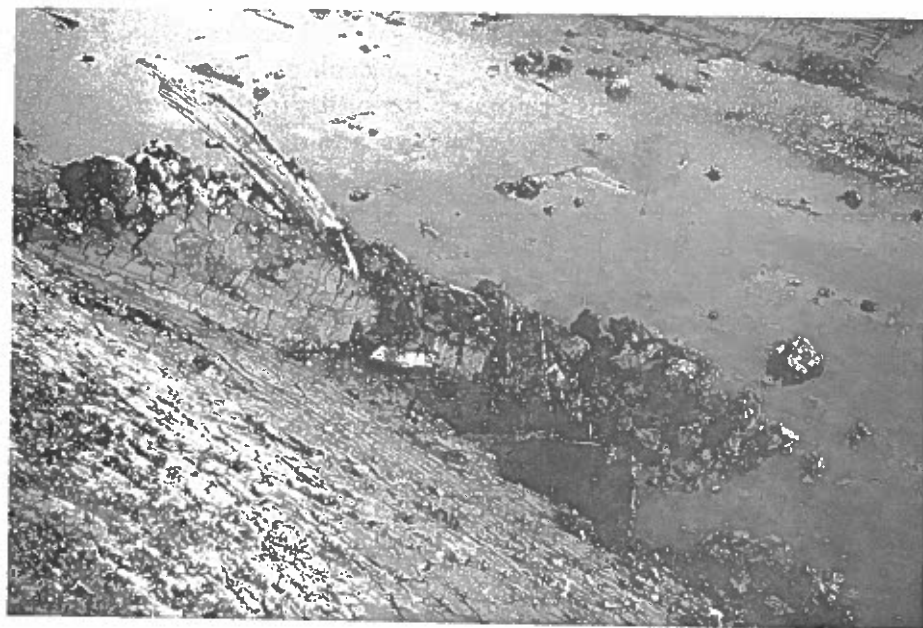


Fig. 1.1.2 View of Hammond Drain on Sept. 26, 1970, showing frame R9, dislodged by the mechanical excavator, and the broken starboard extremity of the boat  
© Frank Jenkins

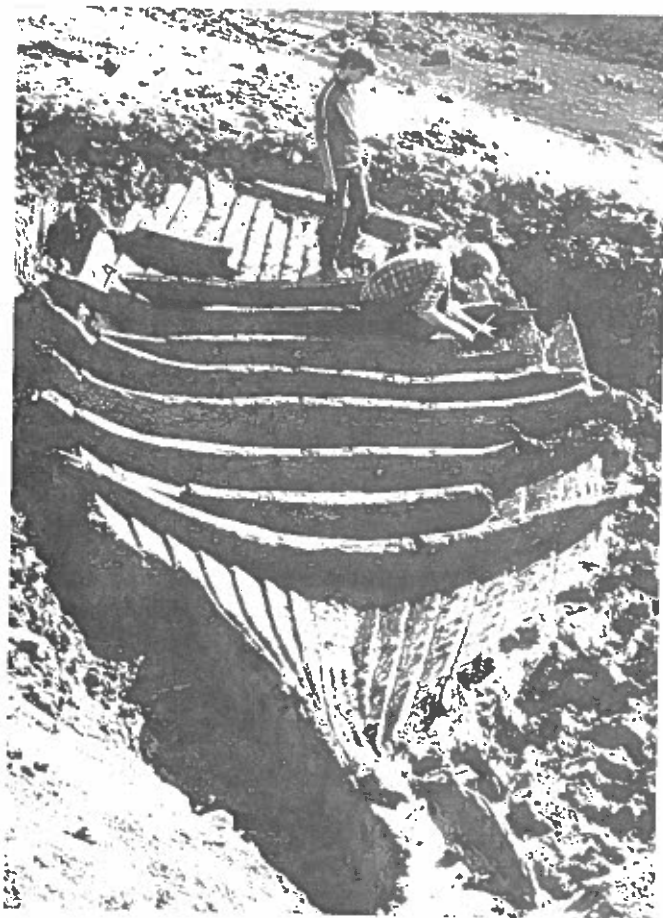


Fig. 1.1.3 The boat was excavated by local archaeologists, including school-children. Note the rope attached to the sternpost (foreground right).  
© Frank Jenkins

2. For glossary of nautical terms see pp. 331-9.
3. Pottery identified as local Roman by the writer, but see chap. 4.3.

CHAPTER 1: DISCOVERY, EXCAVATION AND RECOVERY  
OF THE REMAINS

PART 2. EXCAVATION, PHASE II,

by Angela Evans, Department of Medieval and Later  
Antiquities, British Museum,  
and Valerie Fenwick, then Department of Medieval and Later  
Antiquities, British Museum, and subsequently  
Caird Research Fellow, National Maritime Museum

The first phase of the rescue excavation had taken a fortnight. The inception of the second phase<sup>1</sup> took place in the Royal Museum, Canterbury. It was decided to record the vessel in as much detail as possible between October 17 and 19 and then if possible to dismantle it, lifting each separate timber out of the channel and sealing it in heavy-duty polythene in the manner adopted for the Skuldelev ships (Olsen and Crumlin-Pedersen, 1967).<sup>2</sup> Funds and help were promised by individuals and organizations.<sup>3</sup> Dr Rupert Bruce-Mitford, then Keeper of the Department of Medieval and Later Antiquities in the British Museum, placed the authors' reports before the Ancient Monuments Board on October 16 with a view to obtaining an interim preservation order on the posts and sticks around and beneath the hull (Fig. 1.2.9), which could have possibly represented the remains of a harbour installation, and as such would have qualified for an order, whereas an ancient wreck would not. He officially requested the assistance of the British Museum Research Laboratory and Mr Andrew Oddy was asked to advise on conservation. Mr Basil Greenhill, Director of the National Maritime Museum, visited the site and indicated that the museum was interested in acquiring the vessel for exhibition and would therefore finance its recovery and provide staff and facilities for its excavation. At a meeting on the site convened by Dr Bruce-Mitford the joint recovery operation by the two museums was planned.<sup>4</sup> The writers were given the task of directing the work, and Dr Alan McGowan of the National Maritime Museum organized the necessary manpower and equipment from Greenwich, whilst the presence of Mr Greenhill on site throughout most of the recovery meant that any need for extra manpower or equipment was met immediately, thus allowing the writers to concentrate wholly on excavation.

In a rescue excavation of this kind priorities were not immediately obvious, but soil samples were obtained before the site was completely churned up, and a small vertical section was cut over the tip of the 'painter' (by then the only part of the ship with overburden). With the help of Mr Roy Botting the area around the sternpost was enlarged and a sloping path was made down the steep side of the newly cut bank before the main work-force arrived. At this stage loose material lying on top of the bank was sorted; wood was put into improvised containers and material from in and around the vessel was bagged in polythene (Fig. 1.2.1).

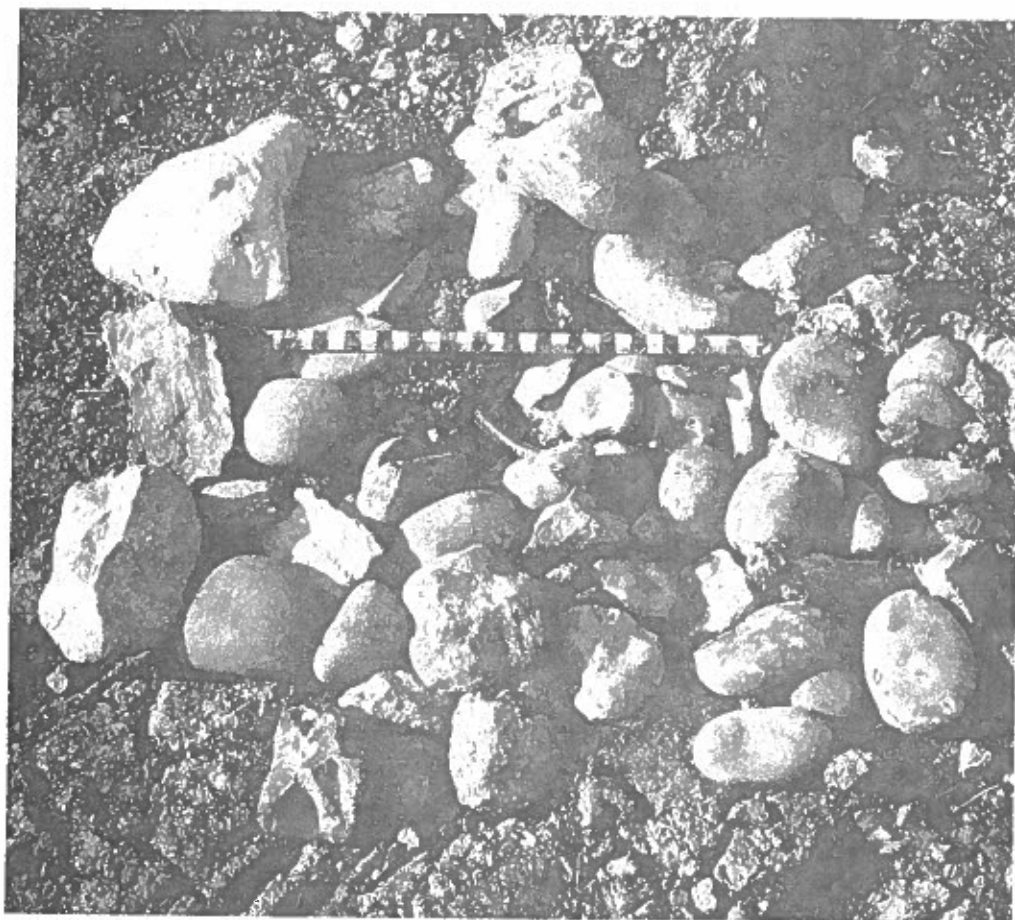


Fig. 1.2.1 Material from in and around the hull consisting mainly of beach pebbles and fragments of Kentish ragstone. Scale in cm  
© National Maritime Museum



Fig. 1.2.2 To prevent waterlogged wood from drying out, water from the bottom of the channel was circulated with a sludge pump.  
© V. H. Fenwick

As the ship had to be uncovered during recording it was very important to keep the wood as wet as possible. At this time the site could not be reached by vehicles, so that in the absence of any alternative supply, water, which had collected in puddles and in a sump dug in the bottom of the channel, was circulated with a sludge pump (Fig. 1.2.2). Making a measured drawing on site had to be abandoned because of the difficult conditions and the need for speed. Instead, as described on p. 25, some 700 measurements were taken, using plumb-line and measuring tape and standing inside the ship. These were noted in diagrammatic form, so that a measured drawing could be made later. (Fig. 1.2.4). Waterproof copies of Miss Millard's sketch plan were made on which to record specific aspects. The bottom of the channel around the ship soon became a treacherous morass. Duck-boards were laid around the hull and these also provided a foundation for scaffolding to support an awning,<sup>5</sup> which was so expertly erected that measuring could continue uninterrupted.

As soon as this measuring was finished, the inside of the ship, which was now covered by a fine gritty sludge from the recirculated water, was cleaned again, so that a detailed photographic record could be made. Foam plastic mats were used when it was necessary to stand on the planking. The awning, which had been erected over the vessel for the moulding process, made photography difficult, although planks could be suspended from the scaffolding above the hull. These reduced the need to walk on the planking and the first vertical photographs could be taken.<sup>7</sup>

The frames were the first part of the ship to be removed. At this stage a plaster of Paris mould (chap. 1.3) was made of the inside of the shell before any strakes were lifted. Such was the speed at which the British Museum plastering team worked that those removing the frames only just managed to stay ahead of them. Before each frame was removed silicon bronze pins were gently knocked into the strakes on each side of each frame (approximately 5 to 10 mm clear of it to prevent incidental damage) to mark the extent of the lands. There was a risk of damaging the planking if the frames were merely prized loose. Therefore, a sharp scraper and mallet were used to slice through each trenail at the junction between frame and strake. The frames were then tilted sideways for photographs of the faying surfaces (Figs. 1.2.5) and were then removed on supports. Loose fragments of trenails were given frame and strake numbers to enable them to be relocated. The small amount of debris under each frame was scraped up for laboratory examination.

Once the plaster of Paris mould had been removed, the runs of the lands were in turn marked with silicon bronze pins as 'matching marks', before the work of dismantling began (p. 19). Other features were planned diagrammatically and numbered as they occurred (Fig. 1.2.4). As the plank-joins, for instance, were sometimes invisible until the strakes were actually being dismantled, the plank-join numbers occur at random (p. 97). When each section or fragment of planking reached the top of the bank, it was photographed with a scale and corresponding codes lying alongside. (Fig. 1.2.3). In the last stages of the operation the supply of letters was being lost in the deep sticky mud and improvised tickets had to be made. The appearance of the detached planks at this stage shows how impossible any detailed field recording was in the absence of running water.

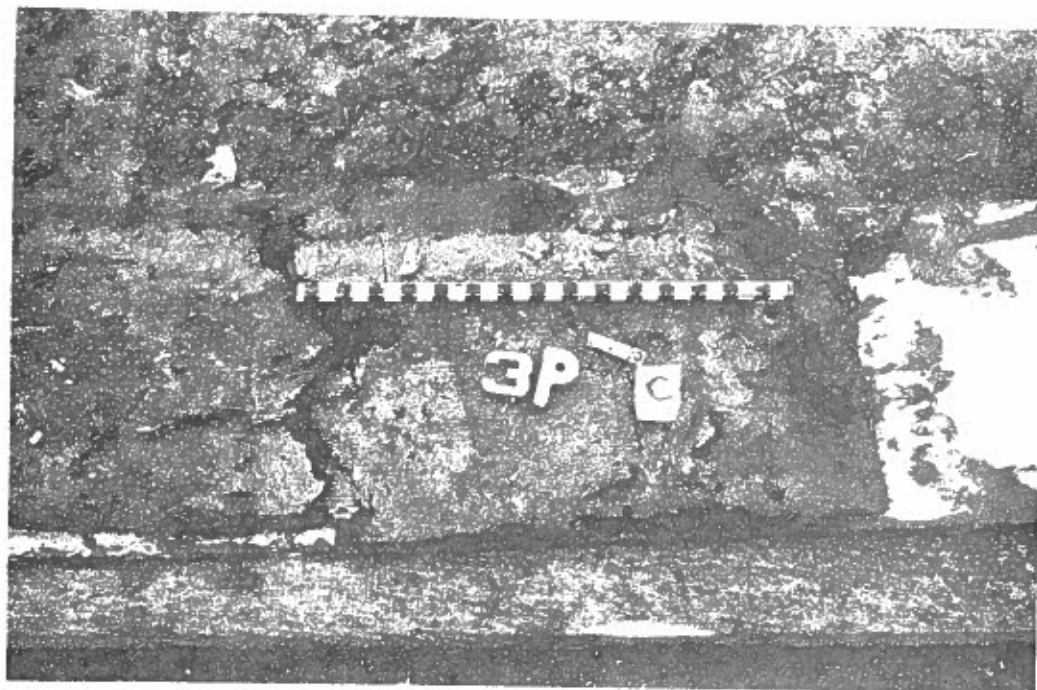


Fig. 1.2.3 Fragment C of the third strake port showing its relationship with fragment B. Note the felt of wool on the scarf near the right-hand end of the scale. Photographs of lettered and numbered fragments with scales made reassembly possible. Scale in cm  
© National Maritime Museum



Fig. 1.2.4 Diagrams on washable plastic film supplemented photographs  
© National Maritime Museum

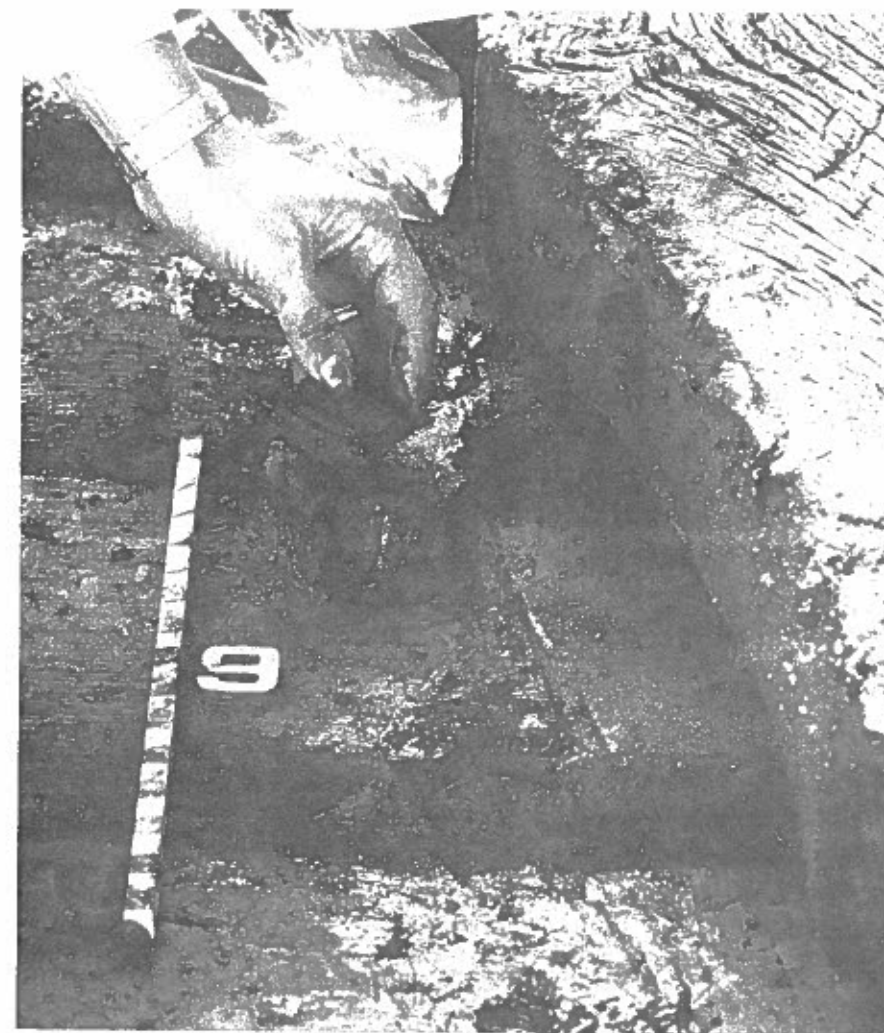


Fig. 1.2.5 After severing the trenails at the junction of frame and planking, the loose fragments were recovered and given a coded identity. Scale in cm  
© National Maritime Museum



Fig. 1.2.6 Three-strand rope, Gr15 (0.14 m long) from beneath port side. After impregnation with polyethylene glycol it was strong enough to handle. The structure of vegetable fibres was too incoherent for identification  
© National Maritime Museum

After strake 5 port had been removed the port side of the sternpost was excavated, so that an outboard view could be obtained of some of the hood-ends in position (Fig. 8.27). Unfortunately it was not possible to photograph the relationship of the sternpost to the keel, because, as earlier site photographs show, the keel had been damaged in antiquity (Fig. 8.16).

The strakes were undercut by hand and not with trowels for two reasons: to prevent the planks from being scratched, and to make it possible to feel anything in the mud that might otherwise have been missed. It was in this way that several fragments of rope (Gr 16) were discovered beneath the port side, although they were incoherent when recovered. A determined attempt was made to save another fragment and, as a result of Miss Pye's splinting and bandaging, a short length of three-strand rope was recovered (Fig. 1.2.6). The sticky mud made it impossible to see all the material which lay underneath the ship. It appeared to consist mostly of mussel shells adhering to its bottom, and of sticks lying obliquely, mainly in a single layer. Samples of this material were taken (Fig. 1.2.7).

The keel, the last and largest component of the ship, was raised on October 28, the penultimate day. The deep trenches which had to be dug on both sides of it provided an opportunity to take a sample of the clay below it and also to look for any sign, for instance, of a lower peat horizon. On the last day the sides of the recut banks were examined carefully; the only horizon found, which was a ferruginous pan and a single layer of shells, c. 100 m downstream of the ship, was sampled and sectioned, (chap. 5.3). In the bottom of the channel, c. 33 m downstream of the ship, the points of six posts were lying where they had been dislodged by the mechanical excavator (Fig. 1.1.1). They were plotted and photographed and the two least shrunken and torn specimens were recovered.

On the next day the channel was flooded as the final clearing up was in progress; the recovery operation had been completed in exactly thirteen days.<sup>8</sup>

#### NOTES

1. By Mr Peter Marsden and the writers, together with Mr Frank Jenkins and Miss Louise Millard.
2. For key to shortened references see list at end of each section.
3. Including the Canterbury Archaeological Society, the (then) Ministry of Public Building and Works, who gave permission for £80 of the Canterbury excavation grant to be diverted for purchase of materials; B.B.C. Chronicle (Fig. 1.2.8), who undertook to hire a lorry to transport the lifted sections; and the Port of London Authority, who offered to make available a room in their Cutler Street warehouse for cold water storage of the sections.
4. Dr Bruce-Mitford released members of the Sutton Hoo research team and other departmental staff as required in particular Mr Peter van Geersdaele, Mr Nigel Williams and Miss Elizabeth Pye.

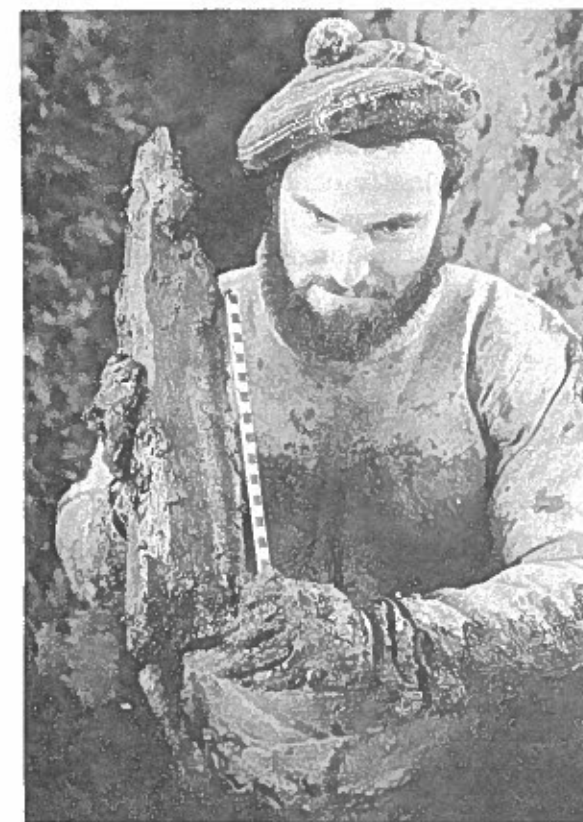


Fig. 1.2.7 Point of post 1 recovered from mud below the hull. Absence of a water supply made measured drawing on site impossible. Scale in cm  
© National Maritime Museum

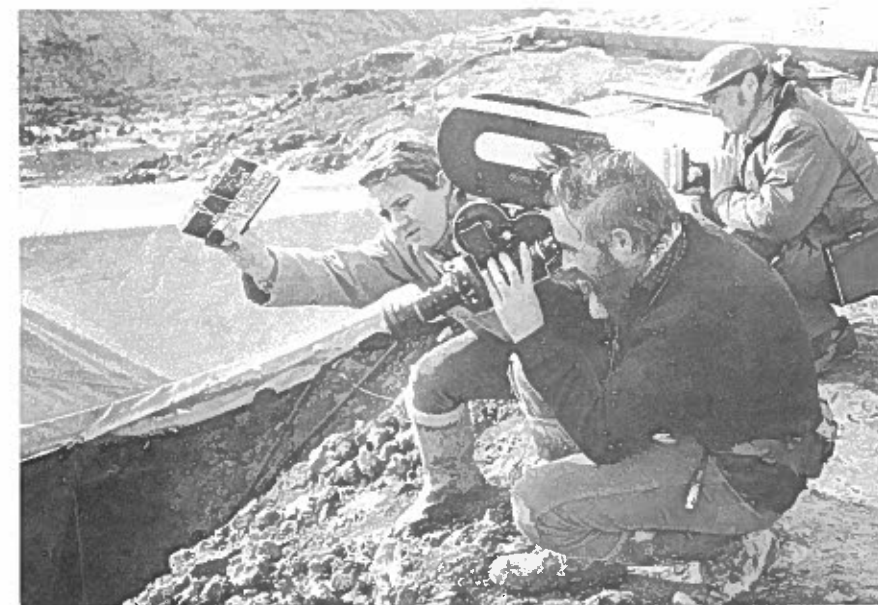


Fig. 1.2.8 The colour-film made by the B.B.C. 'Chronicle' team was a valuable record of the rescue operation. Paul Johnstone is on the right.  
© National Maritime Museum

5. By the Cory Barge Works of Charlton, working under contract to the National Maritime Museum.
6. By Mr Brian Tremain and Mr Barrie Cash of the National Maritime Museum photographic section.
7. The photo-recording system used was that already devised (Fenwick, 1972b). Thin washable plastic centimetre rods were included in each photograph; for vertical photographs one was placed on the nearest part of the hull and a second in the bottom of the ship. Plastic letters and numbers identified the subject of each photograph by a simple code; they were sprayed beige to enable them to be seen against the waterlogged wood without 'glare'. The system was a substitute for note-books which could not be used in the conditions. The code was carefully dictated, since it was vital that no variation should creep in and that it should be intelligible to the writers at least, once decoding started. The code used in the photographs was also transferred to embossed plastic tape. Taped labels were attached by bronze gripfast pins to each fragment or section as it was detached, so that no identities should be lost.
8. We should like to make the following acknowledgments: to all the staff of the National Maritime Museum, who so patiently carried out instructions to the letter; to Mr Jim Lees, whose devotion to the ship exceeded all, since he spent every night on the site guarding her; to Mrs Arthur Waite for her hospitality; to Mr Philip Annis and his team for removal work; to Miss Elizabeth Pye for saving samples for laboratory examination; and to Mr Roy Botting for his assistance with the mechanical excavator and with information.

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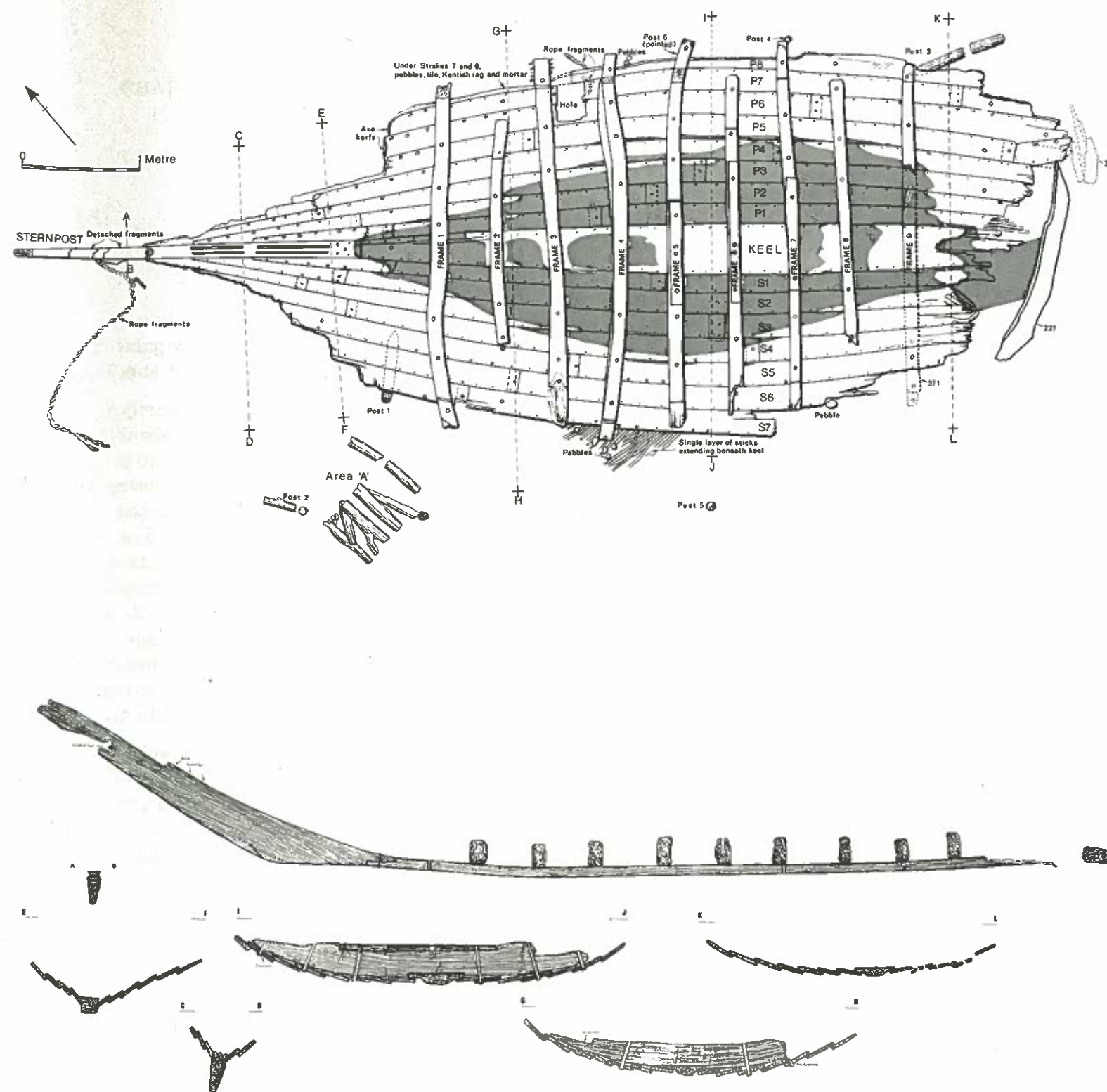


Fig. 1.2.9

Site-plan and sections of the ship *in situ*. Drawn by Eric Eden and V. H. Fenwick  
© V. H. Fenwick

## CHAPTER 1: DISCOVERY, EXCAVATION AND RECOVERY OF THE REMAINS

### PART 3. LIFTING AND REMOVAL

by W. A. Oddy, Principal Scientific Officer,  
Research Laboratory, British Museum,

and P. C. van Geersdaele,  
formerly of Department of Medieval and Later Antiquities,  
British Museum

When the excavation of the boat had proceeded to the stage where the remaining wood was fully exposed and drawing was in progress, a decision<sup>1</sup> was made to lift and conserve it.

In principle there were two possible solutions to the problem of lifting: 1, to insert a cradle under the boat and to use a crane to remove it from the mud in one piece; 2, to dismantle the boat and remove each frame and strake separately. The first alternative was precluded by the distance from the road and the general inaccessibility of the site to wheeled vehicles and it was therefore decided to dismantle the boat. There was one further problem: as the strakes were very soft they were likely to lose their shape as they were lifted because there was not enough time to make individual formers to the exact shape of each plank as it lay in the mud. The three-dimensional shape of the boat had been well documented by measurements, but it was decided as a further precaution that the shape should be recorded by making a mould in plaster of Paris. This would ensure that the strakes could be reshaped exactly after conservation was completed.

The frames were all sufficiently robust to be lifted without serious risk of deformation; they were therefore separated from the strakes by cutting the trenails at this point and then rocked from side to side to release them from the suction of the mud which had filled the small space between the hull and the under sides of the frames. They were removed one at a time, starting at the stern and proceeding towards the missing bow. Each frame was lifted on to a wooden plank and carried to the top of the bank, where it was photographed and then wrapped in a sheet of wet plastic foam and sealed inside a length of wide polythene sleeving. This packaging kept the wood in its waterlogged condition until it could be immersed in a storage tank containing water with an added fungicide. After the removal of all the frames the remains consisted of the keel and sternpost with the strakes on either side, which were supported by the mud underneath (Fig. 1.3.1). The strakes had originally been fastened together where they overlapped by iron rivets which had corroded away.

The next stage was to make the plaster of Paris mould; this was complicated by the continual spraying to which the timber was subjected to prevent it drying out. As it would have been impossible to mould the hull in a single section, it was necessary to plan a 'piece mould', consisting of nineteen sections of plaster, each of which measured between  $\frac{1}{2}$  and 1 sq m (Fig. 1.3.2).

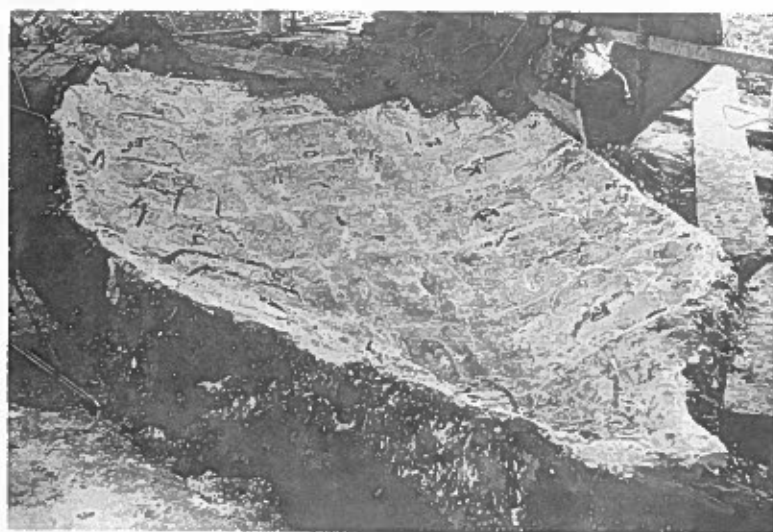


Fig. 1.3.1 Shell of the boat after the removal of frames: the strakes were undercut by hand.

© National Maritime Museum



Fig. 1.3.2 Plaster mould of the inside of the planking before removal

© A. Oddy

Starting at the stern a wall of modelling clay, 50 mm high, was built round a suitable area to retain the wet plaster. Within this area any under-cuts, such as gaps between planks, were filled with more modelling clay to prevent the plaster being keyed on to the hull. Sheets of paper towelling were laid on top of the strakes to prevent the plaster from adhering to it. They absorbed water from the wood and were dabbed with paint brushes to bring them into intimate contact with the wood. Plaster of Paris, mixed to a creamy consistency, was applied to the prepared area to a thickness of c. 25 mm, increasing to c. 50 mm round the edges. As an added precaution plasterers' scrim was used to reinforce the mould and lengths of 12 mm metal piping were embedded in the plaster round the edges. Finally two lifting handles were added. When the plaster had partially hardened, the clay retaining walls were removed and the edges of the mould which would abut other sections were smoothed off at an angle of between  $50^{\circ}$  and  $60^{\circ}$  to facilitate eventual separation of the different pieces of the mould. When the mould had dried these edges were treated with soft soap solution and petroleum jelly to act as release agents.

This moulding operation was repeated nineteen times so that the hull was completely covered, each section abutting one or more of those already in position. All the sections were numbered and plotted in three dimensions, so that the mould could be re-assembled at a later stage (pp. 311, 314), and were then lifted in the reverse order to that in which they were made (Fig. 1.3.3).

After the plaster mould had been removed, spraying of the hull with water was re-started and the strakes were lifted one at a time. The exact length of wood to be lifted in each operation was determined by the position of joints or breaks. A sheet of plywood, 5 mm thick, was cut to the approximate length of the section of the strake, and the mud below the strake was dug away carefully by hand. At the moment when the part of the strake was about to come away from that next to it, the plywood was inserted underneath and used to lift the wet timber on to a scaffolding plank, upon which the curvature was maintained by chocking up the plywood with blocks of wood (Fig. 1.3.4). The strakes were recorded photographically and then packed, like the frames, in wet plastic foam and polythene sleeving. Specially made crates were used to transport them in a lorry lined with plastic foam to the storage tank in the National Maritime Museum. These crates were not unpacked but were loaded into the tank as they had left the site, although slits were cut in the polythene to allow circulation of water. The crates were so buoyant that they had to be wedged under water. All trenails and small fragments of strakes were packed separately in polythene bags.

The final task of the rescue operation was to lift the keel, which was the largest of the existing timbers. The sternpost had already been removed and treated like the frames, as it was strong enough to support its own weight. However, the length of the plank-keel in relation to its cross-section necessitated a more careful procedure. A framework of the same shape but a little larger than the keel was constructed of timber, 100 by 50 mm, and covered on one side with 5 mm plywood. The top of the keel was padded with thick pieces of plastic foam and the framework laid on top, plywood side down. Meanwhile trenches about 1 m deep were dug along both sides of the keel, and the



Fig. 1.3.3 Plaster mould being lifted from the planking in small manageable sections  
© A. Oddy



Fig. 1.3.4 Each plank was slid on to a plywood support for removal; blocks of wood maintained curvature.  
© National Maritime Museum

framework was fastened to the keel with strips of canvas webbing and plastic foam padding, which were tied round both the keel and the framework by tunnelling through the wall of mud supporting the keel. These fastenings were positioned along the keel at intervals of c. 0.5m. The suction of the mud on its lower side was so great that it was impossible to lift the keel assembly directly; it had to be rolled off the supporting wall of mud and lifted out of the trench in one smooth (more or less) movement. It was packed in wet plastic foam and sheets of polythene in the usual way for its journey to the storage tank.

The process of removing the frames, making and lifting the plaster mould and lifting and packing the strakes and keel took seven days. This exceptional speed was necessary because of the imminent flooding of the Hammond Drain; it was made possible by the large number of staff available from the British Museum and the National Maritime Museum. Further details of the recovery and plaster moulding operations are to be found elsewhere (Oddy, 1972; Oddy and van Geersdaele, 1972; van Geersdaele, 1975a).

#### NOTE

1. By the Director of the National Maritime Museum with the agreement of the landowner, Lord Sondes.

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## CHAPTER 2: RECORDING

### PART 1. PREPARING A MEASURED DRAWING OF THE BOAT IN SITU

by Peter Marsden, then Guildhall, Museum, London

The purpose of preparing measured drawings of the Graveney boat in situ was to have an accurate factual record to scale of its form and extent before it was disturbed, and before any attempt had been made to reconstruct its missing parts and to 'correct' any distortions. For the sake of completeness this record needed to include a plan of the vessel as well as longitudinal and transverse sections (Fig. 2.1.1). Later, after the vessel had been dismantled, another and quite separate series of drawings of the timbers was prepared which show the construction in great detail; it was then possible to use the outline drawings of the boat in situ as the basis for a detailed series of drawings of the vessel as it was found (Fig. 2.1.2).

A number of alternative methods of recording boats still in situ has been developed, based either upon direct measurement of the craft as it is uncovered on site (e.g. van der Heide, 1955:42) or upon photogrammetry (e.g. Olsen and Crumlin-Pedersen, 1967:86-88). The method chosen depends usually upon site conditions, limitations of finance, length of time available to complete the site investigation, and immediate availability of equipment. For a variety of reasons, particularly because of the limitations of time and equipment, it was necessary to use a direct-measuring method of recording the Graveney boat, the technique being a development of that used to record the ship of the Roman period discovered at Blackfriars in the City of London in 1962 (Marsden, 1967).

Where time for archaeological work is severely restricted there are disadvantages in using both the photogrammetric and direct-measurement methods of recording. The success of the photogrammetric record cannot be checked at the time, and if there is a failure on the part of the procedure this can cause subsequent difficulties in plotting the vessel in adequate detail (Olsen and Crumlin-Pedersen, 1967:86). In addition photogrammetry requires considerable cleaning of the timbers which is not always possible in an emergency. It may also not allow enough time after cleaning and photography for a detailed study of the boat in situ before it is dismantled. On the other hand its speed and its ability to be used for plotting the form of the vessel accurately and to scale at any time in the future make photogrammetric recording extremely valuable.

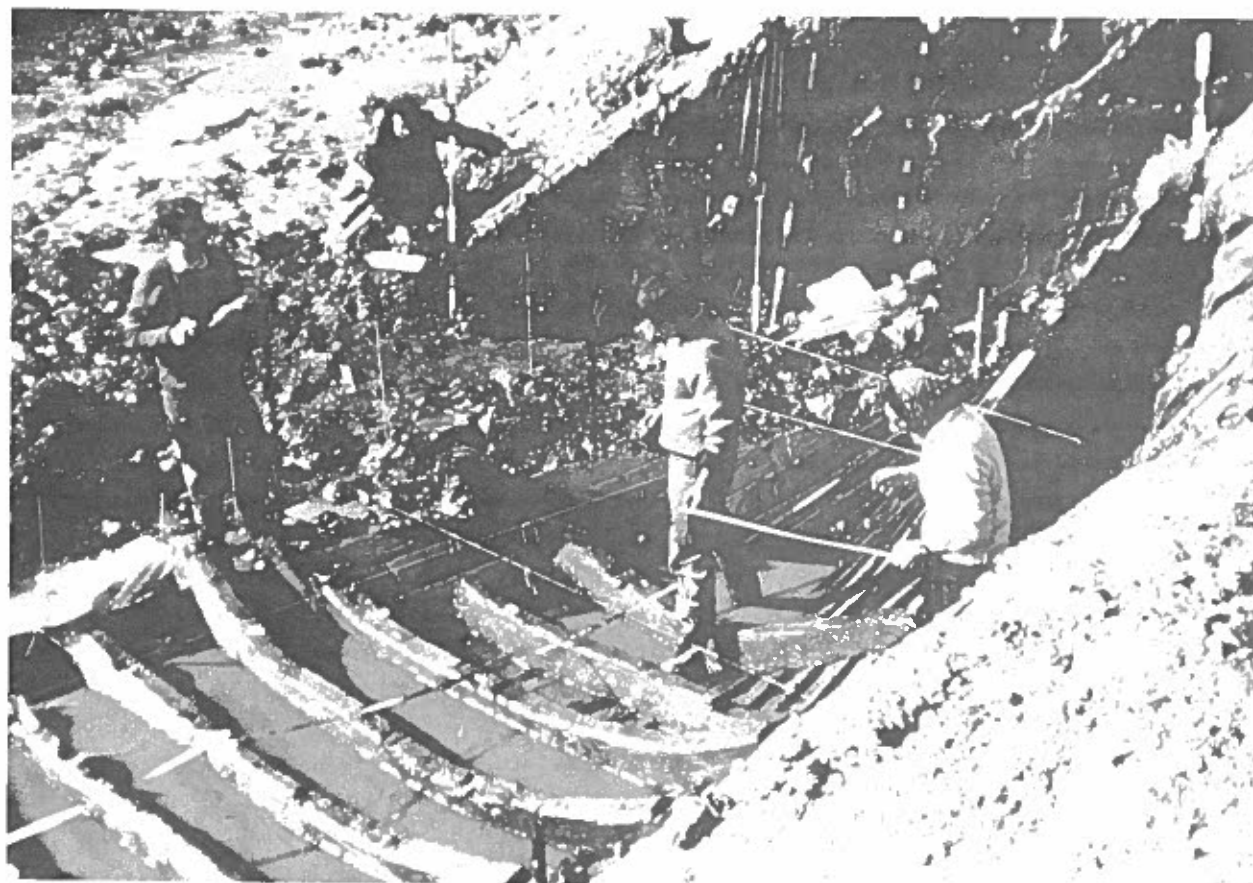


Fig. 2.1.1 Recording the boat in situ  
© P. R. V. Marsden

The main disadvantage of direct-measurement recording in an emergency is that it takes considerably longer than photogrammetric recording. For the Graveney boat it took two days and involved 700 measurements. Even when planks can be set up over the vessel as a platform from which to take measurements, it is almost impossible not to damage the soft timbers of the boat by treading on them. On the other hand drawing the vessel by direct measurement gives a valuable opportunity for a detailed assessment of its form and construction while in situ.

There is no single correct way of recording an ancient vessel in situ, but it is essential that it is recorded accurately, in sufficient detail, and at a large enough scale (at least 1:10) to be a clear statement of its form and construction. Whichever method is used, it must not be seen in isolation, but as a part of a standardized boat-recording process which includes a comprehensive photographic survey and detailed recording after the recovery of the remains.

#### EQUIPMENT

The equipment used was very hurriedly brought together and included: a large roll of nylon string for the horizontal datum-lines from which the timbers were measured; many brass or iron nails, about 2 cm long to mark significant places in the boat; a hammer, a plumb-bob and a pair of scissors; a notebook and pencils; a 30 m measuring tape; several 3 m steel measuring tapes; a line spirit-level; several rigid metal or timber posts to which the ends of the datum-lines were tied. In view of the wet and muddy nature of the site the measuring tapes easily became jammed, and several spare tapes were kept for emergencies.

#### METHOD OF RECORDING

The first step was to establish one longitudinal and several transverse horizontal datum-lines over the boat from which to take measurements, the positions of these lines being so arranged as to record the changing form of the hull. At the ends of each line a post was firmly driven into the clay beside the vessel, and the nylon string which was tightly tied to each post was made horizontal by using the spirit-level. The longitudinal datum-line was used as the general datum-line of the boat, the levels of the transverse datum-lines each being measured in relation to this at the points where they crossed beneath the longitudinal line. In addition the positions of the transverse lines were triangulated from the longitudinal line.

The actual measuring and recording process was simple. A sketched profile below each transverse line was made in the notebook, and vertical measurements were taken from the line to the features to be recorded, usually the edge where the strakes overlapped. Making sure that the measurements were absolutely vertical was essential; this was achieved by holding the plumb-bob over the feature to be recorded and then marking the point vertically above on the datum-line with a short piece of thin cord tied to the line. It was then possible to take not only the vertical measurement, but also a measurement to establish the horizontal location of the feature from the longitudinal datum-line (Fig. 2.1.3).

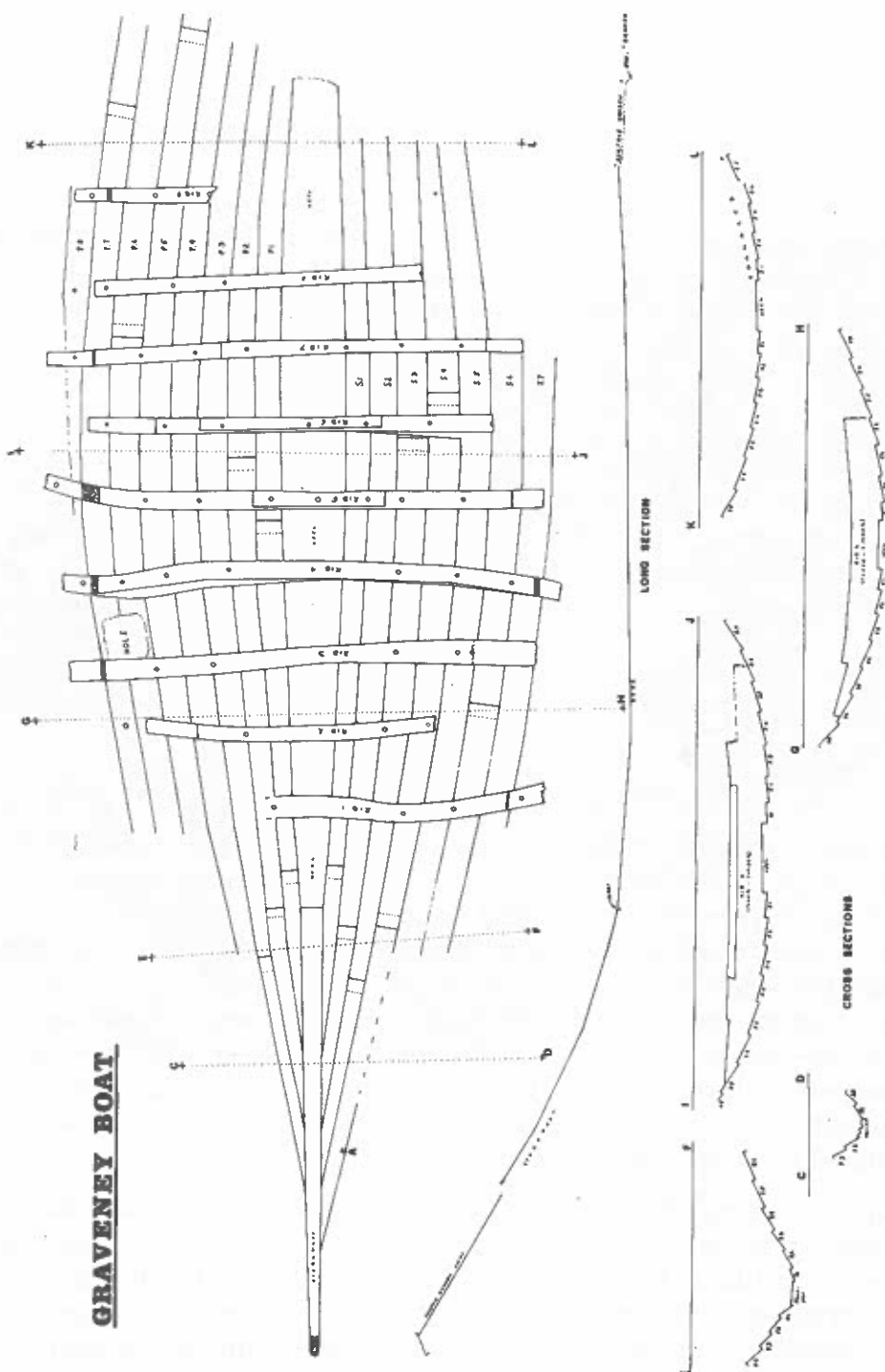


Fig. 2.1.2 Drawing of the boat made from 700 measurements taken in situ (original scale 1:10)  
© P. R. V. Marsden

Although the profiles of the vessel formed the basis of a plan, much information was needed, particularly the location of the frames. These were recorded by measuring horizontally from the transverse datum-lines (Fig. 2.1.4c) to points vertically above the after face of each frame (established by plumb-bob: Fig. 2.1.4d). Each of these positions was related to the longitudinal datum-line (Fig. 2.1.4a-b). Having established the position of each frame a few measurements of their widths were taken, and locations of trenails and of any other features needed to complete the plan were plotted.

The location of the faces of each frame provided a series of most useful transverse lines across the boat, which could be used for making additional measurements of the strakes. For example, the positions of the overlaps between the strakes were recorded where they were crossed by the after face of each frame, these being measured from a point directly below the longitudinal datum-line; and measurements were also taken from the frames to establish the positions of plank-joints in the strakes, and to fix the positions of trenails marking the location of missing timbers. Had there been enough time, it would have been possible to measure the positions of the corroded rivets which once held the overlapping strakes together.

#### NOTE

1. I would particularly like to thank Miss Angela Evans, Mrs Valerie Fenwick and Mr Peter van Geersdaele, who suffered much in the chill and damp air of Graveney Marshes while taking measurements.

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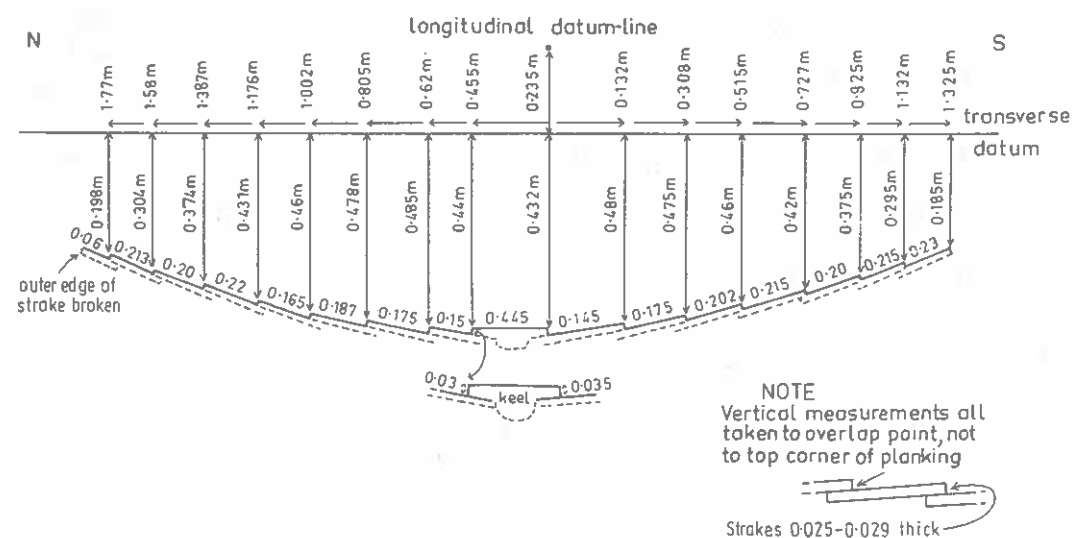


Fig. 2.1.3 Section across the hull measured from a transverse horizontal datum-line, which is related to a main longitudinal datum-line  
© P. R. V. Marsden

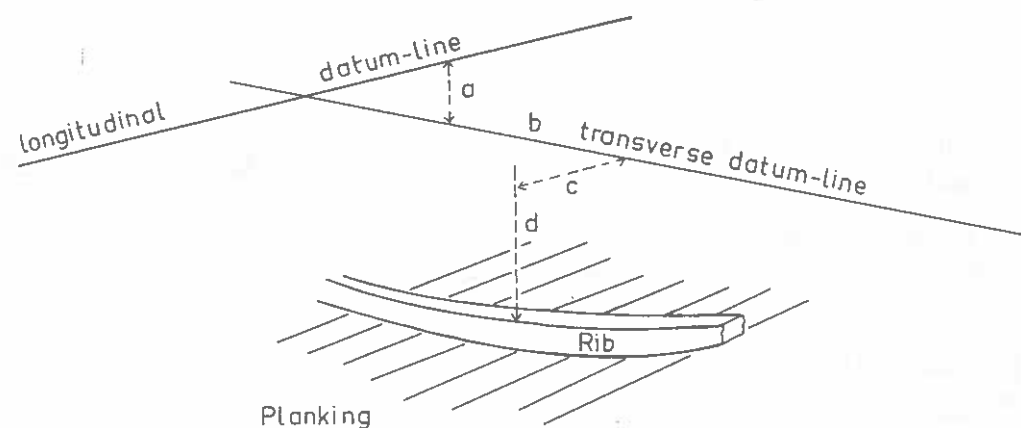


Fig. 2.1.4 Method of recording position of frames (ribs)  
© P. R. V. Marsden

## CHAPTER 2: RECORDING

### PART 2. PHOTOGRAPHY

by Brian Tremain,  
Principal Photographer, National Maritime Museum

#### INTRODUCTION

In common with many photographic assignments the site photographs of the Graveney boat were eventually put to many more uses than was at first envisaged. A member of the photographic staff of the National Maritime Museum was present throughout the rescue operation; during the first visit the first of some 300 negatives taken on site were exposed. These had been taken before the awning over the hull was constructed and have proved to be the most useful pictorially, for the boat had been completely revealed by Frank Jenkins and his team and was in a beautifully cleaned condition (frontispiece). On the first visit a walking stick which was measured afterwards was used as an improvised scale. Subsequent pictures always included a centimetre scale and sometimes several scales at different distances from the camera to help confirm the perspective in subsequent reading.

The main purpose of the photographs was to record visually the whole and every detail of the boat. This was done by photographing perpendicularly where possible every visible inch whilst the vessel lay *in situ*, and every part when it was removed but still on site. Subsequently every individual piece was photographed from every side as it was cleaned in the National Maritime Museum. Tool marks and tiny details were photographed in close-up at all stages. In addition to the scale a code letter or number was used in most photographs (Fenwick, 1972b:178-9), so that parts could be identified without the need of a note-book.

These visual records have been used in many ways, e.g. for identifying individual pieces and relating similar ones, for helping to provide missing information for the final drawings, and for exhibition and lecture purposes. Owing to lack of apparatus at the time no colour photographs were taken by the photographic staff. These would have been helpful in differentiating colour changes, such as rust marks on timbers, which in monochrome are barely detectable.

#### APPARATUS

The apparatus consisted of one Nikon F camera with an FT photomic head, and two lenses, a 55 mm Micro-Nikkor and a 28 mm Nikkor. The latter, being a wide-angle lens, enabled the photographer to include more of the subject into the picture without changing his position (which was extremely difficult to do in the confined, sticky, muddy conditions) and without too much distortion of the image. A Braun electronic flash was used to supplement the low level of light beneath the awning. Ilford FP4 and HP4 film developed in Ilford Microphen was used throughout.



Fig. 2.2.1 Awning over the boat made photography difficult.  
National Maritime Museum

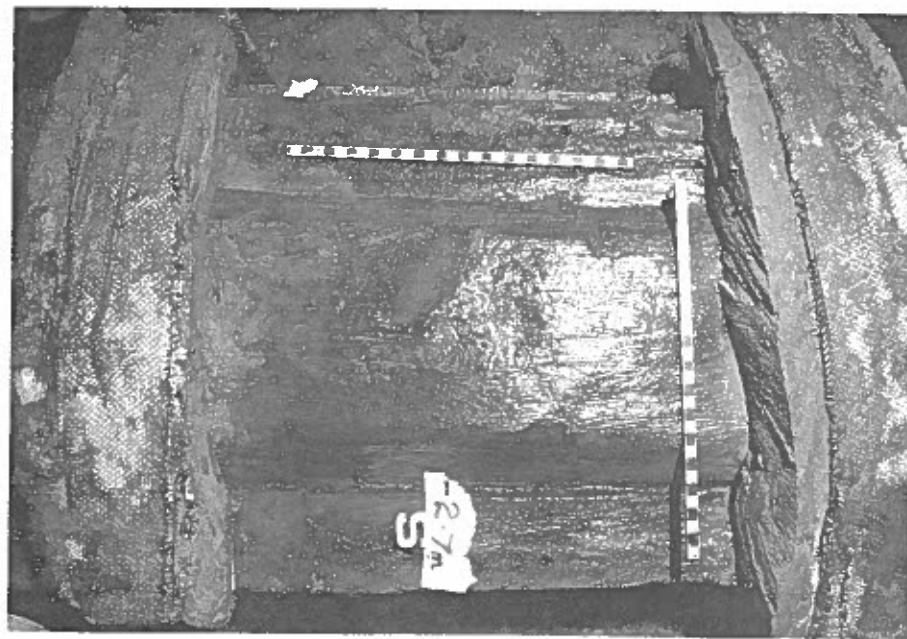


Fig. 2.2.2 Spectral reflection shows up the detail of the inverted plank-keel  
© National Maritime Museum

#### PHOTOGRAPHY ON SITE

In order to have a complete coverage in plan it was necessary to take vertical photographs of each part of the hull. These were taken from planks which were placed across the scaffolding supporting the awning over the whole boat (Fig. 2.2.1). The position of the photographer squeezed between the planks and the canvas roof of the awning which vibrated in the wind made it extremely difficult to hold the camera steady. A tripod was out of the question because of the awkwardness of the position and the very muddy conditions. As fast a shutter speed as possible had therefore to be used; when lighting conditions deteriorated (late afternoon to evening), it was necessary to use flash.

The detail of some surfaces was clearer when the surface was wet and the light was reflecting from it straight at the camera (Fig. 2.2.2). When possible, cross-to-slightly-behind light was used, so that the subject was more readable, with the shadows of any raised portions appearing beneath them (Fig. 2.2.3). If the light was strong enough, obviously the smallest aperture size was used, with as slow a shutter speed as possible without a tripod. Exposures were geared to give good shadow detail. Two complete sets of 10 x 8 in. prints were made initially; one was used as a working set by the archaeologists and the other filed for reference. The negatives were numbered in sequence with existing negatives in the National Maritime Museum.

#### PHOTOGRAPHY IN THE MUSEUM

Photographs were taken in the yard of Feather Place.<sup>1</sup> The part of the boat to be photographed was laid on a painted 0.1 m grid at ground level, taking great care over proper support. The part was identified by plastic numbers and letters before photographs were taken of each side and any significant details. As shadows from sunlight and heavy rain delayed work and dry easterly winds rapidly absorbed the moisture in the wood, dull, quiet days were best for photography. With the right amount of water, surface texture could be reproduced with great clarity. A two-story scaffolding was used so that by photographing from the proper distance, up to 7 m being available, optical distortion was minimized. The negatives were developed immediately, so that, if necessary, photographs could be retaken before the part was replaced in the storage tank.

#### CONCLUSION

The most popular photographs were those which were taken showing the whole boat before it was covered by the awning and whilst it was still as complete as possible. In other words photographs of a whole site and of the main features on it receive more attention and are used more often than specialized small-detail work, although the latter is extremely important. Colour negatives and colour transparencies should be made to supplement black-and-white photographs, especially as publication and lecture requirements cannot be known on site. Processing to archival standards is assumed, with the possibility of sepia toning at least one set of black-and-white prints, as sepia prints do not fade. Closest liaison with site direction and supervision leads to understanding of requirements and thus the most useful reportage and recording.



Fig. 2.2.3 Remains of timber hard or standing (foreground), and the massive frames of the boat are thrown into relief by cross-to-slightly-behind light  
© National Maritime Museum

#### NOTE

1. The Archaeological Research Centre of the National Maritime Museum.

#### REFERENCE

Fenwick, 1972b. V. H. Fenwick, 'Thoughts on the recording of old ships,' International Jnl. Naut. Archaeol., I, 177-80.

## CHAPTER 2: RECORDING

### PART 3. RECORDING DETAILS OF THE HULL

by Eric McKee  
sometime Caird Research Fellow, National Maritime Museum

#### INTRODUCTION

In addition to giving a description of what was found, records of the boat were needed for two other purposes: first, so that the remains could be put together again; and second, to collect the evidence on which a reconstruction might be based. While most records can serve all three purposes, the approach to restoration and reconstruction is not the same, and both call for special additional recording. The former calls for a photographic method, the latter for an analytical one. In the photographic approach coverage must be complete, as it is not then known what will be of importance later. This also applies to reconstruction. Taking a mould of the inside of the planking was, as it were, a three-dimensional extension of photography; within the limitations of the technique everything that was there was recorded. In the analytical approach the recorder is free to select or ignore. This is dangerous, as some degree of negligence, ignorance and bias is normal. In the end, however, conclusions have to be reached, and this involves sorting and selecting the evidence. With more skill and experience a draughtsman should be able to expend less effort than was so for the Graveney boat.

#### EXAMINATION OF SEPARATE COMPONENTS

The greater part of the recording took place after the recovered pieces had been stored in water to which fungicide<sup>1</sup> was added at the National Maritime Museum. Taking much the same action, each separate piece was examined in turn. While the larger and more complicated pieces needed more complex treatment, an effort was made to employ a constant level of recording throughout.

The short time available for recovery had prevented the parts from being arranged in any particular order. Small items had been sent direct to the British Museum where they were listed in an inventory (nos. 1 to 164) before conservation and analysis. Larger items were taken to the National Maritime Museum, crated according to size and not provenance. Nor was it practical afterwards to find and remove any particular item at will, as this would have meant double-handling the far from robust waterlogged wood. Items had to be extracted in the order which caused the minimum disturbance, and then for as short a time as possible. It would have been preferable to have studied them in the same order as they had originally been made and built into the vessel. This would have given an earlier assessment of the nature of the boat and a clearer picture of how the work was going. Having adjacent pieces to study would have helped to show where any errors lay.



Fig. 2.3.1 Members of the Graveney Boat Unit from the photographic scaffolding. Each part had to be carefully handled and supported during recording  
© National Maritime Museum



Fig. 2.3.2 Thorough washing of planking with a soft brush in gently running water revealed details of construction.  
© National Maritime Museum

## GENERAL ORGANIZATION

There were three members of the Graveney Boat Unit during this stage, a conservation officer and a draughtsman, who worked five days a week, and an archaeologist, who worked two days a week (Fig. 2.3.1). Each member had a specific job, but there were frequent discussions and occasions when mutual assistance was essential for a steady flow of work.

Although the layout of the work-place in what was to become the Archaeological Research Centre of the National Maritime Museum was austere and improvised at short notice, it was suitably compact and adequately equipped. The large storage tank was in a room with only a narrow gangway all round. The tank could be drained and there was a supply of fresh water for refilling. At one end double doors opened into a courtyard, which in turn gave access to a public road. At this end of the tank two tables were fitted level with its top. As this was about 1.2 m high, it was necessary to stand on low platforms to work at the tables. There was artificial light but no heating, which might have dried the wood, while it was out of the tank. Between the tables there was space to store items waiting for further treatment.

## PREPARATORY CLEANING

The conservation officer removed a packaged piece of wood from the tank and placed it on his table, which was in the form of a large draining board. Taking care that the wood was properly supported on foam rubber, the piece was stripped from its polythene sheet and foam plastic wrappings. It could be identified by its embossed plastic label, which had been fixed to it while in situ.

Although the wood had been washed once already, it was still very dirty. The mud was removed using a soft brush and water, but encrustations round fastening-holes called for the careful use of a probe (Fig. 2.3.2). To begin with, stoppings in the lands and scarfs were left in place to be recorded, as were some encrustations; later on when sufficient data had been collected, anything which might interfere with tracing was removed during this preliminary cleaning. When all surfaces were clean, the part was temporarily re-wrapped in wet foam plastic and polythene sheet, and passed to the draughtsman on the other side of the tank. At all times when any part was out of the tank, care was taken to keep it wet.

At any stage of cleaning, the Conservation officer might call over other members of the Unit, if he saw anything of interest. Ferrous remains in particular could be very short-lived, and this might be the only chance of recording them.

## PRIMARY RECORDING

Both the archaeologist and the draughtsman carefully examined every piece, recording between them its features and shape by notes, tracings, measurements and photographs. For convenience this information was later embodied as far as possible on drawings at 1:10 scale on transparent material,

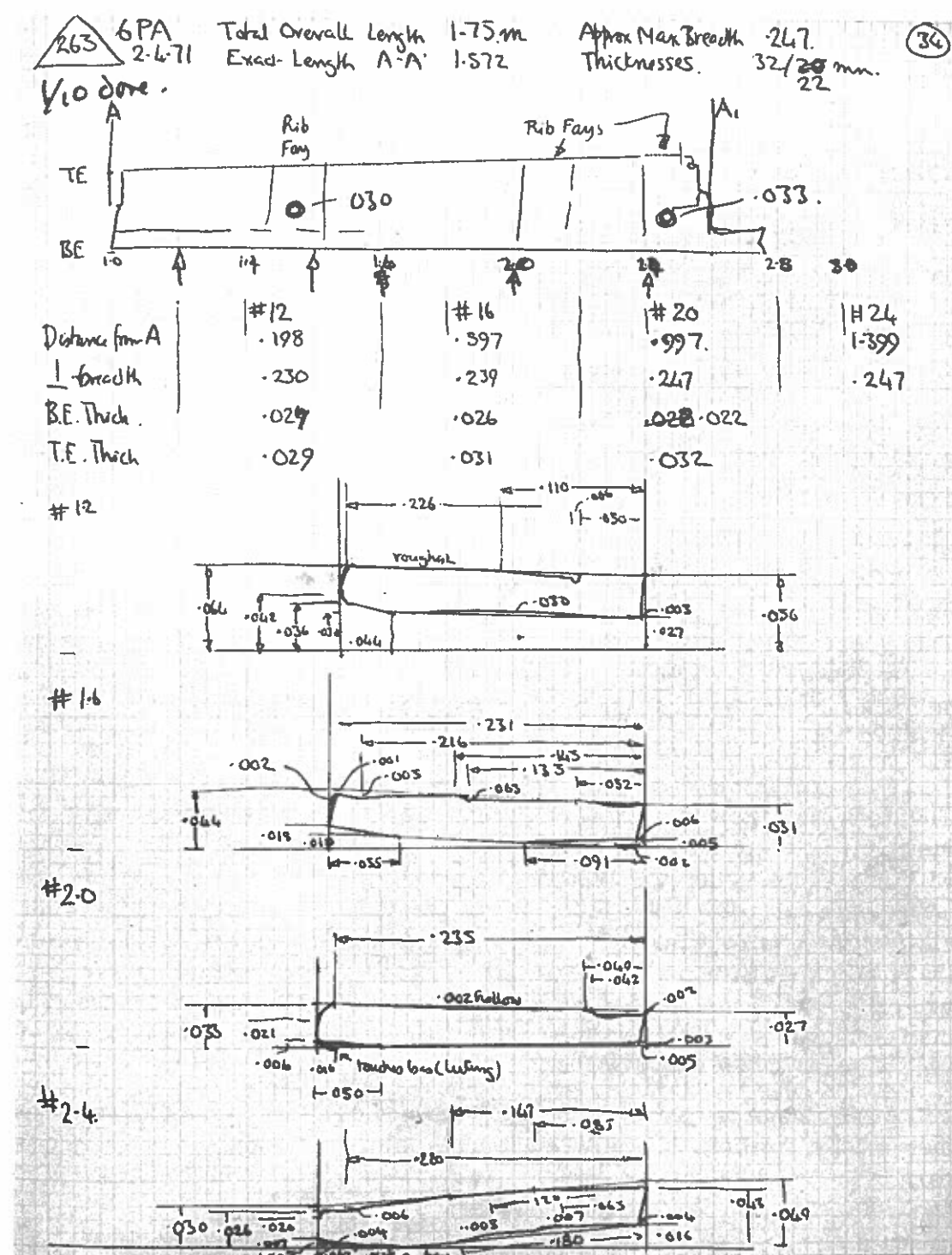


Fig. 2.3.3 Page out of Eric McKee's direct-measurement book giving details of a plank  
© National Maritime Museum

so that copies could be made at will. The mass of scattered information from these different sources has been sorted and re-issued in chap. 3.2. This discusses each structural feature of the boat, quotes the serial numbers of the parts where the evidence was seen and provides factual backing for more general statements elsewhere. It should be consulted on any point of detail.

### DIRECT MEASUREMENT

The table on the draughtsman's side of the tank was level and made from a sheet of marine grade plywood, approximately 3.5 by 1.0 m, accurately marked out into a grid of 0.1 m squares and varnished. The part to be examined was uncovered and supported on this table with foam plastic pads. A standard method of location was used; planks were placed with their inside uppermost and bottom edge towards the draughtsman, and each rib on one of its flat sides with the notch for the keel parallel to the edge nearest the draughtsman. The position relative to the grid was noted so that the part could be turned over accurately.

Direct measurements were recorded in a book of squared paper. Fig. 2.3.3 is a page out of this book, showing the entry for a plank fragment. After writing down the serial number, part code and date, sufficient lengths, breadths and thicknesses were measured to provide a check on any changes that might occur later. A sketch was next made to show the orientation of the part on the grid, its general shape, its most important features and the stations at which sections were to be taken. Sections were normally taken on one of the grid-lines, choosing representative and, if possible, undamaged portions. The distance of the section from the left hand limit of length was noted, as was the perpendicular breadth and the top and bottom thickness taken 0.025 m from the edge at this station.

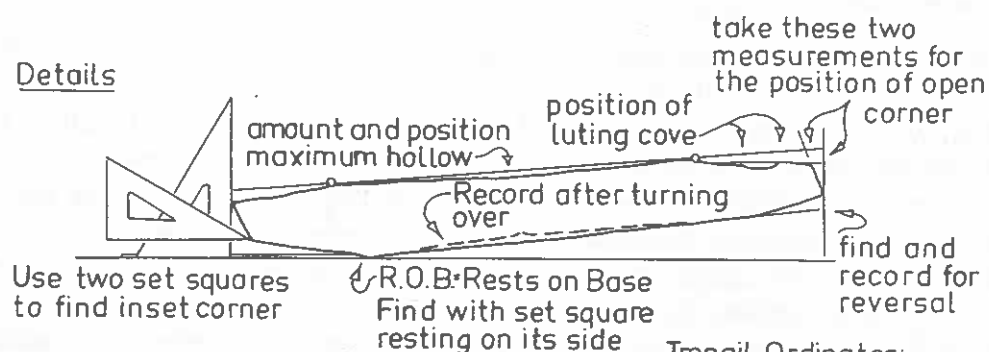
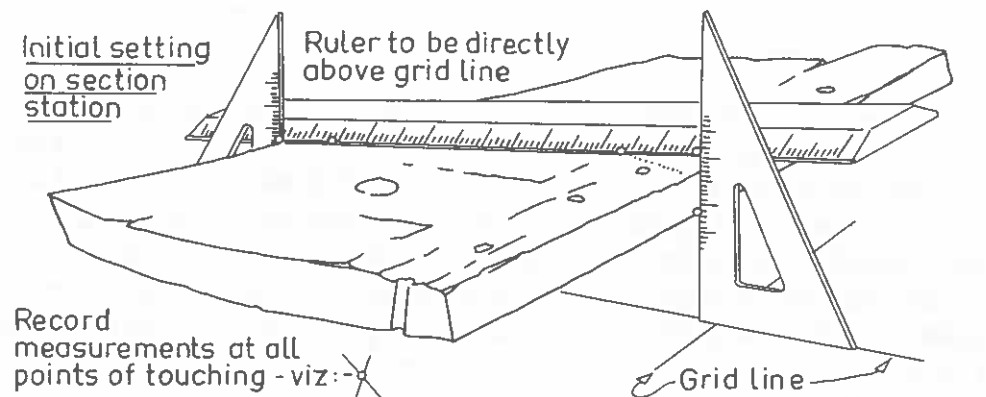
The sections were taken using straight edges and set squares with metric graduations.<sup>2</sup> Arrangements for doing this are shown on Fig. 2.3.4, the readings being put into the book in the form of a free-hand scale drawing. This was a running check and eased the job of making a fair drawing later. Only three sides could be measured until the part could be turned and repositioned on the grid. The complexity of the rib shape needed fuller treatment. The two outer corners of all ribs were projected down to the grid using set squares. The readings were tabulated and plotted, as were those for trenail and notch positions. Fig. 2.3.5 shows the page for rib 8, with a sketch to show how these projected readings were obtained.

The keel and sternpost were too bulky for the grid table. A datum-line was established on the under side of the keel and the port side of the sternpost and all other measurements related. The direct-measurement book shows how this was done. The position of the datum-lines and section stations were recorded in the book showing where reference pins had been inserted. Otherwise the procedure was the same as before.

### TRACING

A tracing is a development of a part's surface; direct work on the grid table gives a projection of it. Both have their uses. For most flat planks the

## DIRECT MEASUREMENTS



## Additional Readings for Ribs

Ordinates of all corners

Take maximum ordinates of inboard surface

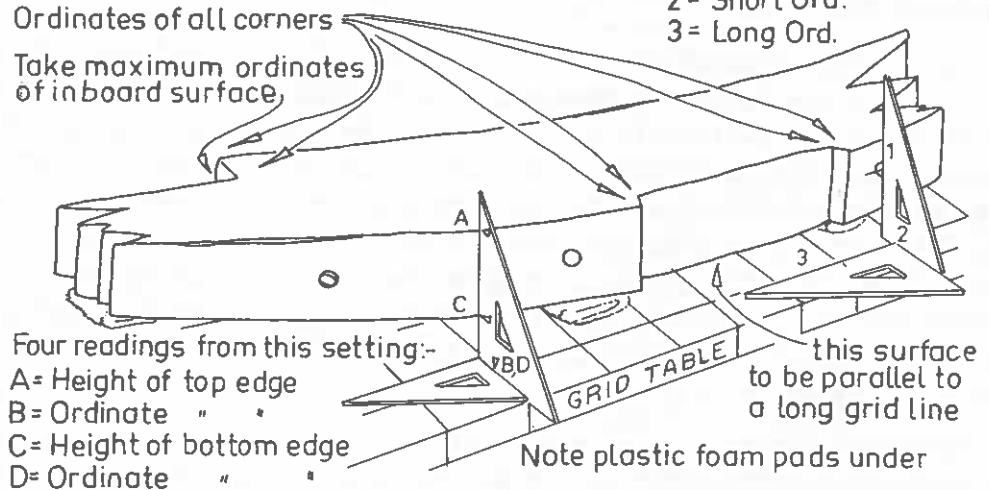


Fig. 2.3.4 Direct measurements drawn by Eric McKee  
© National Maritime Museum

difference between developed and projected dimensions can be ignored. There is a 1% error between them when the surface is tilted  $8^\circ$ . But, for twisted hood-ends, ribs and back-bone components, the difference is enough to be taken into account. In this investigation it was the developed shape of the planks and the projected shape of the ribs that were used most.

After taking all the direct measurements accessible in the first position, the upper surface was traced. This was started by flooding the wood with water and then covering it as quickly as possible with a clean sheet of 5 mm thick polythene. The surface tension pulled the wood and the sheet into close contact, giving high transparency but low evaporation. The sheet was then identified by writing on it: the part's serial number and code; the side uppermost; the date. Felt-tip pens<sup>3</sup> were used for this and all other tracing work (Fenwick, 1972b:179; Fenwick, 1972c:11). The waterproof ink is slow-drying on non-absorbent materials like polythene. Except for black, all colours are liable to fade if left in bright light for long periods. Although a new tracing could not be rolled up for several hours, therefore, it was eventually inserted into a cardboard tube with other tracings from the same strake and kept in a cupboard. The felt-tip pens were trimmed with a razor blade if necessary to give lines no more than 2 mm broad. This is within the accuracy normally found in full-size boat-building, and well inside what can be reduced and drawn at a scale of 1:10. Smooth surfaces are essential for good tracings. Any bump will interfere with the surface tension and then condensation produces an opaque area. The most common offenders were half-driven reference pins, embossed plastic tapes, stopping, encrustations and damaged timber. Tracing shapes not in contact with the polythene sheet may look right but will not be accurate. A test such as tracing the same part twice, then laying them on top of each other, will show how difficult it is to judge correctly that one's eye is always directly above the point being traced.

Four colours were used on the tracings. Black was used to show all lines that were thought to have been part of the original boat. Edges, fastening-holes and builder's tool marks were therefore shown in this colour. Blue was used to show any subsequent damage, such as fractures or other signs of wear and tear through the ages. Red was used to show the positions of reference pins and section stations. Green was used for any matter sticking to the wood, such as luting and caulking.

When the tracing of the first side was complete, it was peeled from the surface and hung up by bulldog clips to dry (Fig. 2.3.6). The part was then turned over, upside-down if it was a plank, or on to its next side if it was a rib. Care was taken to place the part correctly on the grid so that the section lines were aligned on their stations. The measurements for the blind side of the sections were then taken and a tracing made of this.

When the ink on both tracings of a plank was dry, they were brought together to check for anomalies (Fig. 2.3.6). This showed at once if any fastening-holes had been missed or a section was out of line, so that steps could be taken to find where the mistake lay and to put it right. When this had been done, the part was wetted and wrapped again to await photography (see p. 31) before final cleaning.

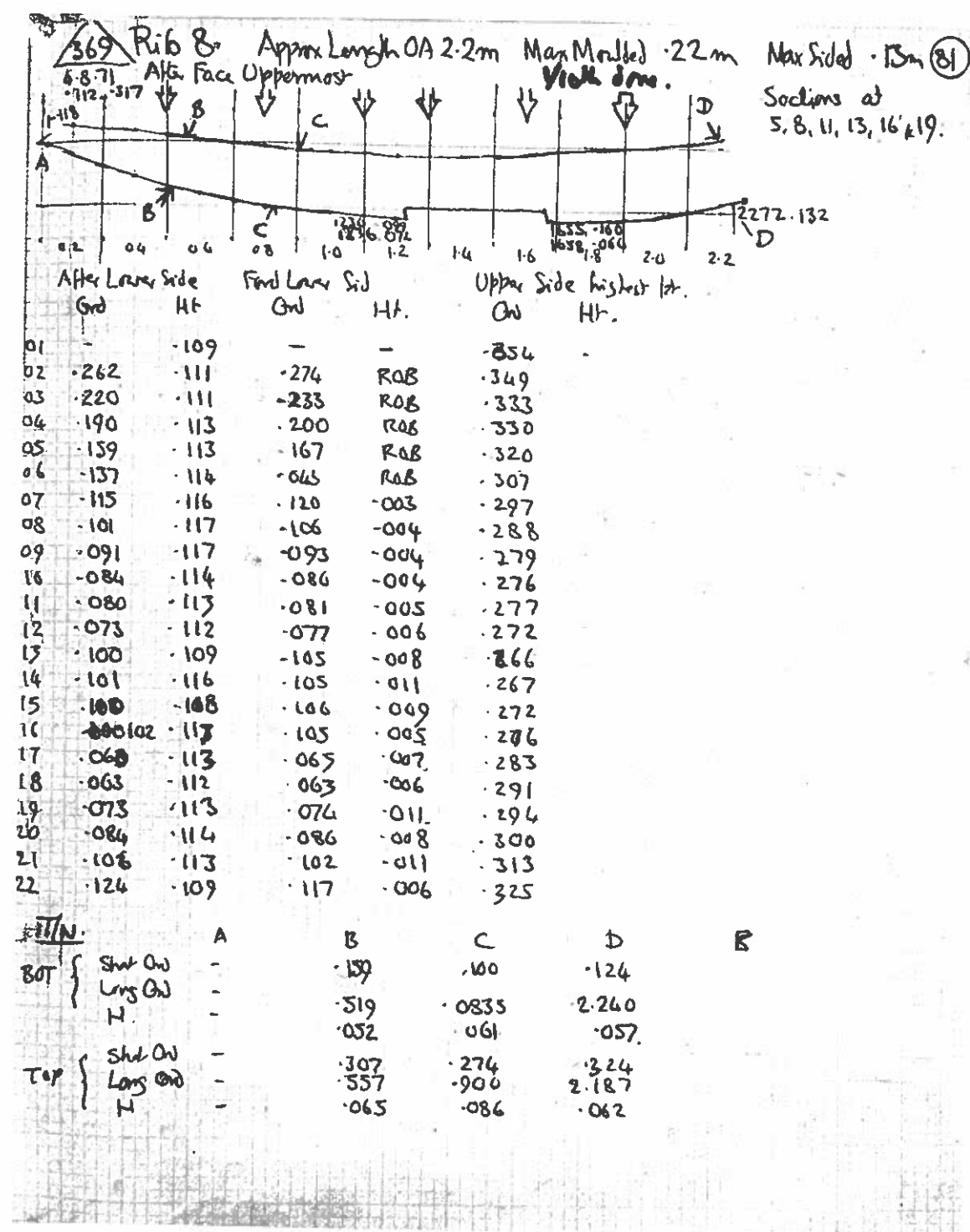


Fig. 2.3.5 Page out of Eric McKee's direct-measurement book giving details of a rib  
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If anything of interest was seen during tracing, it was noted directly on to the polythene sheet. These notes appeared on the 1:10 scale drawings and are the source of much of the detailed comments in chap. 3.2. However the tracings are master documents and when conserved the wood will be compared with them.

#### FINAL CLEAN AND RE-STORAGE

With the examination complete, the part was taken back to the cleaning table. Over the years mud had penetrated everywhere that water had and kept coming to the surface. After meticulous final cleaning, during which all stopping and encrustation were removed, the conservation officer wrapped the piece in foam plastic and polythene sheet. The contents of the package were clearly marked on the outside before immersion. Planks were stored in tiered racks, the ribs and the sternpost flat on the bottom of the tank, while the keel had its own carrying pallet.

#### DRAWINGS AT 1:10 SCALE

Although primary records, neither the tracings nor the direct-measurement book were convenient for study. A reduced scale drawing, to combine both these sources of information, was needed for every important piece. Taking into account the probable size of the whole vessel, as well as ease of conversion, a scale of 1:10 was chosen. Each drawing was made before examination of the next piece to avoid an accumulation of unprocessed data. Although this stage of the draughtsman's work tended to form a bottleneck, it fitted in to some extent with the cleaning and the photography.

In the office of the Graveney Boat Unit there was another grid table similar to the one on the tank. Each tracing in turn was brought into alignment with this grid and then secured with masking tape.<sup>4</sup> The 1:10 drawing was made on a transparent sheet, which had been fastened over a 10 mm grid on a small drawing board. Using proportional dividers all the features of the tracing were reduced and transferred to the smaller drawing (Fig. 2.3.7). After this had been done for each side, the sections were copied from the direct-measurement book, and lastly any notes from the tracings and the book were added.

The surface of the tracing film was sharp, not unlike fine glass paper, so that it was difficult to keep pencil points sharp, even using a 9H lead. Eventually a propelling pencil<sup>5</sup> was found that took a 0.3 mm 2H lead. This gave a clear line of constant thickness which reproduced well. Both pencils and all the rest of the equipment can be seen on Fig. 2.3.7. After photo-copies had been made from the transparencies, the drawings were inked using a 0.15 mm pen and ink.<sup>6</sup> Although this gave permanency, some accuracy was lost, and for this reason prints from the pencil drawings were much preferred for use during reconstruction.

#### CONCLUSION

Fifty-five reduced scale drawings of sixty-two major parts were made by this method. It took the Unit thirty-two weeks to prepare the pieces,

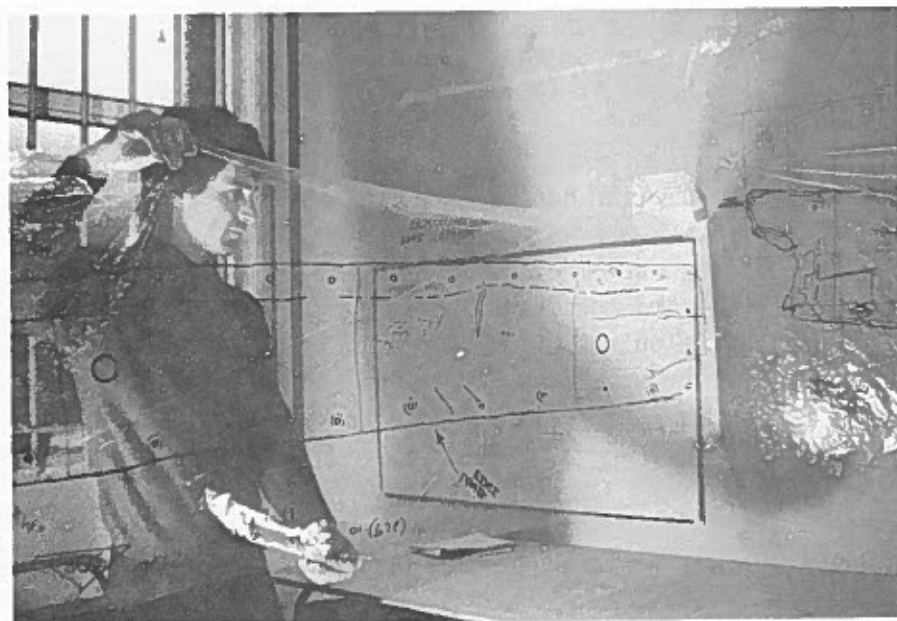


Fig. 2.3.6 Checking completed colour-coded polythene tracings which are drying before storage  
© P. R. V. Marsden



Fig. 2.3.7 Reducing full-scale tracing of a plank to a 1:10 scale drawing  
© National Maritime Museum

record the data and work on the drawings, that is, about two important pieces per week. The keel took two weeks and larger items like the sternpost and ribs one week each. However extravagant of effort this may seem in comparison with photogrammetry, it is not as much as it might appear. Photogrammetry would have produced only projections and would have saved only one member of the Unit. Without the experience of handling and examining every part of the boat, the work of reconstructing it from photographic evidence alone would have been even more difficult.

#### NOTES

1. The fungicide used was Panacide.
2. It was found that plastic instruments were worn down by the abrasive nature of the muddy water. They were replaced before becoming a source of error.
3. Felt-tip pens: Letramarker-Letraset, St George's House, 195-203 Waterloo Rd., SE1.
4. Masking tape: 3 M Scotch Tape, 19 mm ( $\frac{3}{4}$ "); transparent tracing film: Permatrace, Imperial 75, 3 mil double matt drafting film (Imperial Red-line Products).
5. Propelling pencil: Pentel Mechanica—The Japan Stationery Co. Ltd., Nihonbashi Koami, Chuo-ku, Tokyo.
6. Pen: Rotring—Riepe-Werk—D 2 Hamburg 54, Postfach 54, 1060 Germany.

#### REFERENCES

- Fenwick, 1972b. V. H. Fenwick, 'Thoughts on the recording of old ships', International J. Naut. Archaeol., I, 177-80.
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## CHAPTER 3

### DESCRIPTION OF FINDS

#### PART 1. SUMMARY OF FINDS

by Valerie Fenwick

The finds are easily divided into four main groups by material: A, wood; B, pottery and tile; C, stone and lava; D, bone and shell. The finds of wood can be further divided into parts of the ship and extraneous material, such as posts, sticks and rope. Most of the parts of the ship were in position; those that were dislodged were mostly identified (chap. 3.2).

Of the other groups of finds the pottery and tile, stone and lava, and bone and shell are described in chaps. 4 and 5.

#### A. Wood

##### I. Ship in situ (NMM reg. no. ARC1973/6)

The dismantled parts were each numbered<sup>1</sup> separately as they were drawn (see p. 5).

Small fragments not reproduced on Figs. 3.2.1-27): 101, 107 (scarf of keel and of sternpost); 121 (frame R3 starboard); fragments of planking.

##### II. Ship dislodged

The dislodged fragments were given an identity when this was known. There is, however, some doubt whether 225 constituted part of frame R10.

Dislodged fragments not reproduced on Figs. 3.2.1-27: 88-9 (sternpost); 225 (frame R10); fragments of planking.

A selection of trenail heads is shown on Fig. 15. The fragments cannot be brought together and studied as a whole until conservation is completed.

A selection of trenail heads is shown on Fig. 8.3.1. The fragments cannot be brought together and studied as a whole until conservation is completed.

III. Unplaced worked fragments from the site, probably derived from the ship, or another: 48-50; 58-65; 71; 76-7; 81; 85; 105; 108; 111; 119; 122; 124-8; 130; 150; 207; 272-3; 302-5; 307-9; 313; 319; 367; 377.

IV. Posts and large sections of worked wood: 78; 123; 338; 358; 370; 373; 381-5.

V. Sticks and small fragments: 95-6; 104; 111; 113-4; 117; 129; 131-3; 138; 152; 380

VI. Rope (see pp. 145, 153): 15-16; 162; 164

#### B. Pottery and Tile

Pottery (see chap. 4.3): 44; 46

Tile (see p. 151): 45; 47

C. Stone and Lava

Ragstone: 83-4; 87; 132; 135; 138; 141-3; 146; 149-50

Lava (see chap. 4.4): 84; 136

D. Bone and Shell

Bone (see chap. 5.4): 108; 112; 115-16; 119-20; 137; 140

Shell (see chap. 5.3): 104; 133-4; 140; 145; 147-8; 152; 367; 387-8

NOTE

1. When quoted in other parts of the text all numbers are preceded by Gr.

CHAPTER 3: DESCRIPTION OF FINDS

PART 2. SET OF DRAWINGS OF THE PARTS OF THE HULL, AND  
DRAUGHTSMAN'S NOTES

by Eric McKee

In the drawings planks are shown upright when the inside is being drawn, and upside-down when the outside. The full-size polythene tracings<sup>1</sup> are to be preferred to the 1:10 scale drawings. All drawings are copyright of the National Maritime Museum.

The following abbreviations have been used in this section and on the polythene tracings:

|        |                                           |
|--------|-------------------------------------------|
| B.E.   | Bottom edge (nearest keel)                |
| For'd  | Forward                                   |
| H.L.C. | Hair-line crack                           |
| P.J.   | Plank-joint or scarf                      |
| pce.   | Piece of fragment of larger component     |
| R.F.   | Rib fay (where rib crosses keel or plank) |
| R.O.B. | Rests on base or datum                    |
| Sl.    | Saddle on rib                             |
| Stbd   | Starboard                                 |
| T.E.   | Top edge                                  |
| T.M.   | Tool mark                                 |
| T/N    | Trenail or hole for one                   |
| U/P    | Unplaced or location uncertain            |
| V.M.   | Vandal mark (p.                           |

The following symbols have been used:

|                                                                                       |                                             |
|---------------------------------------------------------------------------------------|---------------------------------------------|
| Dotted line .....                                                                     | Boundary line of stopping                   |
| Pecked line-----                                                                      | Luting coves, stains and radii              |
| Chain line-.-.-.-.-                                                                   | Intersection of planes and axis of holes    |
|  | Perpendicular measurement along a grid line |
|  | Dead flat, station of maximum breadths      |
|  | Reference station for taking a section      |
|  | Reference pins (p. 9)                       |
|  | Centre-line                                 |

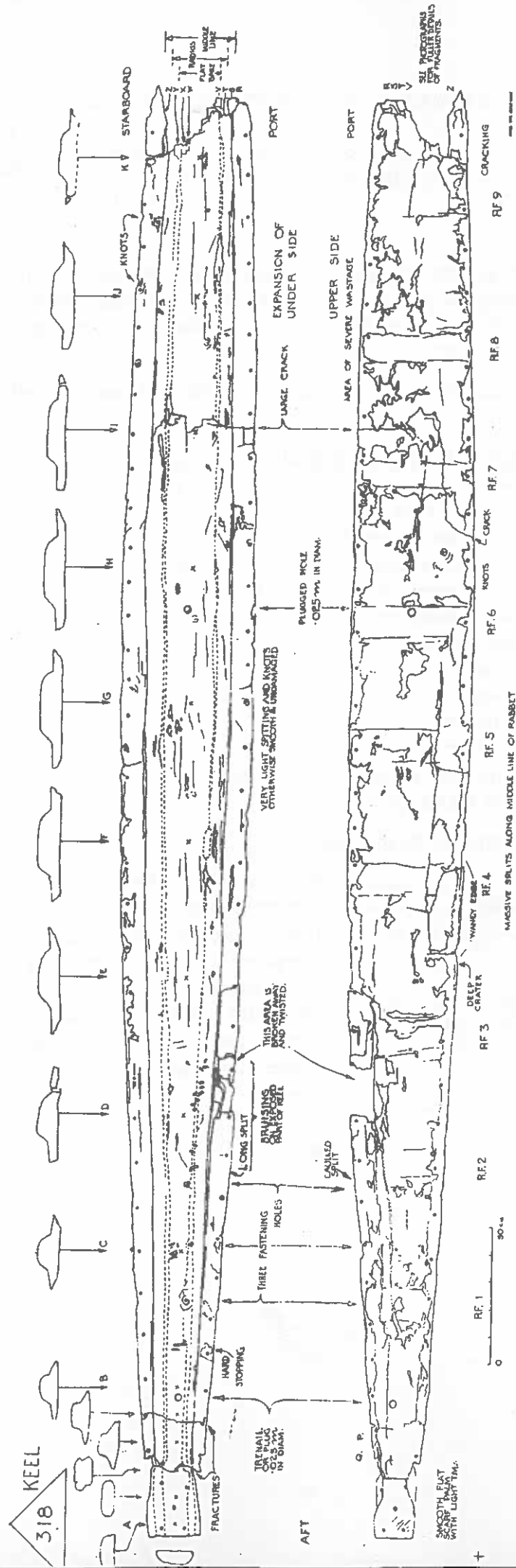


Fig. 3.2.1 Keel

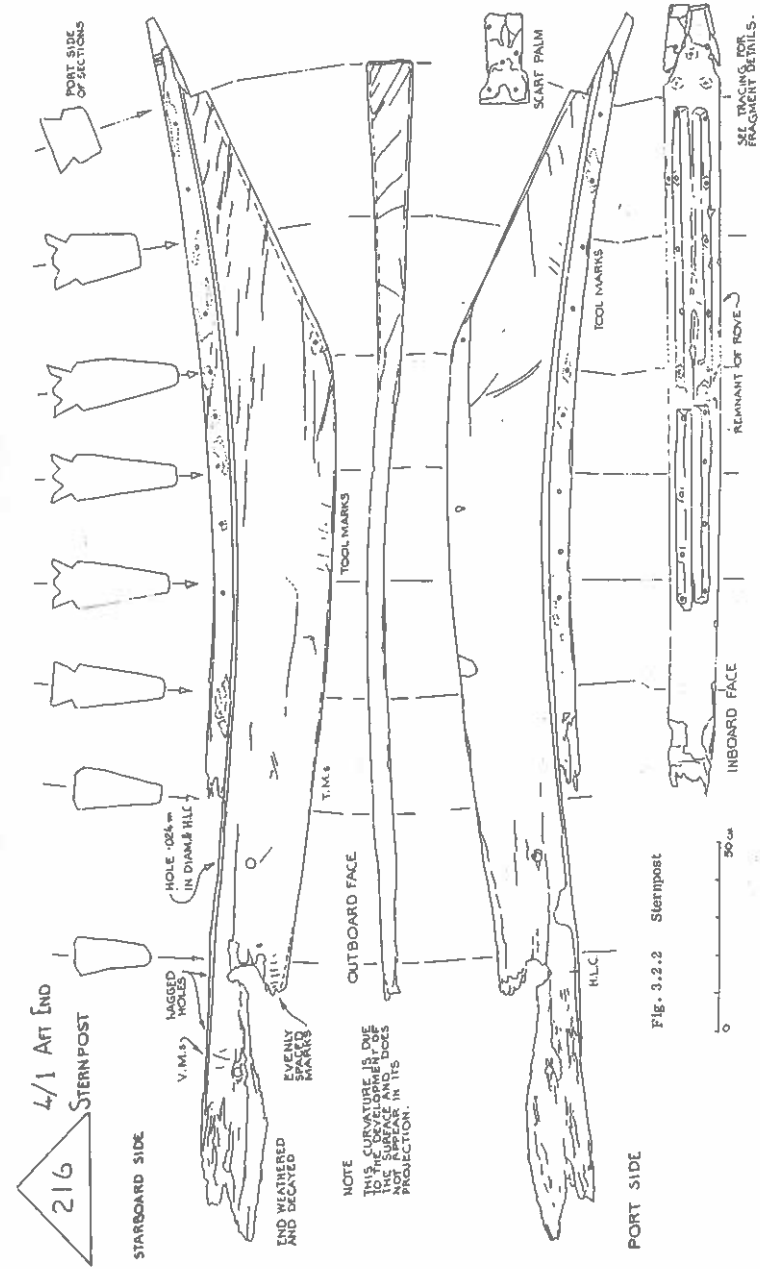


Fig. 3.2.2 Sternpost



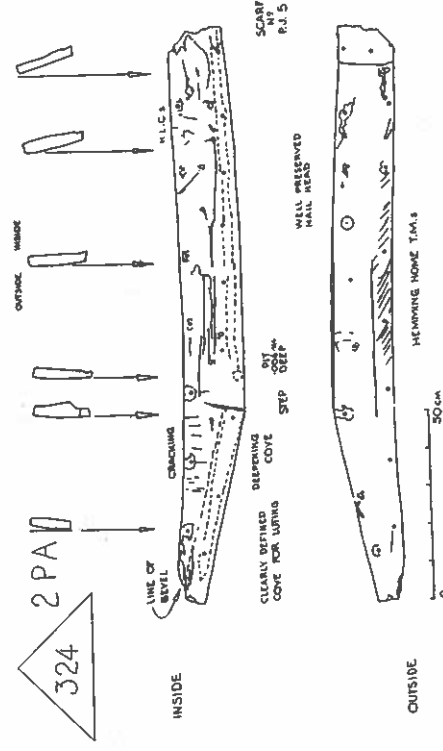
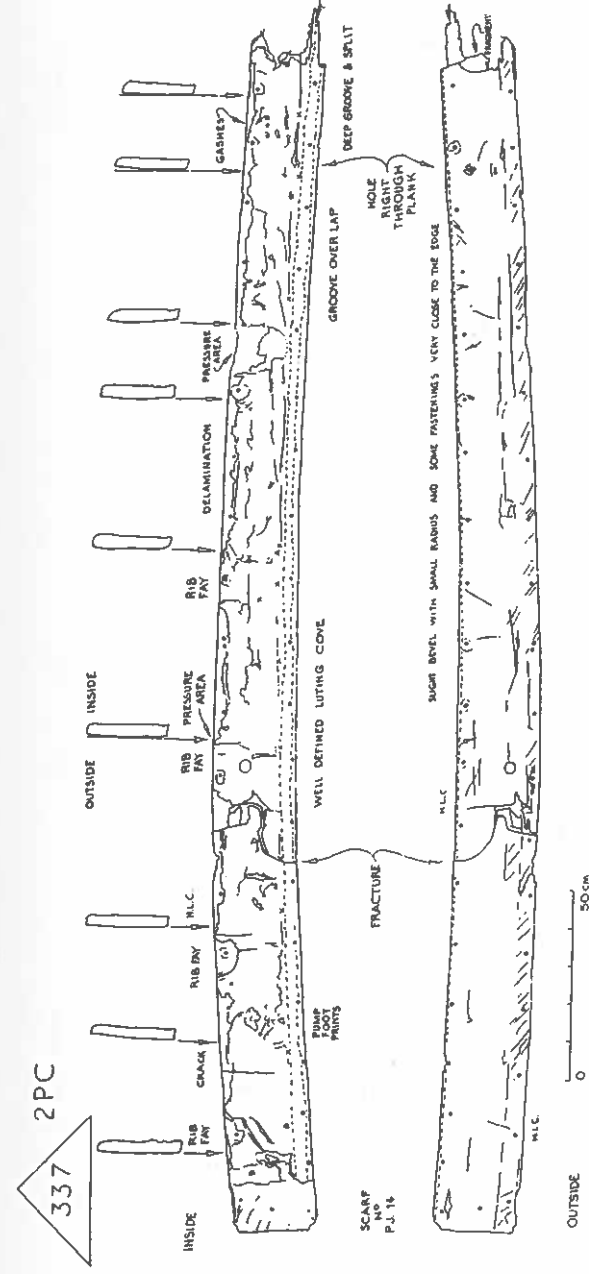
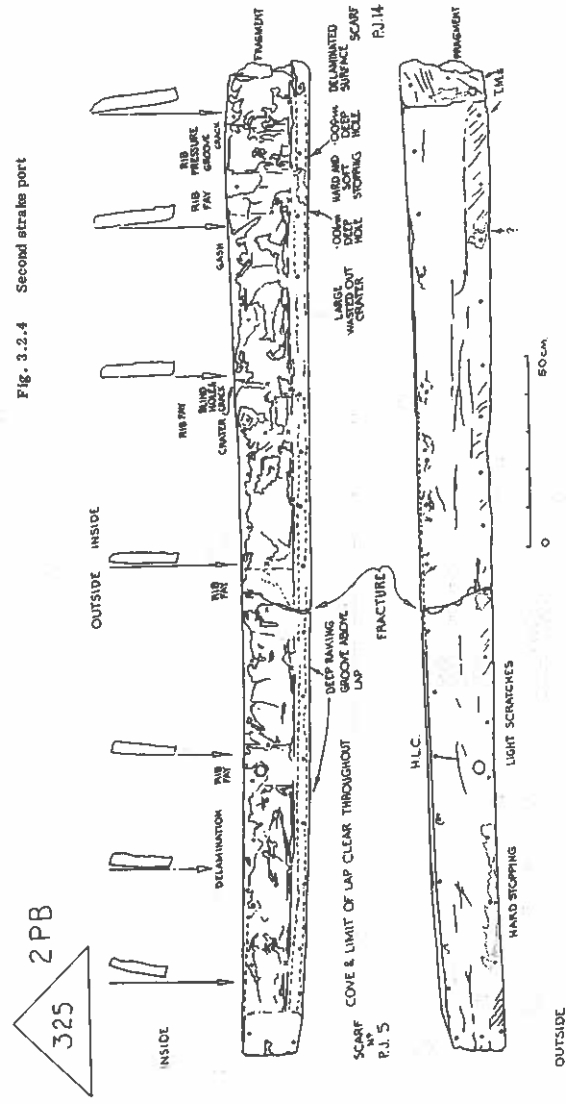


Fig. 3.2.4 Second strake port





346 2 PIECES OF 4PC AND 1 OF 4PB  
INCLUDING 297  
4PB → 4PC

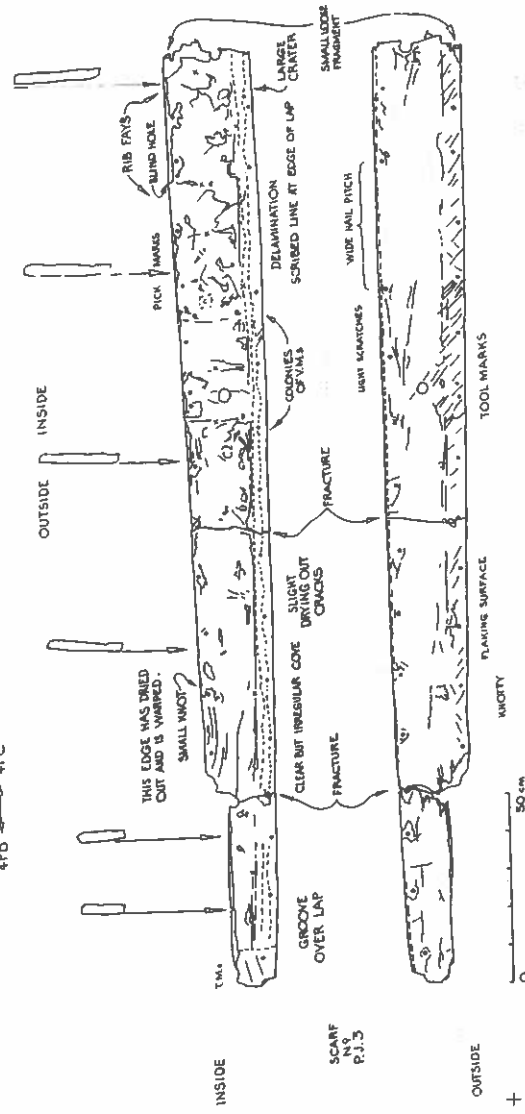
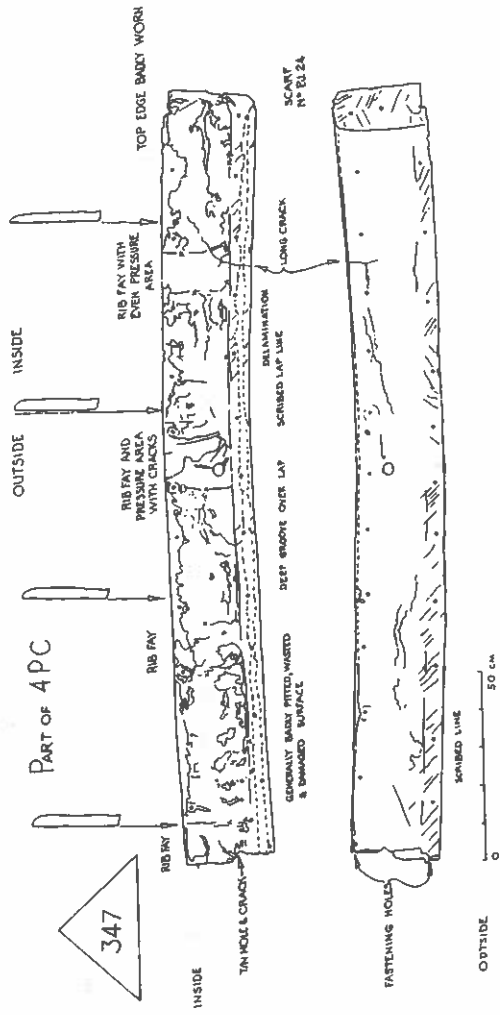
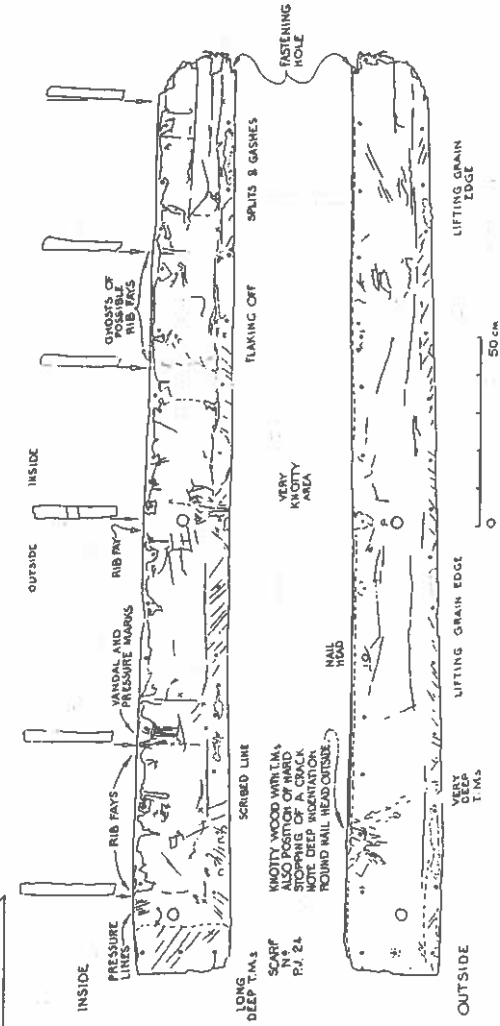


Fig. 3.2.6 Fourth Beak port



292 4 PD



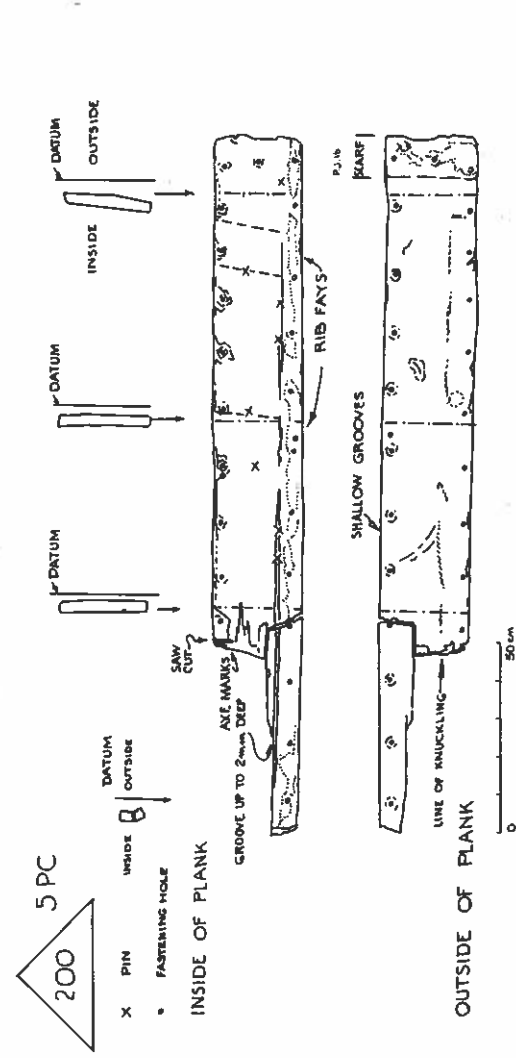
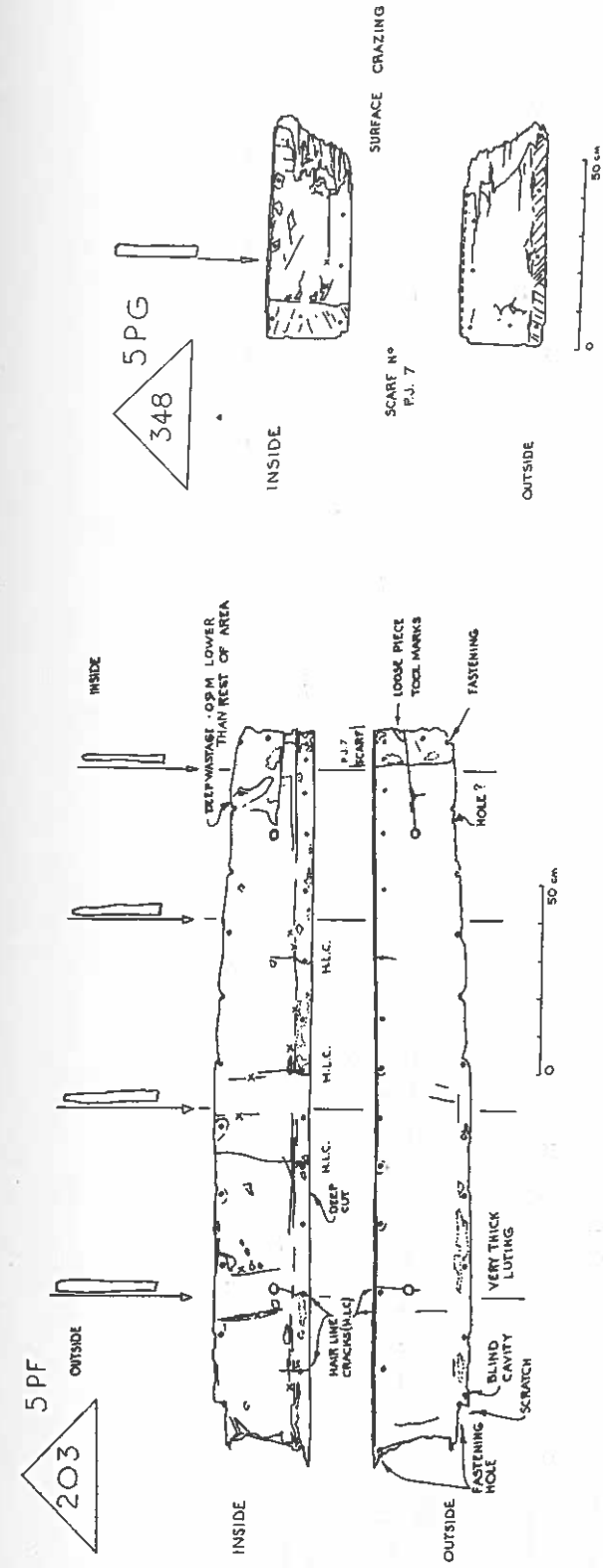
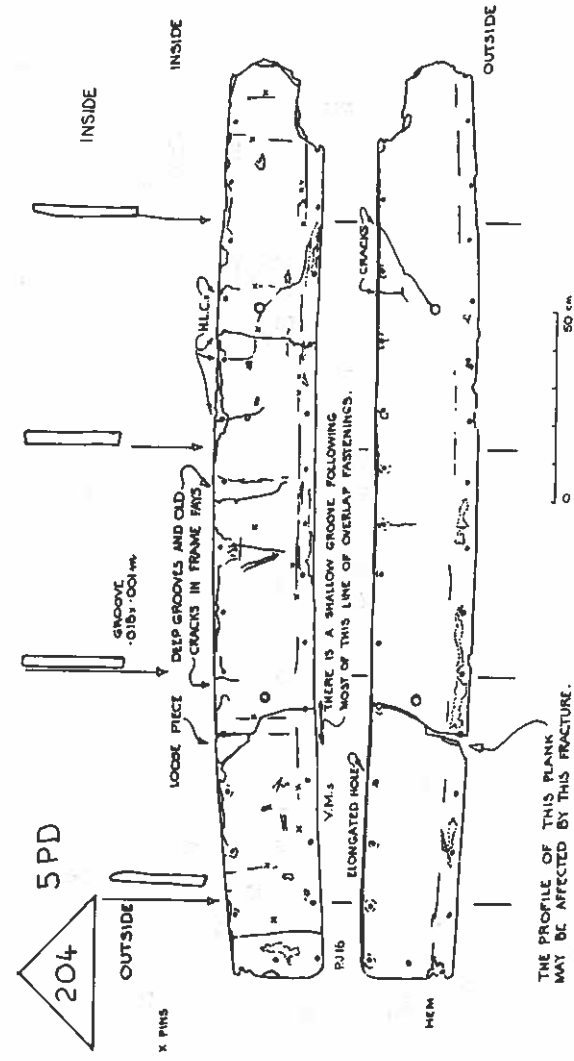


Fig. 3.2.7 Fifth strake port



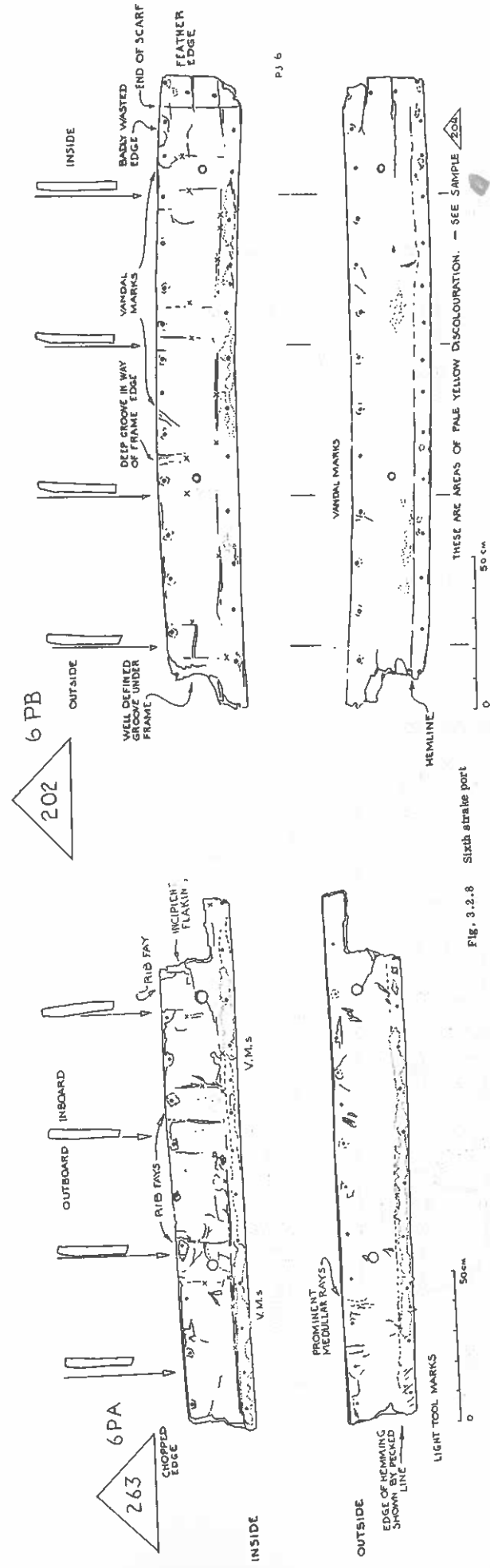
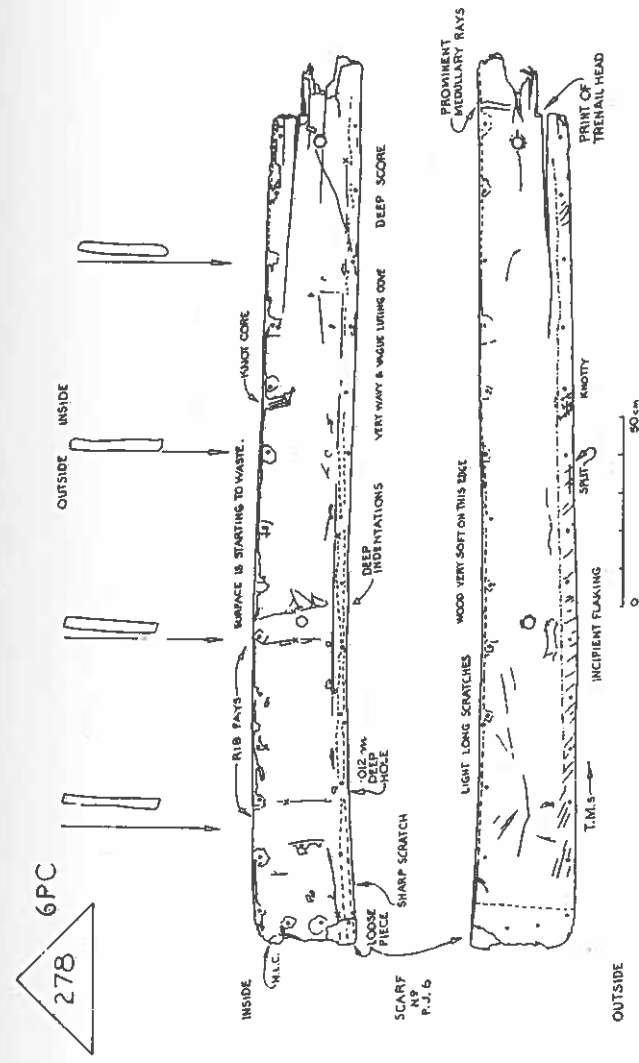


FIG. 3.2.8 Sixth airframe part



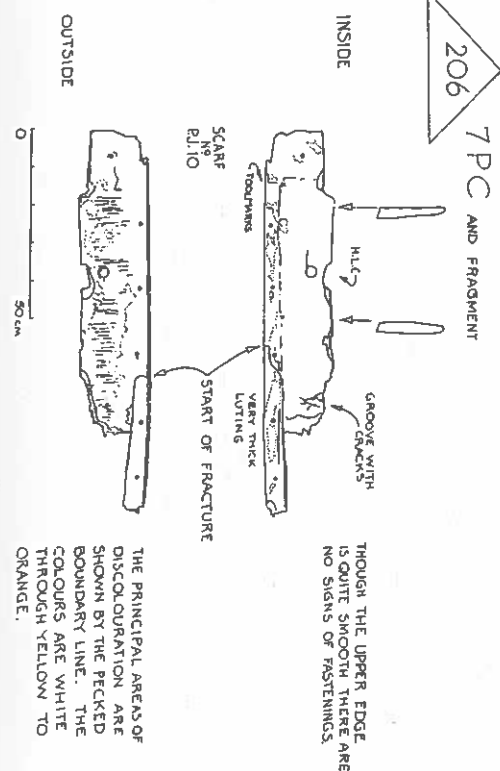
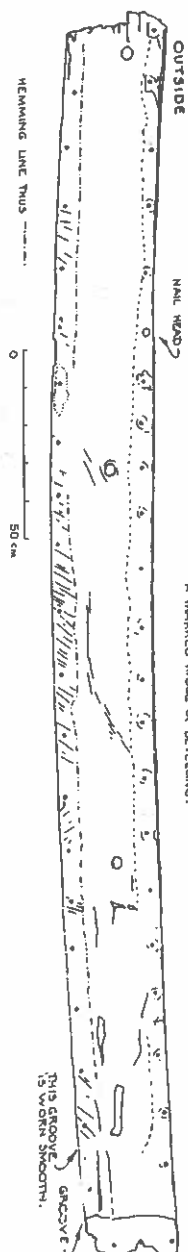
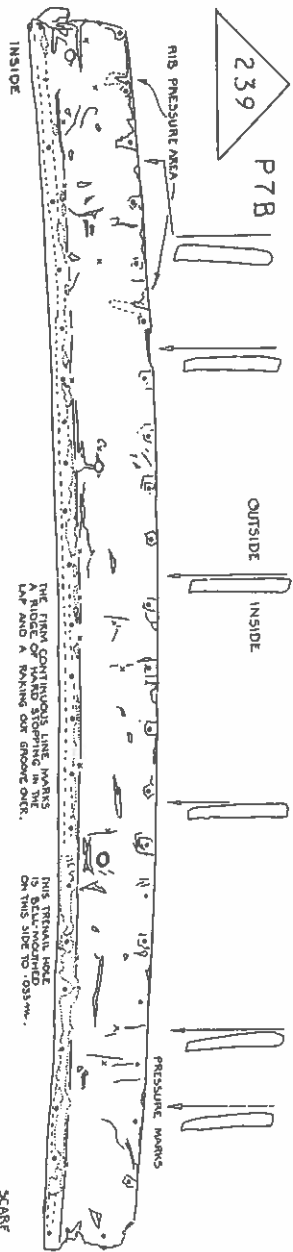
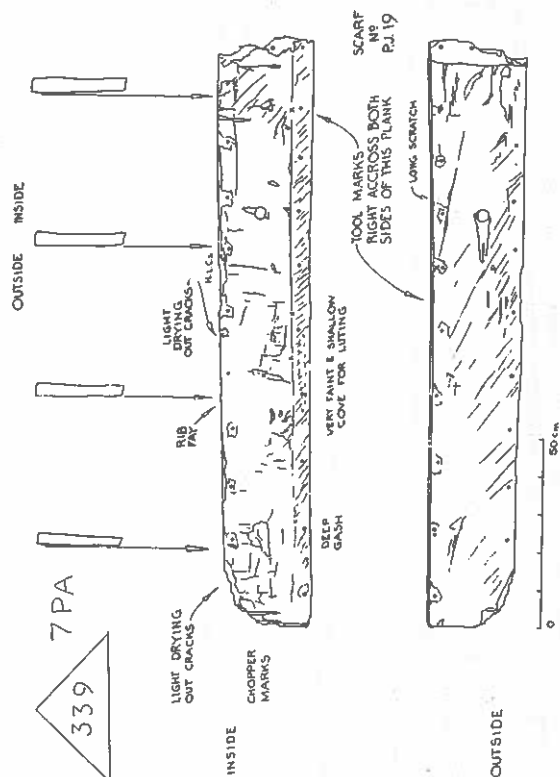


Fig. 3.2.8 Seventh strike post



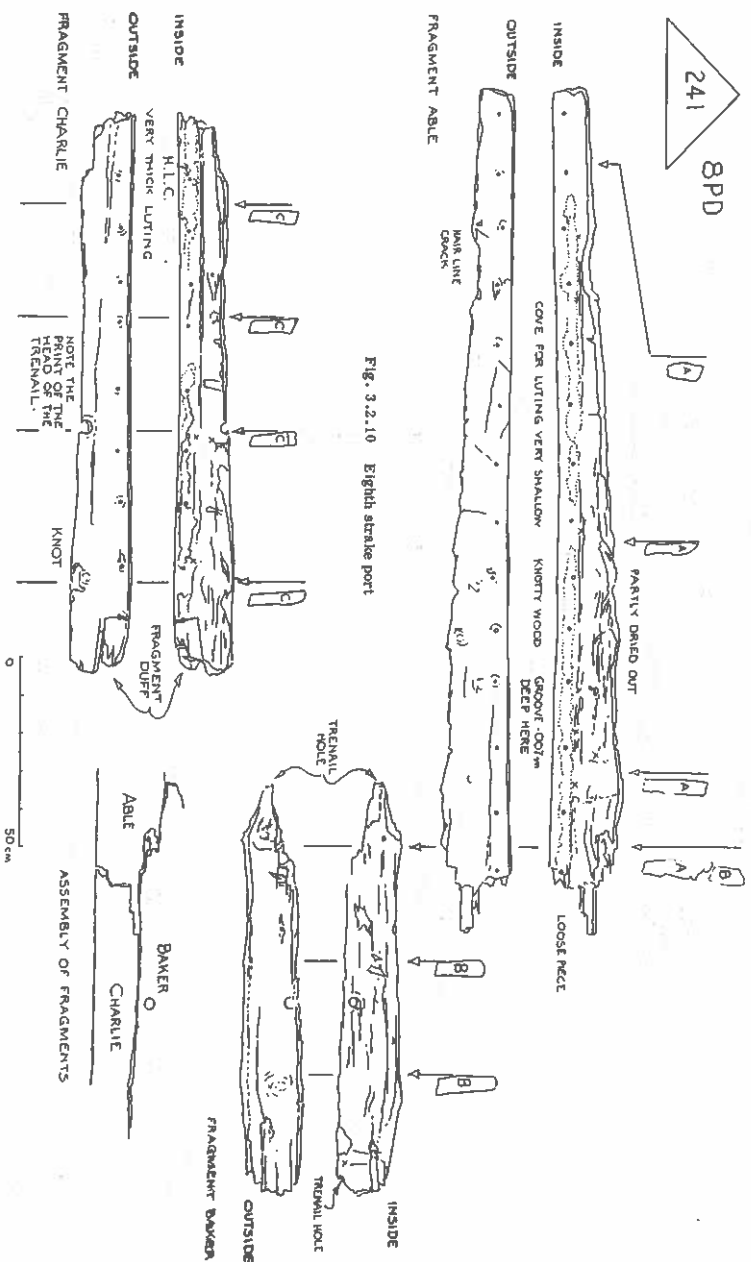


Fig. 3.2.10 Eighth strake port

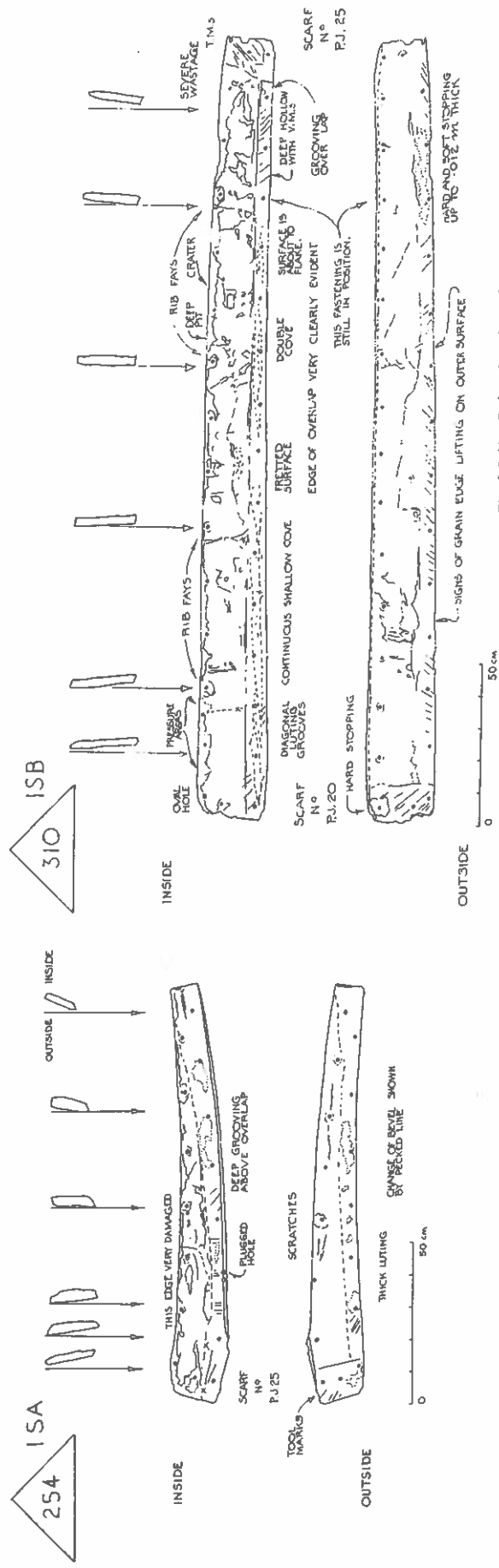
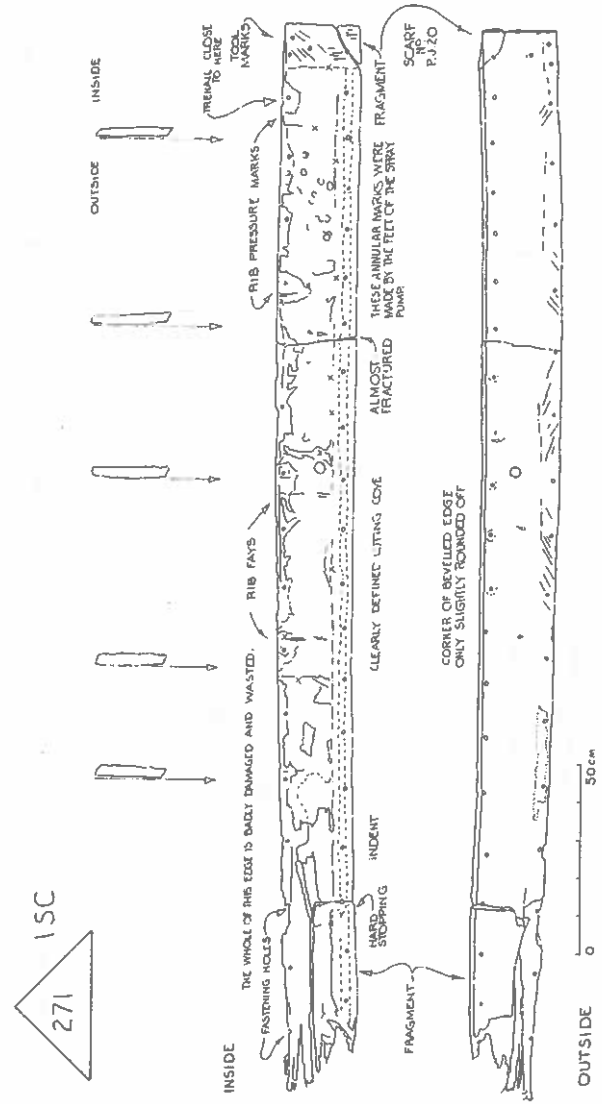


Fig. 3.2.11 Garboard strake starboard



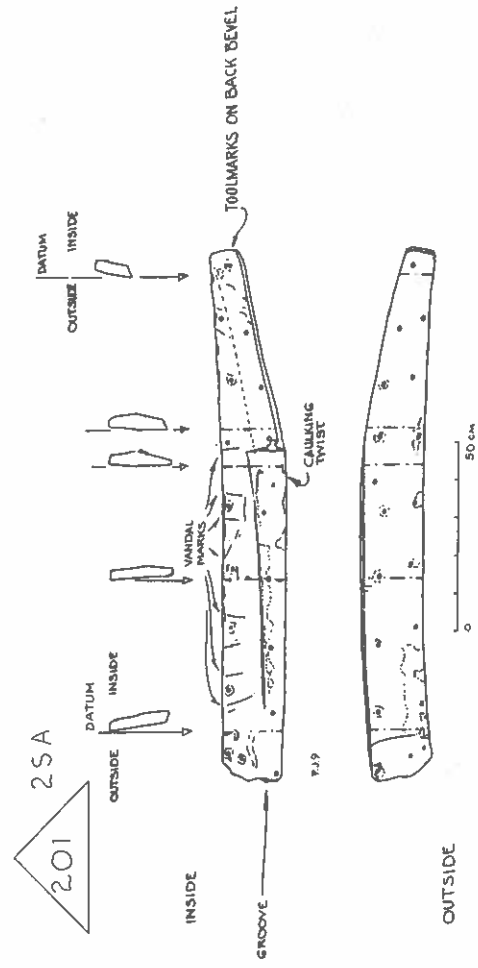
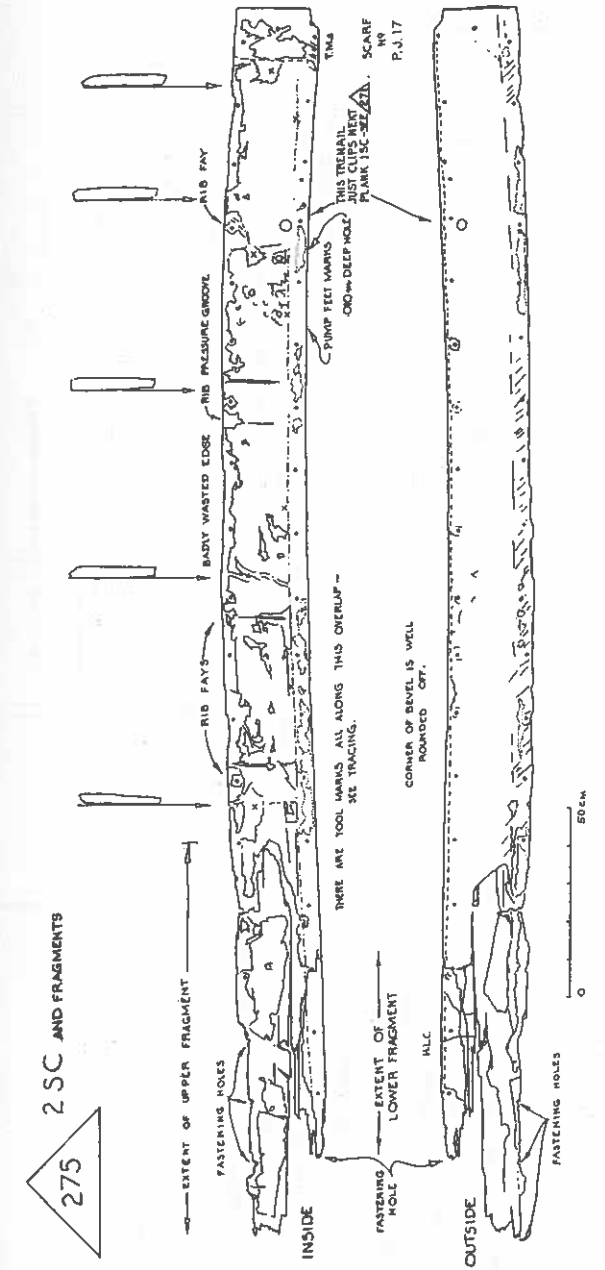
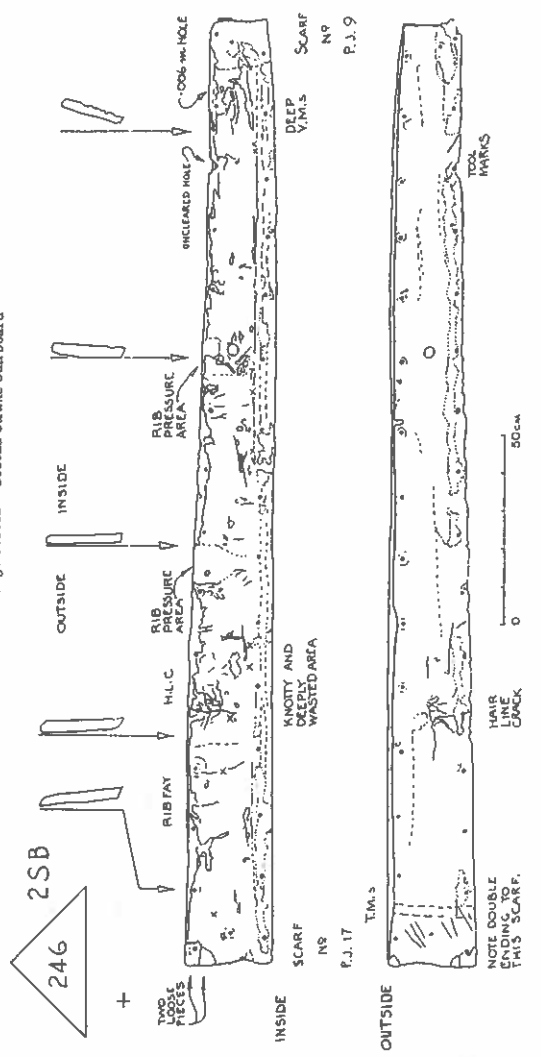


Fig. 3.2.12 Second strike starboard



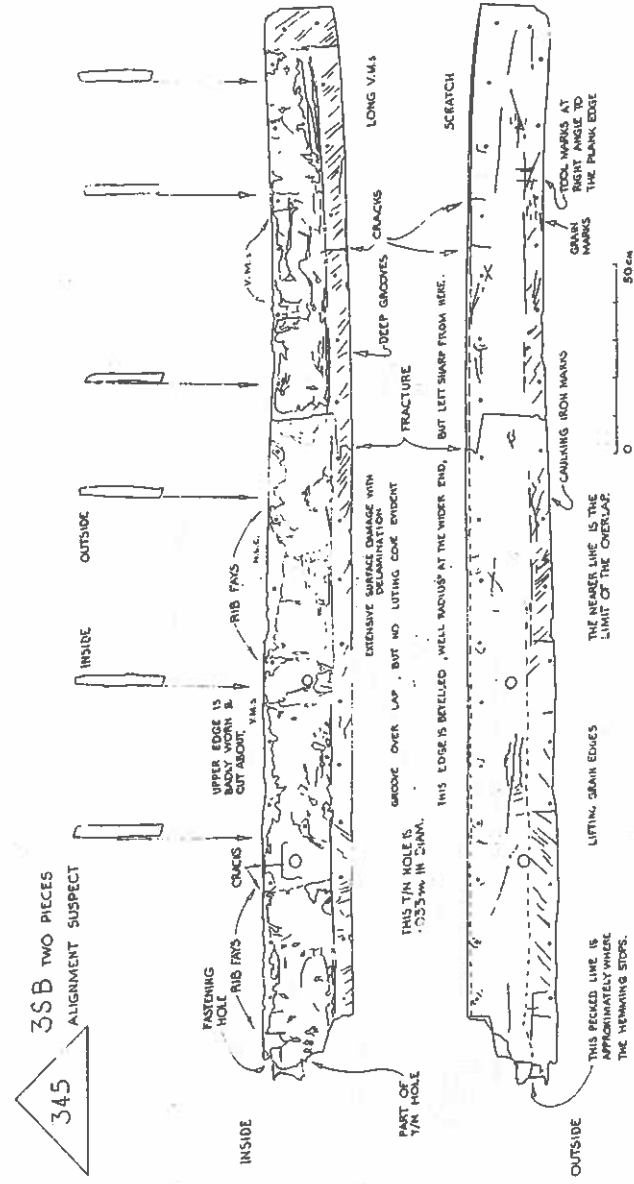
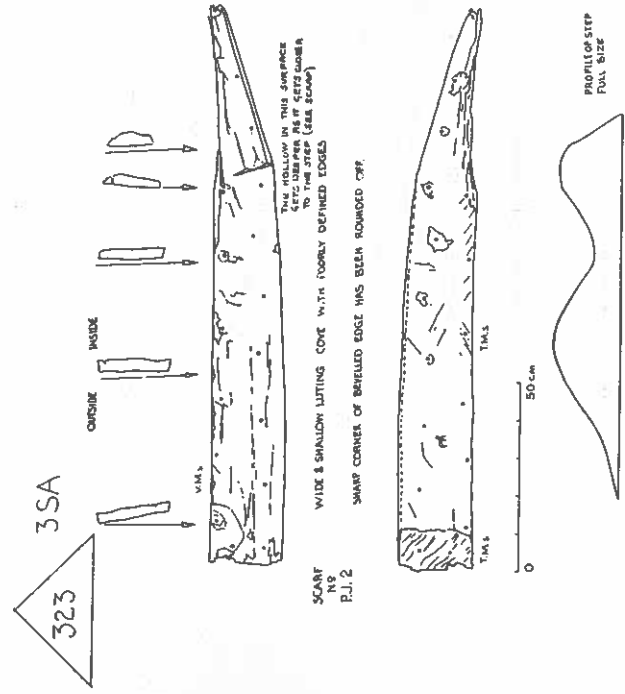
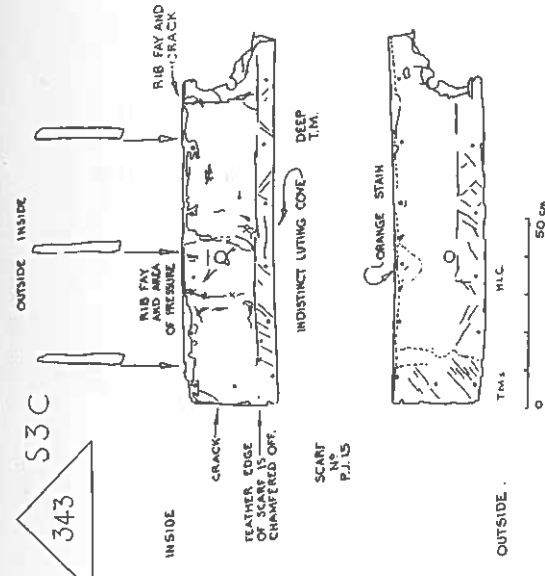
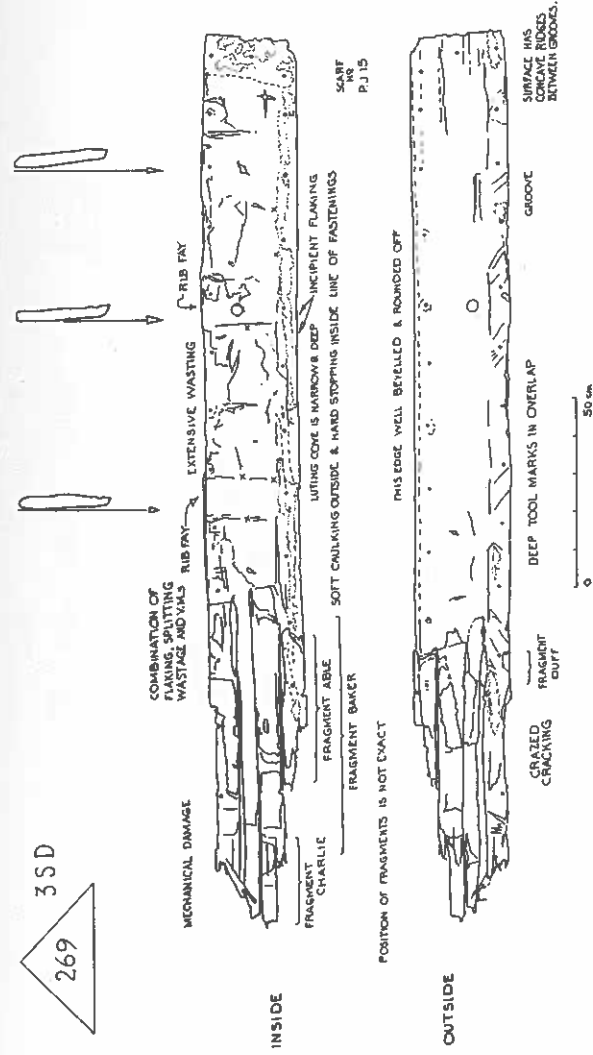


Fig. 3.2.13 Third strake starboard



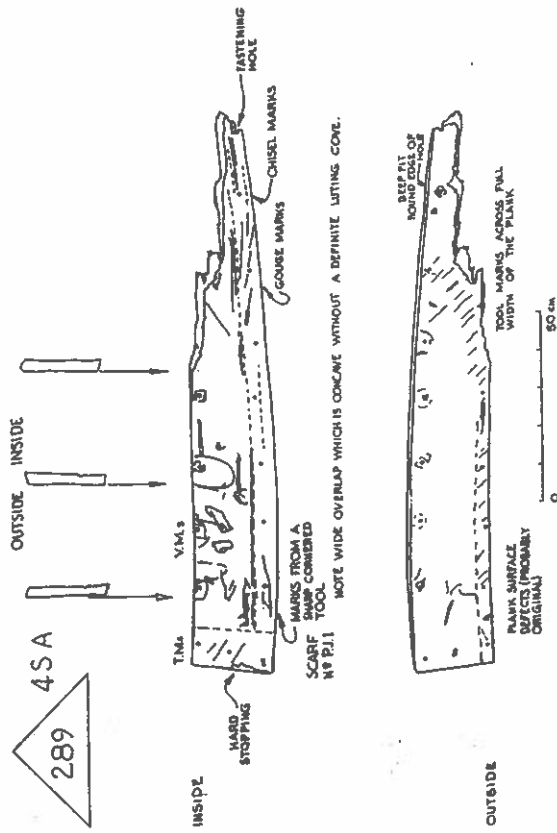
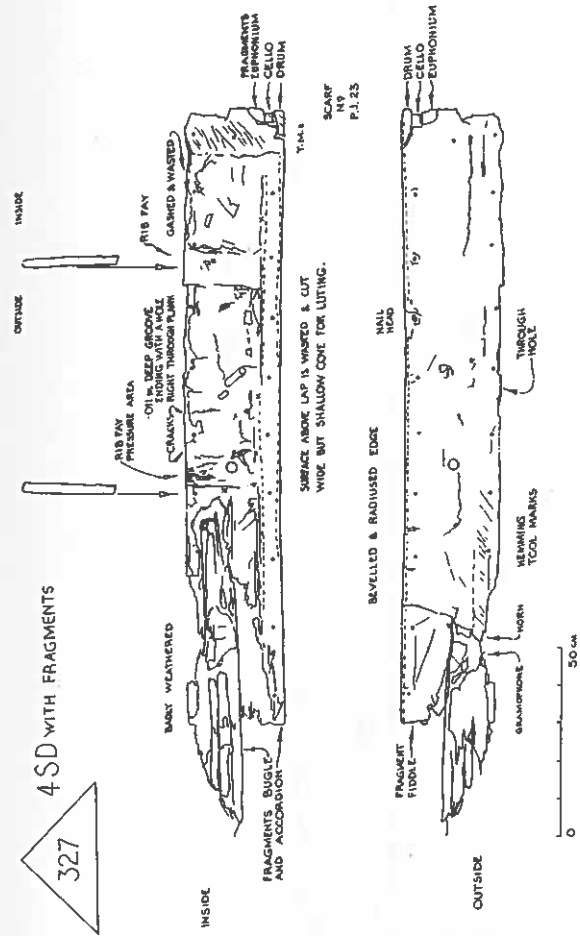
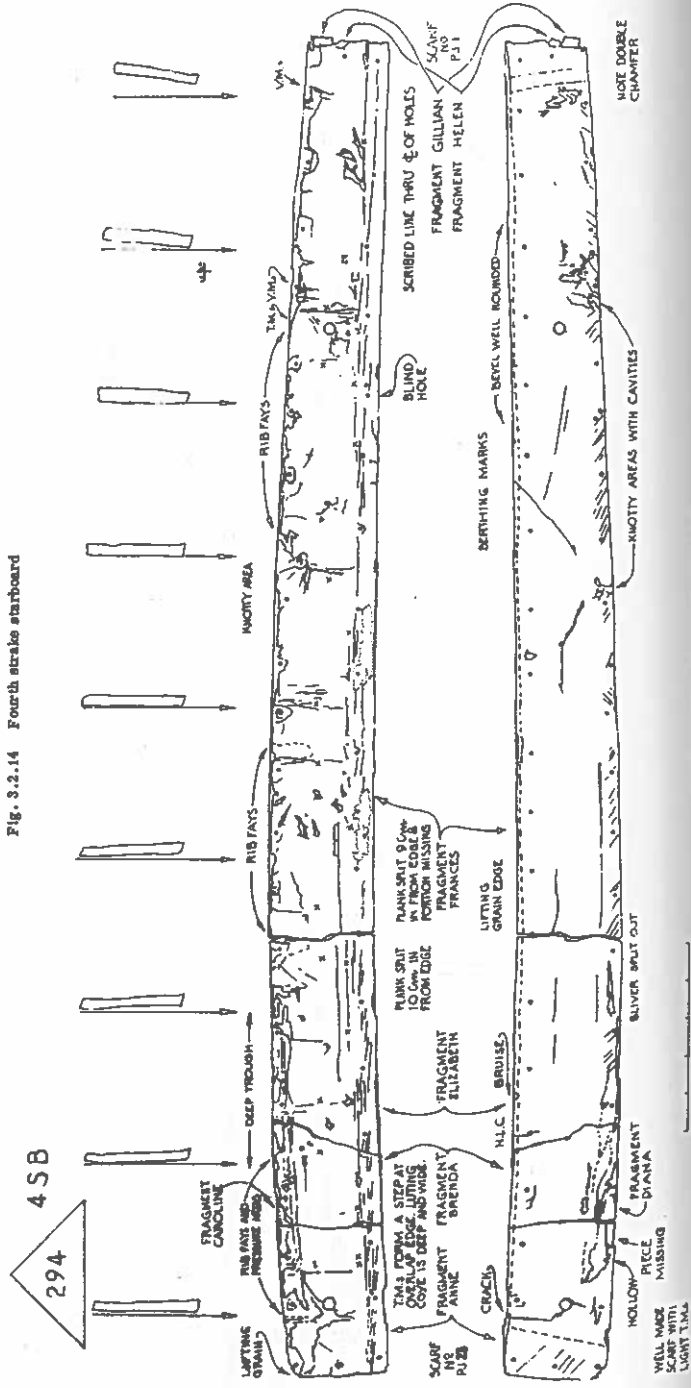


Fig. 3.2.14 Fourth strake starboard



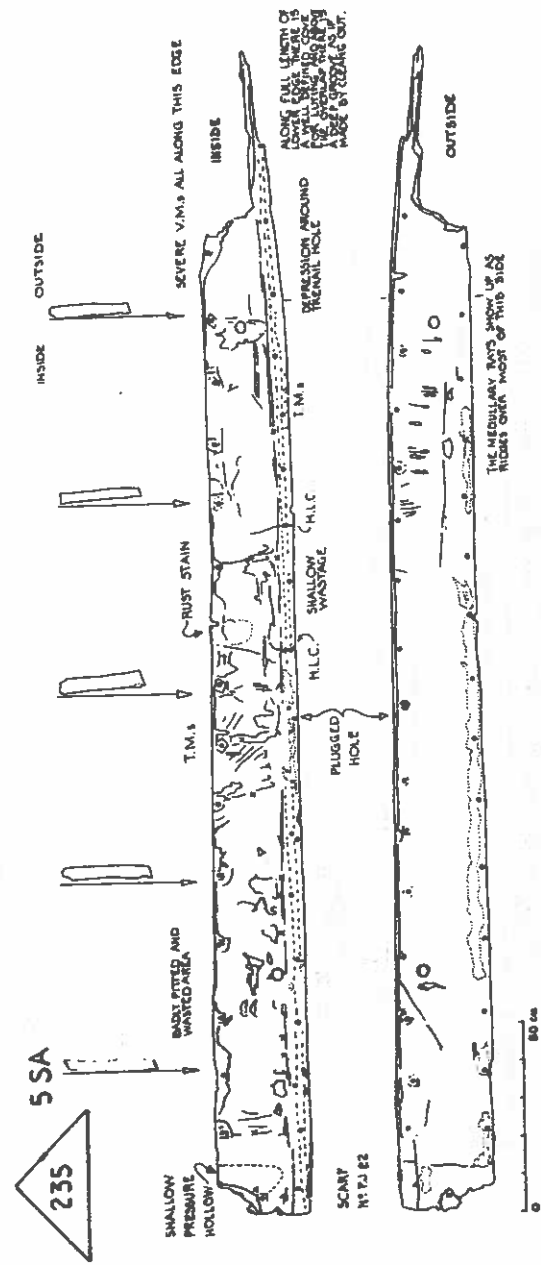
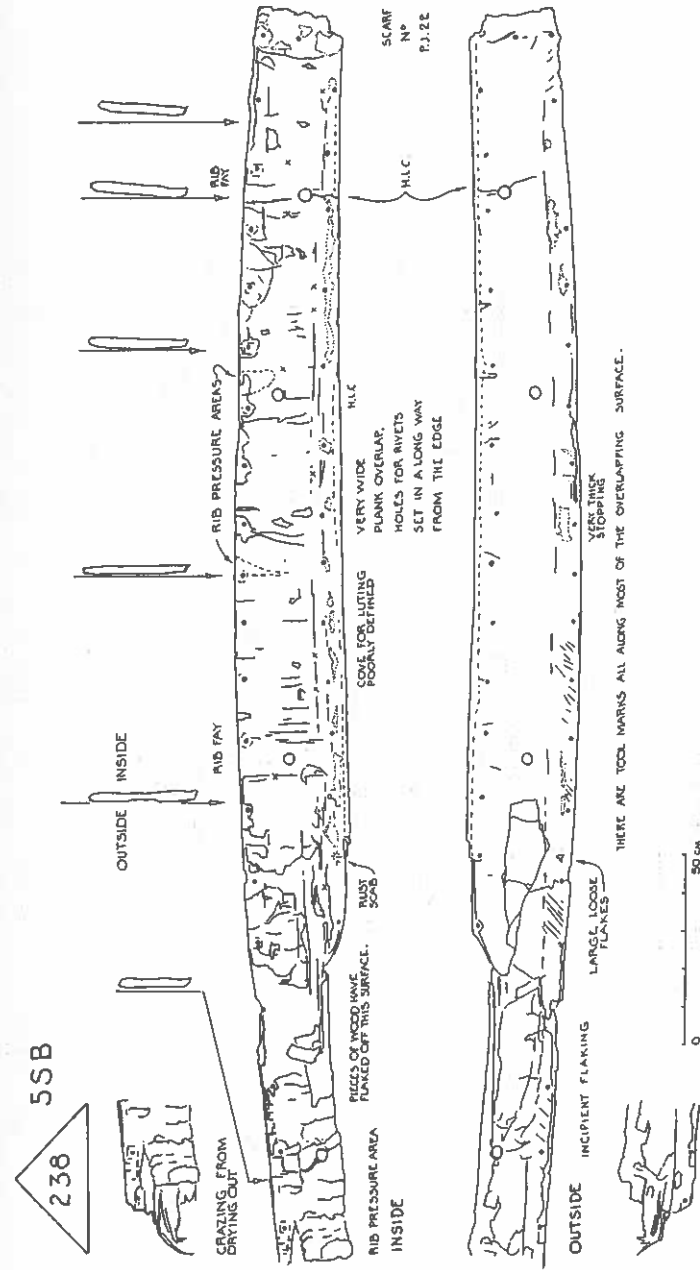


Fig. 3.2.15 Fifth strake starboard



232 6SA&B

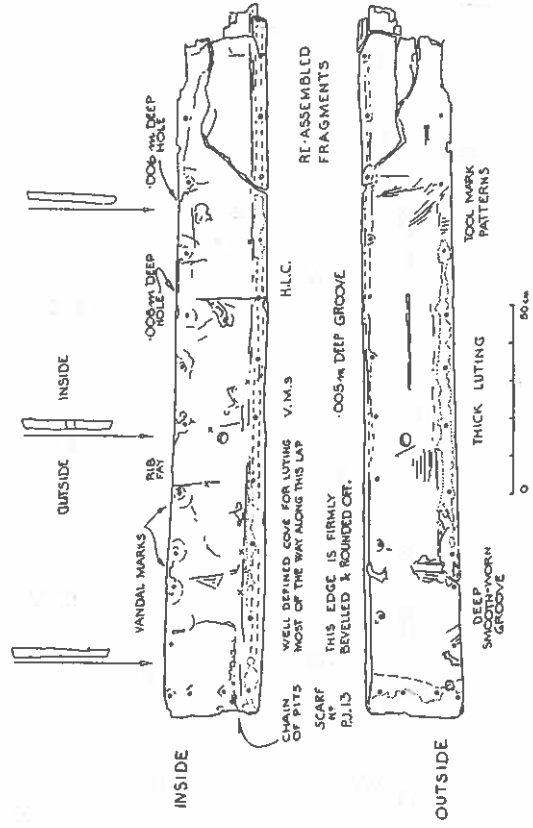
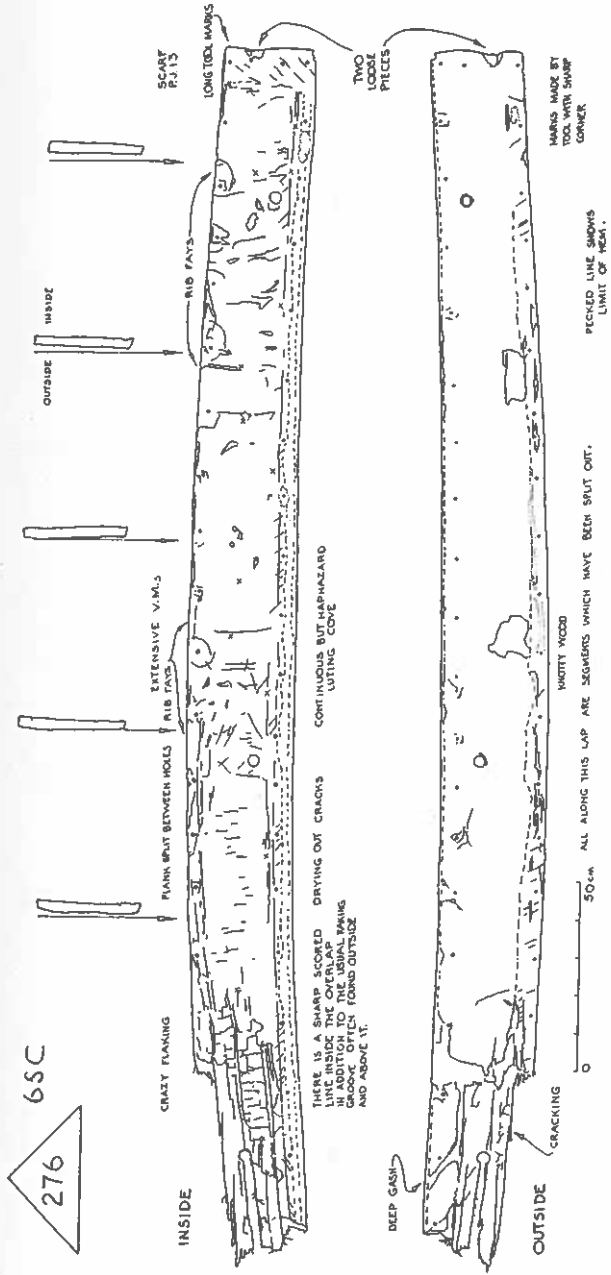


Fig. 3.2.16 Sixth starboard

276 6SC



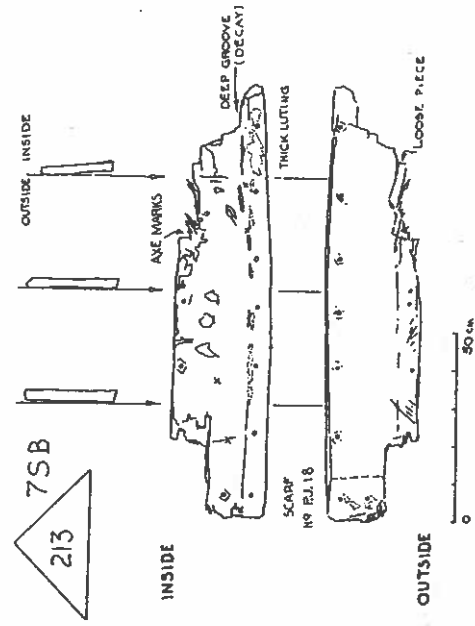
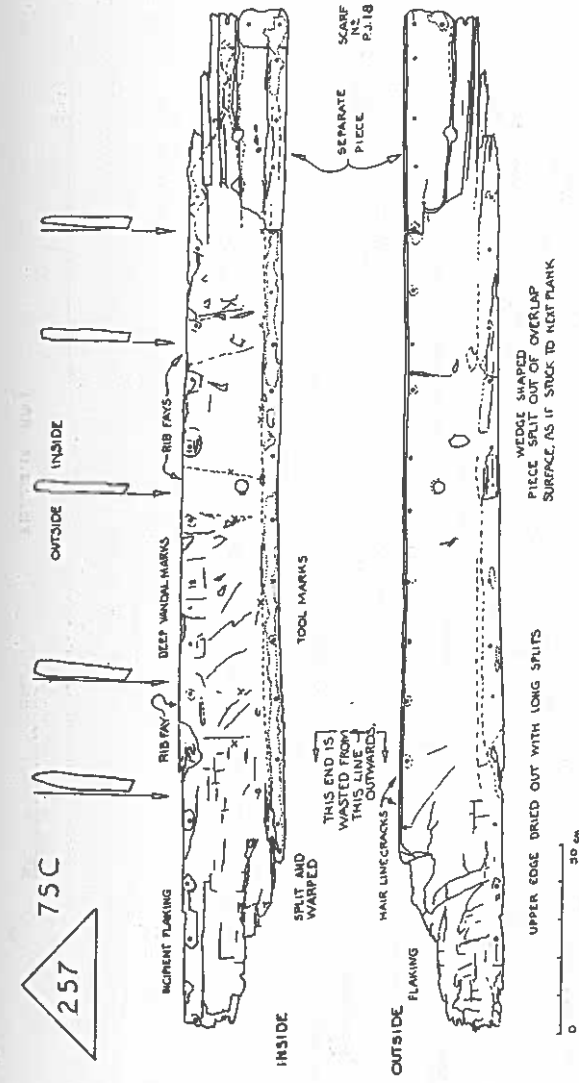


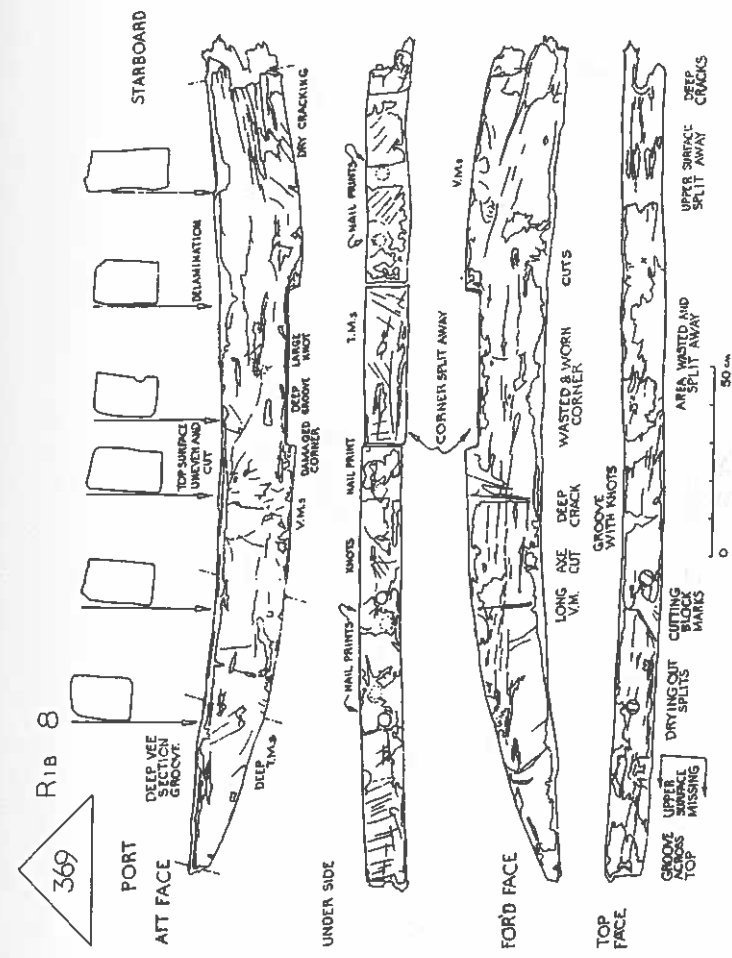
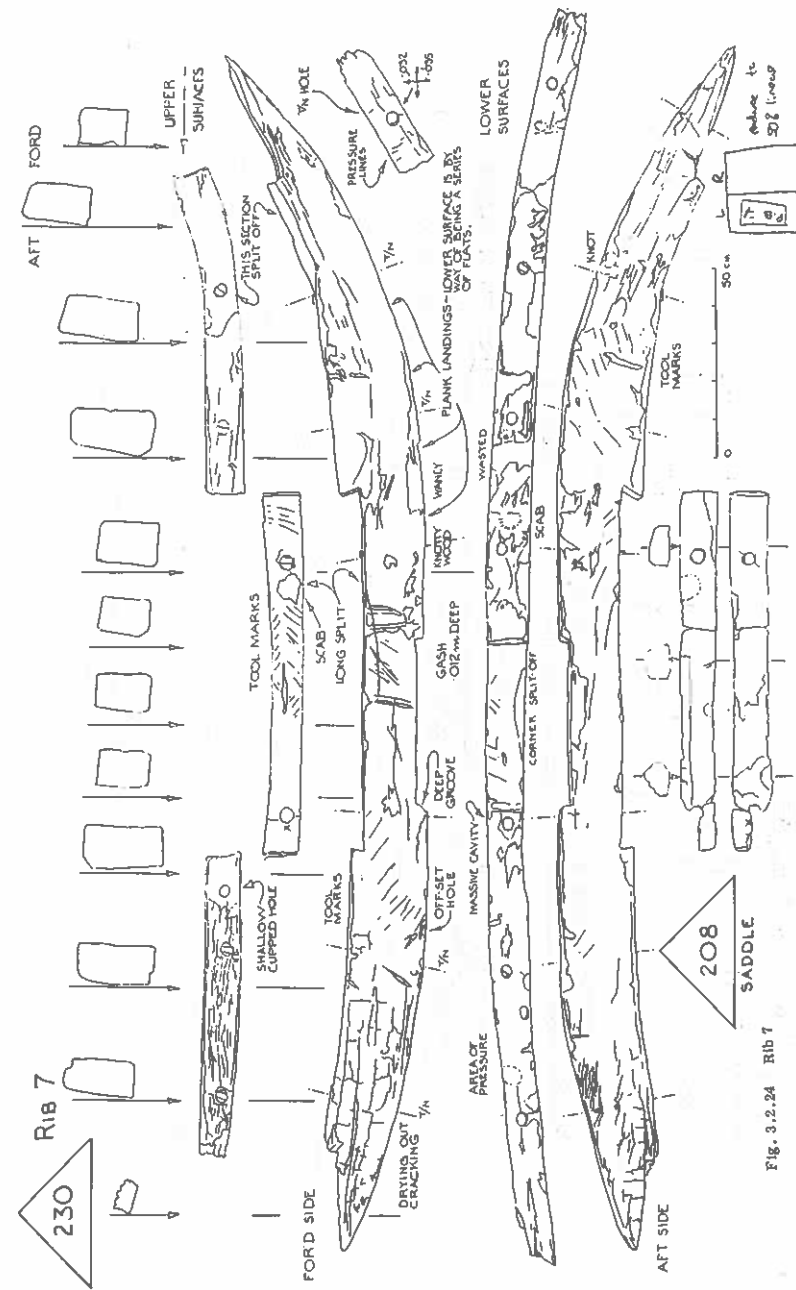
Fig. 3.2.17 Seventh strake starboard













## SPACING OF LAND NAILS

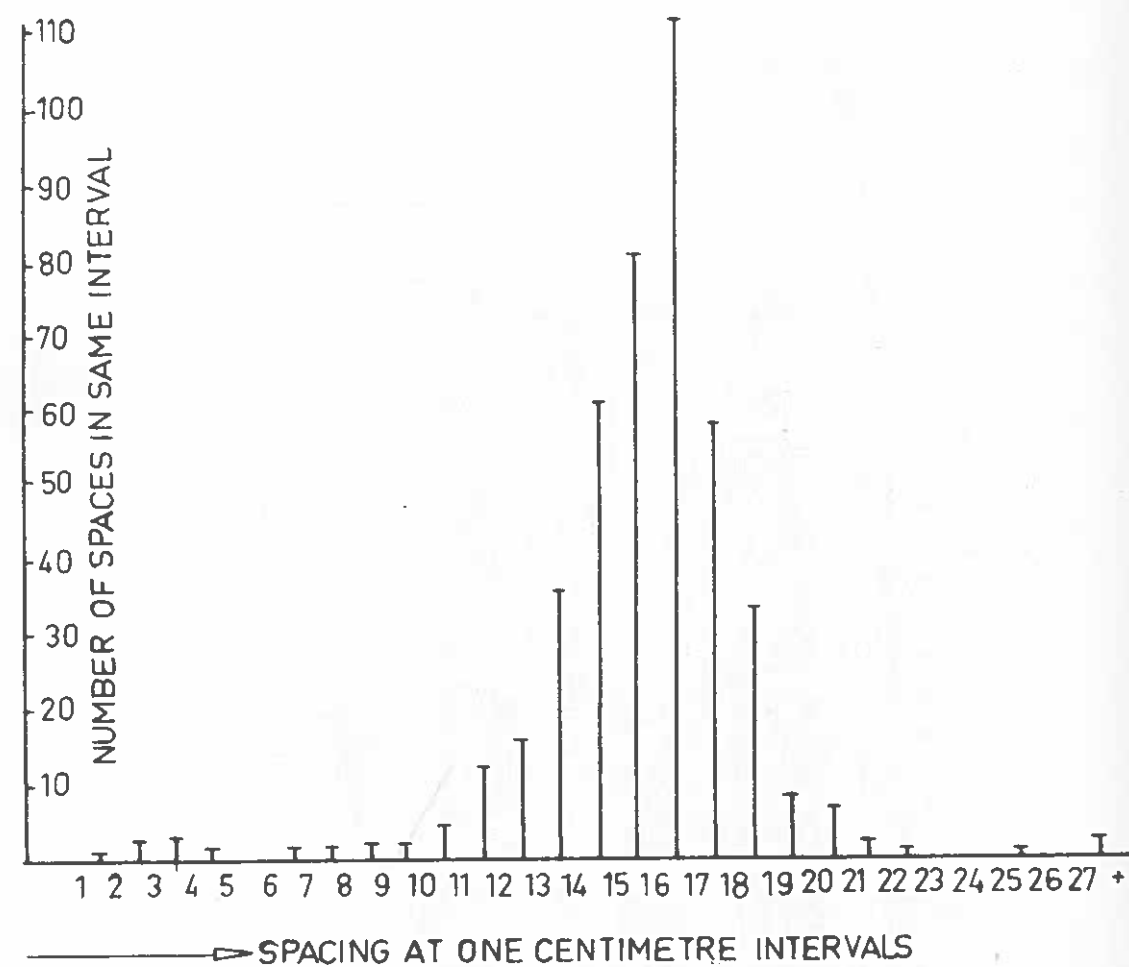


Fig. 3.2.28 Histogram to show the spacing of the nails used to fasten the planking. Drawn by Eric McKee  
© National Maritime Museum

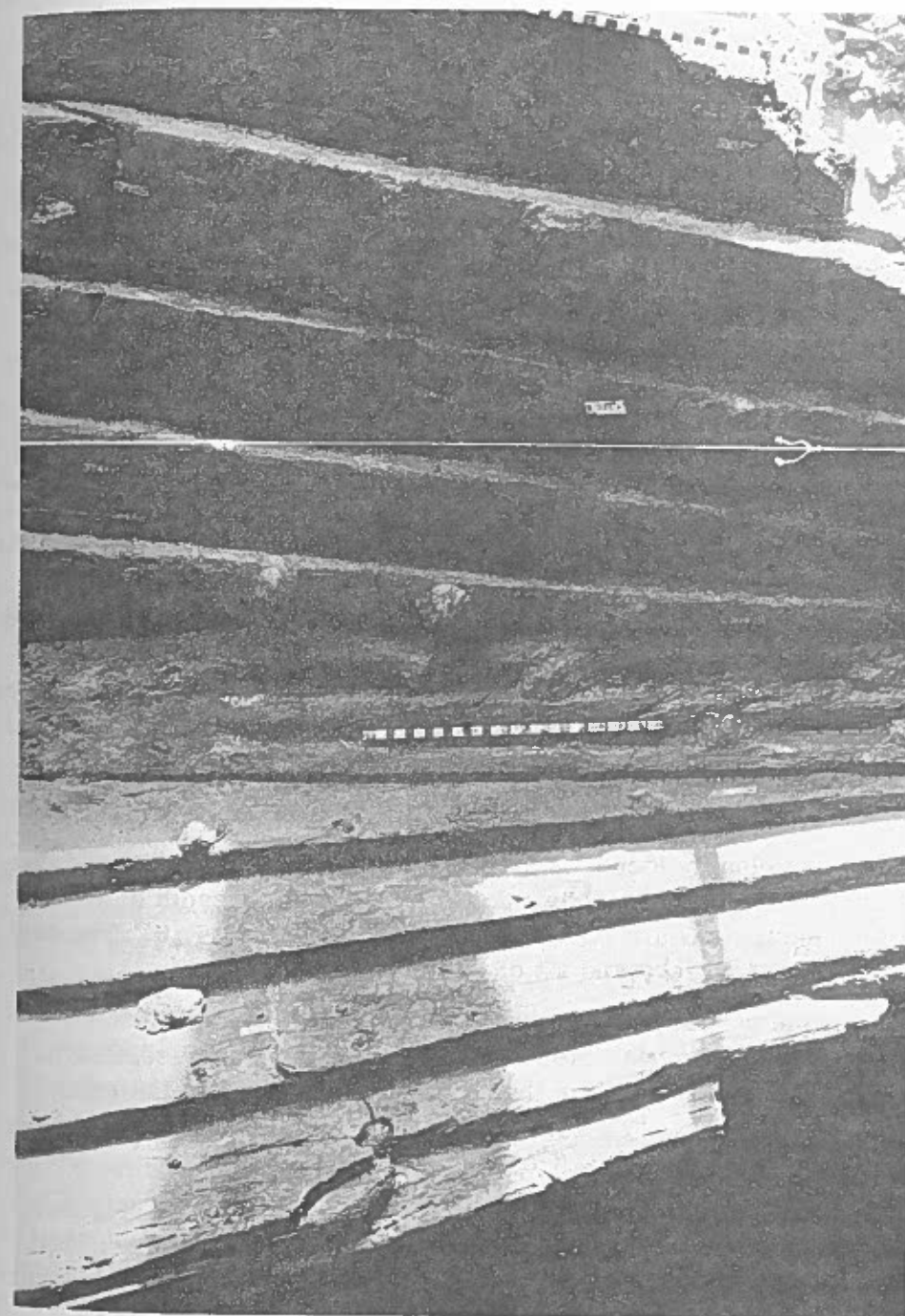


Fig. 3.2.29 Pressure marks and hair-line cracks on a line joining the left-hand end of the centimetre scales suggest that a transverse member was once fitted by the two trenail holes in the stern of the vessel. One can be seen in the middle of the plank below the upper scale; the other is at the bottom of the picture  
© National Maritime Museum

#### KEEL (Gr318; Fig. 3.2.1)

Of oak, the keel was a centre-line strake thicker than the rest, so hewn on the under side as to leave a central web between the garboards, deep enough to take the knocks and rubs of grounding and with enough material left at the end for cutting a box scarf for the sternpost. Like the other strakes the keel was broadest amidships, tapering towards each end. The foremost quarter of this component was missing.

The wood on the starboard side of sections E and F is waney, indicating that the largest possible breadth had been taken from the available timber. It seems that this tree trunk had to be 7 m long and 0.7 m in diameter.

The undamaged state of the port side of sections D and E gives a reliable shape for the inside portion of the keel. Apart from extensive localized damage in three places (sections C, D and E, section I, and the scarf), there is plenty of evidence to show the outboard shape of the keel. The smooth condition of the lower surface does not suggest heavy wear over a long period, unless berthing had been restricted to mud banks (Fig. 2.2.2). The shape of the transition of the under-keel shape into the sternpost rabbets shows craftsmanship of a high order. The asymmetry here suggests that a certain amount of fitting of the keel to the garboard hood-ends had been necessary.

The damage to the keel meant that its shape as found was of little use in determining either the rocker or the angle the sternpost made with it.

Rib fays 1-9 are clearly identifiable by the condition of the protected surfaces. Plotting station breadths shows that the maximum breadth of keel occurred between sections G and H, and this coincides with R.F.6. The keel appears to be symmetrical fore and aft of this station.

Also at this same station is a plugged hole, c. 0.025 m in diameter. A hole of similar size and also near the centre-line lies very near section B. These holes are significantly smaller than those used for trenail fastenings.

#### STERNPOST (Gr216; Fig. 3.2.2)

The sternpost is a flitch of oak, tangentially cut from one half of a tree trunk. This makes it probable that the sternpost would have been fashioned from the other half of the same trunk; hence it would have had the same overall dimensions and even much the same shape. To judge from the way the grain runs, the sternpost was cut to shape from a trunk almost as big as that used for the keel, rather than made from a crook which had grown to a suitable shape. The profile, with its gripe or barde, brings to mind Dutch estuary craft over many centuries (boijers, botters, hoogars, and shokkers for instance; Witsen, 1970). The gripe adds lateral water plane area, which shoal craft otherwise lack.

The workmanship in the scarf and rabbets is good by modern standards. The clenching grooves in the inboard face for the roves of the hood-end fastenings were only roughly made. Although smooth in finish the two sides of the sternpost are slightly different.

The three transverse holes through the upper end of the sternpost all appear to have been 0.025 m in diameter originally, although the middle hole is greatly enlarged and misshapen. There is a small hole in the apex of the chin or angle of the heel. The fastening-holes in the rabbets marry up with those in the hood-ends of strakes 1 and 2. Farther up, the lack of holes and inboard material makes the placing of plank-ends dependent on their shape and land-nails. Luting appears to have been used on the bearding surfaces of the rabbets (see p. 98).

#### PLANKING (STRAKES; Figs. 3.2.3-17)<sup>2</sup>

The run of strakes was only roughly symmetrical about the centre-line, with the top edges of strakes 4 and 6 being the most accurate in this respect. Although no forward ends of any strake were recovered, the way in which the strakes tapered forward of rib R6 makes it likely that the two ends were very similar. A little less than half of the original planking was recovered; this represented about two thirds of the number of strakes. Apart from being waterlogged and damaged near their boundaries the planks were in good shape.

#### Material and conversion

All sampled planks are of oak, breadths of up to 0.28 m being used amidships, S5B, Gr 238, and S6C, Gr 276 (Figs. 3.2.15-16) being examples of the broadest planks used. Up to and including strake 6 all planks were of much the same thickness. Although this varied considerably even in a single plank, it was evident that a common dimension had been sought; only difficulty in conversion had prevented it. Taking average figures from 180 sections, the top edge = 0.0275 m and the bottom edge = 0.0262 m. Allowing that the top edge had suffered reduction both from bevelling and from the severer wastage inboard, it appears that the planks were originally distinctly wedge-shaped with the thicker edge uppermost.

Strake 7, P78, Gr139 (Fig. 3.2.9) was thicker than those below it, having an average top edge of 0.037 m and bottom edge of 0.029 m, while S7C, Gr257 (Fig. 3.2.17) averaged 0.030 and 0.028 m respectively. Evidence from strake 8 is very meagre, but it looks as if this is another thick strake. Their measurements hardly qualify for the term meginhúfr or even wale for these strakes; they may have been more in the nature of binding strakes, made thicker by selection, to offset any weakness caused by the rib scarfs and extra trenails used at this level.

The wedge section of the planks strongly suggests the use of radially split clove-board for the skin of this boat. The following evidence contributes to this view. The medullary rays in Gr235 and 263 (Figs. 3.2.8, 15) and the axis of a knot-core lie in the same plane as the plank surface of Gr278 (Fig. 3.2.8). Most planks are free of knots, being clear run stuff with a slight

wave in the surface. A few planks had knots or knotty areas (Gr246, 276, 278, 292, 294, 346; Figs. 3.2.4, 6, 8, 14, 16), mostly lying in strakes 4 or 6 amidships. It is unlikely that the knots gave the clovier much trouble as they are close to one or other edge.

Although lifting grain edges suggest that some planks had been split tangentially rather than radially (e.g. P4D, Gr292, and S1B, Gr310; Figs. 3.2.6, 11), subsequent sectioning for dendrochronology has shown that most were split radially. Delamination and flaking often found in the forward limit of the strakes is thought to be due to the total breakdown of the cellular structure of the wood, rather than the effect of the natural growth rings in it.

#### Shape

The shape of a clinker boat comes from the shape of the strakes as marked out by the run of the nails. Secondary to this, the hemming or bevel applied to the top land of the lower plank stabilizes the structure and enables the laps to be made watertight.

#### Laps

As the width of the lap varied, the shape of the outside edges of the planks would not adequately indicate the form of the boat. For this reason the greatest care was taken over the position of fastenings.

The varying thickness of the planking must have raised problems not met with in the sawn and planed boards used today. Wood to wood joints were not often possible, as they would have involved the removal of so much material that boats would have been weakened in the vital overlaps. The difficulty was overcome by the insertion of a strand of wool treated with vegetable tar between two planks before they were assembled.<sup>3</sup> Soft stoppings retain their pliability, whilst hard stoppings set hard. Luting where the material was found completely surrounding nail holes was very common. In all, soft stoppings had been used (Gr203-4, 232, 235, 239, 241, 246, 254, 257, 265, 271, 275, 284, 290, 294; Figs. 3.2.5, 7, 9-12, 14-17). Some of this luting was so tenacious that slivers of wood had been pulled out of one surface, when the planks were separated (Gr257, 276, 290, 294; Figs. 3.2.5, 14, 16-17), and it must have helped hold the boat together after the iron nails had rusted away.

Most laps were supplied with a shallow groove, cut along the nail line of the inner and lower surface. The purpose of this groove, it is assumed, is to retain the luting. As no word has yet been found in modern English for this feature, the term 'luting cove' was coined. Well-defined examples of this feature may be seen in many planks, most of which lie amidships (Gr204, 232, 235, 239, 243, 246, 263, 269, 271, 276, 284, 294, 310, 325, 327, 337, 346-7; Figs. 3.2.3-9, 11-16). In some the cove is weak, very shallow or indeterminate (Gr238, 241, 257, 287, 289, 291, 339, 342-3; Figs. 3.2.3, 5, 9-10, 13-15, 17), while in some there was no cove (Gr213, 275, 292, 345; Figs. 3.2.3.2.6-7, 12-13). These omissions look more like carelessness than intention, but to some extent the impression given is that above strake 6 preoccupation with getting the joints watertight decreased.

The presence of thick, hard or soft, stopping near the edge of a lap, especially if the surface is uneven or damaged, indicates that the seam has been

caulked to stop a leak (Gr203, 238-9, 310; Figs. 3.2.7, 9, 11, 15). Only on one plank were there marks which looked as if a caulking tool had been used (S3B, Gr345; Fig. 3.2.13). In Gr269, 291 and 325 (Figs. 3.2.4, 13-14) a mixture of hard and soft stopping had been used (but see p.185).

It seems that there is some relationship between luting coves and hems, as most of the planks with luting coves were also hemmed (Gr204, 239, 257, 263, 269, 271, 275-6, 284, 325, 327, 337, 342-3, 345-7; Figs. 3.2.3-6, 8-9, 11, 12-14, 16-17).

#### Scarfs (plank-joints)<sup>4</sup>

The planks in a strake were joined end to end by simple tapered scarfs with feather edges inside and outside. They were carefully made with true flat surfaces, which, though averaging 0.11 m in length, varied between a maximum of 0.133 m and a minimum of 0.093 m. The scarfs were staggered to avoid too many joins on the same station, but they were much closer than would be acceptable today. All except P.J. 1 and 6 faced the same way. It is usual to have the outer feather edge aftermost so that the flow of water does not run up the join. This is the principal reason for identifying the recovered post as the stern.

The reason for the two exceptions is puzzling. Their position, one at the last plank of S4 and the other between two intermediate planks in P6, does not offer a clue. It is not likely that either is a repair, as the planking pattern is not interrupted by them. As there is other evidence of slip-shod work, it is possible that they were mistakes.

Two scarfs have a double chamfer on one of the planks being joined, P.J. 1 on Gr294 (Fig. 3.2.14) and P.J. 17 on Gr246 (Fig. 3.2.12), in both on the thicker plank of the two. There are signs of several other partial double chamfers. In all it looks as if the taper had been cut away from the boat, but offering up had shown that a correction was necessary.

Most scarfs are fastened with three nails, one through each land, top and bottom, and an extra one through the middle of the scarf. As was so elsewhere, there are exceptions. Some scarfs, P.J. 4, 10, 13, 22, have four nails, the two extra ones being through the middle of the scarf. P.J. 7 and 20 have three land-nails, two in one land and one in the other. P.J. 2 is fastened with two nails only.

Nearly all scarfs had been luted before assembly, traces of soft stopping having been found on both sides of some (P.J. 9, 16-18, 32) and on one side of others (P.J. 6-7, 10, 12-15, 20-1, 25). Although nothing was found on the remaining eight scarf faces, the stopping may have been displaced before examination. It is safe to say that the scarfs in the under-water body had been luted.

#### Edges

The bottom edges of all strakes had been generally bevelled and then rounded anywhere where the edge might have rubbed when grounded (Gr232, 269, 271, 275-6, 278, 284, 291-2, 294, 310, 323, 327, 343, 346; Figs. 3.2.5-6, 11-14, 16).<sup>5</sup> Towards the stern the bevelled corner was left sharper (Gr203, 206, 213, 235, 246, 257, 287, 289-90, 325, 337, 342; Figs. 3.2.3-5, 7, 9, 11-12, 14-15,

17). In Gr202 (Fig. 3.2.8) the bottom edge is quite square. As the top edges had been exposed on the inside of the boat, they were so damaged that their original shape is not clear.

#### Hood-ends

The hood-ends are smaller and more carefully made than the intermediate planks. The technique used for them is one which I had not seen before. It is possible that a similar ending was used in Blackfriars III (Marsden, 1972), but no account of this detail has yet been published.

Six hood-ends were recovered, all from the after end of the first three strakes. It was only when they had been taken apart that they were seen to be unusual. They have been described in detail elsewhere (pp. 229, 236). Although their points had been cut off (or nibbed), they all differed in some way or other.

1st strakes (garboards) (S1A, Gr254, and P1A, Gr274; Figs. 3.2.3, 11) had slight reversed curves in their bottom edges, and no luting coves in the lap with the keel.

2nd strakes (S2A, Gr201, and P2A, Gr324; Figs. 3.2.4, 12) were both stepped to fit the nibbed garboards. Although the luting cove is only faint on the starboard side, it is clear on the port; the surface faying with the rabbet in the sternpost has an exaggerated luting cove to port, but none to starboard. There are no reverse curves on the bottom edges.

3rd strakes (S3A, Gr323, and P3A, Gr290; Figs. 3.2.5, 13) were both stepped. Again the luting cove to starboard is weak but strong to port. Both sides also have exaggerated luting coves in their rabbet fays. The port bottom edge has a reversed curve with a very slight one to starboard.

### FASTENINGS

With the exception of two double-drilled blind trenail holes for the saddles on R5 and 6, all under-water iron and wooden fastenings passed through all components being joined and had positive securing devices at both ends. It was evident that there was no dependence on interference fits below the water-line.

#### Iron

Little remained of the original iron fastenings except the corrosion products, which were removed for analysis. However there was a good example of a nail point riveted over a rove in P1A, Gr274 (Fig. 3.2.3), while in S4D, Gr327 (Fig. 3.2.14) and P7B, Gr239 (Fig. 3.2.9) there were nail heads. Prints left by the metal on the surface indicate that these few remains were typical enough: the roves, although all of much the same size, varied in shape from symmetrical lozenges to quadrilaterals with no two sides the same length. They seem to have been cut from wrought iron sheet, 0.003 m thick.

Examination of the nail holes indicate that the nails were square in section with 4 mm sides. The holes were plugged with the nails driven through the centre of the plugs. S4B, Gr274, shows one of these clearly.

The condition of the surrounding wood suggests that three of the nails had been hardened up (P3B, Gr287, S4A, Gr289, and P4D, Gr292; Figs. 3.2.5-6, 14). This further suggests that the boat had not been in use long enough for the overall hammering up of fastenings that heralds the onset of nail sickness.

Spacing between the nails was analysed by constructing a histogram with 1 cm intervals (Fig. 3.2.28). Out of 439 spaces, 308 lay between 14 and 18 m, with 111 between 16 and 17, giving an average of 16 m. It was evident that the builders had used their judgement rather than any gauge, and had pitched the nails more closely where they felt it was necessary. Excluding holes that had been plugged or not fully drilled, there were several instances of holes being drilled very close together indeed (Gr213 and 301, Figs. 3.2.17; Gr206 and 346, Figs. 3.2.6, 9; Gr235 and 294, Figs. 3.2.14-15; Gr284 and 337, Figs. 3.2.4-5; Gr292 and 284, Figs. 3.2.5-6; Gr275 and 271, Figs. 3.2.11-12; and the double land-nail in P.J.20). These are scattered over the boat and do not seem to be related in any way to the structure. In P2B, Gr325, and P4C, Gr346 (Fig. 3.2.4, 6) it looks as if nails had been left out in error; these spaces have been left out of the analysis.

#### Wood

The trenails<sup>6</sup> were willow and were wedged with oak. The holes for them were of a standard size. Their diameters are given on the full-size tracings. It is thought that only one auger had been used throughout; it produced a true round hole, 0.029 m in diameter. Sizes up to 0.031 m were due to wear and working of the trenail in its hole. One hole, in S3B, Gr345 (Fig. 3.2.13), measures 0.033 m; it is an extreme case of a bodgered hole for trenail TR353.

The trenails all had knobs at their outboard ends. It looks as if the cutting of the cylindrical shafts had been stopped so as to make shoulders at these ends. After fitting, the shoulder was sometimes supplied with a grommet, and the trenail was driven from outboard with sufficient force in some places to leave prints in the plank (Gr241, 257, 278; Figs. 3.2.8, 10, 17). When the trenail was home, its inboard end was cut flush with the inside face of the rib and a wedge hammered into its shaft to secure it positively from moving outboard. Finally the bruised wood of its head must have been trimmed as small as possible, so that it looked like a roughly cut gem.

In addition to the diagonal pattern formed by trenails fastening alternate strakes and ribs, there were more trenails for the rib saddles, rib scarfs and, probably, for a pair of risings as well. The only trenails in the garboards are those associated with the saddles, while none pierce the keel. The blind trenail holes in R5 and 6 would have had to go through the keel if they had been for through-fastenings.

The trenails were not always in the same position in relation to the edge of the plank, although they were mostly in the lower part of the plank, where the gap between the plank and anunjoggled rib would be greatest. This seems to be a weak arrangement. Two holes cut the top edge of the next plank below (S1C, Gr271, and S2C, Gr275; Figs. 3.2.11-12). In P2B, Gr325 (Fig. 3.2.4), on the other hand, the hole is close to the upper lap.

There are a number of holes in planks for which no corresponding structure was recovered:

- a. Five holes between 0.029 and 0.031 m in diameter, whose position suggests that the one in Gr203 (Fig. 3.2.7) is for TR10P5, in Gr278 (Fig. 3.2.8) for TR11P6, in Gr206 (Fig. 3.2.9) for TR10P7, in Gr337 (Fig. 3.2.9) for TR2P7, and in Gr241 (Fig. 3.2.10) for TR8P8.
- b. In P1A, Gr274 (Fig. 3.2.3), a hole, 0.025 m in diameter, is probably for a bung. It looks to be too close to the sternpost to have been used to secure any part of the structure. It is an added source of weakness at a critical position near the scarf between the keel and the sternpost, and must have contributed to the fracture of both the plank and the scarf.
- c. S5A, Gr235, and P4A, Gr346 (Figs. 3.2.6, 15) both have a hole, about 0.031 m in diameter, on the same station. Pressure marks and fractures point to a transverse structural member having once been fitted here (Fig. 3.2.29).

#### RIBS (Figs. 3.2.18-27)

The ribs are remarkable both for their size and for the way they turn and twist out of square. It must have been very difficult to make and fit them. Some of the bruising and even cracking of the inside of the planking seems to have been caused by the uneven bearing of the ribs in the shell.

The sampled ribs are of oak, which mostly lies along the same axis as the shape of the rib. Waney corners in three ribs, R1, 2 and 6 (Gr314, 228, 355; Figs 3.2.18-19, 23), bear this out and show that the butt of the branch or trunk lies towards the longest arm of the rib. In the horns of two ribs, R9 and 10 (Gr354, 227; Figs. 3.2.26-7) the grain does not run true and has been the source of fracture.

Only R1 is fully jogged over the planks. R2 has near joggling with tool marks showing that this is not merely the result of pressure. In R3 (Gr366; Fig. 3.2.20) the degree of joggling is less again, while in R7 (Gr230; Fig. 3.2.24) there is no more than a series of flats.

Saddles were fitted to R5, 6 and 7 (Gr364, 355, 230; Figs. 3.2.22-4), being held in place by three trenails in the first two, but only two in the last. The purpose of these saddles is not certain; there seem to be three possibilities:

- a, to make good defects in the original wood;
- b, to repair worn or damaged surfaces;
- c, to fill a gap left by the removal of a redundant structural member.

The inferior material and fitting of the saddles indicate that they were fitted to level a surface rather than to add strength.

The rib extremities were generally very damaged, but show signs that other structural members had at some time been connected to them. The appearance of the port sides of R2, 6 and 8 (Gr228, 355, 369; Figs. 3.2.19,

23, 25) and the starboard side of R7 (Gr230; Fig. 3.2.24) suggests there were scarfs to make extensions to the ribs. In the following positions there are notches which could have accommodated a stringer or rising: (starboard side of R1 (Gr314; Fig. 3.2.18), port side of R3 (Gr166; Fig. 3.2.23), both sides of R4 (Gr372; Fig. 3.2.21), both sides of R5 (Gr364; Fig. 3.2.22), port side of R7 (Gr230; Fig. 3.2.24), and starboard side of R9 (Gr354; Fig. 3.2.26).

The under sides of many ribs have rusty nail prints where they had rested on land-nails. For instance, R1 shows three prints, R3 five, R6 three or four, and R7 two. These ribs could not have been installed until after the planking had been fastened.

#### MARKS

On most parts marks had been made during building (tool marks), in the course of operation (operational marks), or through damage after the final laying up (vandal marks).

##### Tool marks

Scribing lines were used to assist the builders. The line marking the inside limit of the overlap can still be seen, in spite of the likelihood that such a line would be obliterated during building or later (Gr276, 292, 294, 346-7; Figs. 3.2.6, 14, 16). The nail line is even more vulnerable as it lies in the path of the luting cove; yet an example of it is preserved in Gr 294 (Fig. 3.2.14). It does not seem that much attention was paid to these lines once they were drawn. Both sides of R6 (Gr355; Fig. 3.2.23) and the forward side of R2 (Gr228; Fig. 3.2.19), were scribed for the notch over the keel.

Marks from straight-edged cutting tools were abundant on surfaces which had been fitted to one another. Not only would it have been necessary to work the surfaces of these joints, but once made they would have had mutual protection. The marks were similar to those made by an axe or chisel; only on Gr342 (Fig. 3.2.3) are there tool marks which could have been made by an adze. The luting coves had been gouged, often without care.

Exposed surfaces were largely free from tool marks. As they were not found in rib fays, it is thought that plank surfaces were not tooled, unless they had been scraped smooth. This is unlikely as nothing like repeated ridges, which are left by a scraper and are as distinctive as finger prints, was found. Cutting tool marks were however found right across both sides of P7A, Gr339 (Fig. 3.2.9), and across the outsides of S6A, G232 (Fig. 3.2.6), and S3A, Gr323 (Fig. 3.2.13). As these are the aftermost fragments recovered from the strakes, this may be another indication of the generally more careful workmanship evident in the strake endings.

Holes for trenails were notable for their roundness (p. 99). The auger used must have been an efficient tool. Holes for the nails were probably made by an awl, as they seem too small to have been made by an auger. There was no evidence that a saw had been used during building; hammers and mallets must have been used, although again there is no evidence for them.

### Operational marks

Signs of fair wear and tear and repaired damage both occurred during the useful life of the boat. As they are sometimes difficult to distinguish from marks which occurred subsequently, only those which are almost certainly operational will be considered here.

The keel (Fig. 3.2.1) was severely damaged in way of R2 and there are signs of a repair. It is thought that the plank damage in the vicinity could have been inflicted at the same time.

R1 (Gr314; Fig. 3.2.18) is more carefully fitted than any other rib recovered. It is too near amidships to be an added support for a side rudder, although it could have been used as a fulcrum for a sweep. Alternatively this rib may have been close-fitted to give greater strength to a weakened section of the hull.

The fact that there is no sign that any of the planks had been repaired by the insertion of shorter lengths supports the view given by the state of the nails and unworn keel that the boat had not been used until it was worn out. Raking grooves, however, show that the boat had been kept in use for several years at least (e.g. Gr200-2, 235, 246, 254, 263, 269, 271, 276, 278, 284, 287, 290, 310, 324-5, 337, 342, 345-7; Figs. 3.2.3-8, 11-13, 15-16). In Gr213 (Fig. 3.2.17) there are signs of decay. In clinker-built boats, which are regularly cleaned, either to remove the remains of a cargo which might contaminate the next, or to keep the boat sweet when matter that will decay is being regularly carried, raking grooves occur just above the laps between the ribs, where a sharp tool is needed for cleaning. As it is also a lodging place for moisture, decay may accelerate the formation of the groove.

On the upper surfaces of R3, 8 and 9 (Gr366, 369, 371; Figs. 3.2.20, 25-6) there are groups of small cuts as if made by a knife used to trim ropes ends or fish heads or for some similar light chopping operations.

The excellent condition of the outside surfaces shows up even minor damage, such as scratches or grooves, clearly (scratches on Gr278, 284, 287, 294, 325, 339 and 345, the last in a criss-cross, Figs. 3.2.4-5, 8-9, 13; grooves in Gr232, 239, 327 and 342, the groove in Gr327 ending in a hole right through the plank, Figs. 3.2.3, 9, 14, 16). Grooves in P5C, Gr200 (Fig. 3.2.7) seem to have been made by a pivoted object. All these marks could have been made when taking the ground; they are rather more common on the port side.

Over and above the damage near the limits of the boat, many planks and the keel were fractured. The greatest area of damage occurs on either side of R3 (Gr366; Fig. 3.2.20) with a lesser area where strake 4 crosses R4 and 5 (Gr372, 364; Figs. 3.2.21-2). In both, this could have been the result of stranding on a hard ridge or patch of ground rather than on a sharp rock. It should be noted how infrequently fractures run through trenail holes, areas of rib pressure being much more likely sites for failure.

Hair-line cracks (H.L.C.s) are partial fractures and are common in the fragile wood (Fig. 3.2.29). H.L.C.s only become visible in a wet surface, under tension when they open, and under compression when water is squeezed out. They may develop into full fractures if the wood is not very carefully

handled and supported when out of the water. It is thought that, although H.L.C.s only occur after the wood has become waterlogged, areas of stress were set up when the vessel was in service.

### Subsequent damage (vandal marks, V.M.s)

Even if the boat had not been used as a source of wood for repairs or fire-wood, natural decay would have had much the same result, as the limits of both types of damage were much the same.

The horns of most of the ribs had been wrenched off with great force. Strakes had been cut, by a saw in P5C, Gr200 (Fig. 3.2.7), all well aft and accessible to the bank of the channel.

The nature of the damage running diagonally from side to side at the forward end of the vessel is similar throughout; this suggests that it was done all at one time, probably during an earlier widening of the ditch. The fact that the fractured plank ends are fibrous and springy points to a more recent date rather than a very early one.

The way the boat had held together and still was able to hold water showed that there had been little or no relative movement between the component pieces. Shrinkage and expansion of wood depends on the set of the grain, the length involved and the cross-section of the member. In all, even if the dimensional change had been evenly distributed over large and small pieces alike, it is unlikely that it would have been greater than a boat would normally experience going from a wet to a dried-out state.

The excavation, recording and recovery have probably been the most severe experiences this boat has had, and these too have left their marks. The speed called for and the weakness of the wood heightened the problem. Close supervision kept accidents at a very low level; much has been learnt about avoiding them in future.

### NOTES

1. Available for inspection in the National Maritime Museum.
2. Every part of the boat has a Gr(aveney) number. In addition ribs (frames) are numbered R1, R2 etc.; strakes (planks) are numbered P2A, P2B, P2C, = four parts (A, B, C, D) of the second strake (2) on the port side (P), or S2A, S2B, S2C, S2D = four pieces (A, B, C, D) of the second strake (2) on the starboard side (S).
3. Whereas in caulking the material is forced into joints after they have been made.
4. Although each scarf had been given a P.J. number before the boat was lifted, the system of numbering had to be random.
5. It is not always certain whether the curvature is due to original shaping or wear.
6. Trenail serial numbers consist of components being joined prefixed by T. Thus TR3S3 = trenail connecting R3 to the third strake on the starboard

side. As dismantling involved cutting the trenails at the interfaces of ribs and strakes the two halves acquired separate serial numbers. They will be reunited after conservation.

7. Notch positions are obviously missing where there are no ribs or parts of ribs.

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## CHAPTER 4: DATING

### PART 1. RADIOCARBON DATING

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Seven radiocarbon dates have been obtained by the British Museum Laboratory for wood taken from or associated with the Graveney boat. The laboratory procedures used to obtain these dates are described in outline and the factors which were taken into account in deriving a probable calendar date for the boat from the radiocarbon measurements are discussed.

#### PRETREATMENT

Before age measurement all the samples were pretreated with dilute acid and alkali for removal of possible age-contaminants. This is generally recognized to be an essential prerequisite of nearly all radiocarbon age measurements, although the procedures followed by individual laboratories vary greatly.

The outer surfaces were first cleaned and discarded to a depth of a few millimetres. Each sample was then cut into pieces approximately 20 mm long and 1 to 2 mm thick, and boiled successively in 1.0% aqueous solutions of hydrochloric acid and sodium hydroxide, with intermediate washing in distilled water and several changes of solution. Finally the samples were washed free of excess alkali with distilled water and dried in an oven. The radiocarbon measurements were thus based on pretreated whole wood.

#### MEASUREMENT OF SAMPLES

Most radiocarbon laboratories use either the conventional gas-counting or the more recently developed liquid scintillation counting method for measurement of carbon-14. For a number of technical reasons the former method is still in more common use for dating but there are no systematic differences between the results obtained by either process. The British Museum Laboratory employs the liquid scintillation method, the pretreated samples being converted to benzene for measurement of their carbon-14 activity. From this information and by comparison with a 'modern' carbon-14 reference standard measured concurrently, the dates in radiocarbon years and their associated measurement errors are calculated by computer. These are essentially standard radiocarbon laboratory practices and have been fully discussed elsewhere (Burleigh, 1972; Burleigh, 1974; Burleigh *et al.*, 1976; Hall and Hewson, 1977).

It is of considerable future interest and importance to note that the error terms of these measurements are markedly dependent on the initial amount of sample material submitted for dating. This is particularly important when

Table 4.1.1' Sample weights and radiocarbon measurement errors

| Water content                              | British Museum No. | Weight pretreated (grams) | Final dry weight (grams) | Benzene weight (grams) | Counting time (minutes) | Measurement error (years) |
|--------------------------------------------|--------------------|---------------------------|--------------------------|------------------------|-------------------------|---------------------------|
| Less than 10% H <sub>2</sub> O (air dried) | 956                | 30                        | 13.4                     | 5.2321                 | 1500                    | + 51                      |
|                                            | 957                | 14                        | 5.5                      | 2.4640                 | 1600                    | + 76                      |
| 80-85% H <sub>2</sub> O (waterlogged)      | 1137               | 120                       | 12.1                     | 4.0577                 | 3200                    | + 38                      |
|                                            | 1138               | 105                       | 7.3                      | 3.6056                 | 3000                    | + 37                      |

Table 4.1.2 Radiocarbon dates

| British Museum No. | Sample provenance          | Date in radiocarbon years (5570 year half-life) |                 |
|--------------------|----------------------------|-------------------------------------------------|-----------------|
|                    |                            | bp*                                             | ad              |
| 660                | strake P6 or P7            | 1080                                            | 870             |
| 661                | loose fragment of planking | 1064                                            | 886             |
| 715                | brushwood beneath hull     | 1003                                            | 947             |
| 956                | strake S6C                 | 1283                                            | 667             |
| 957                | strake P4D                 | 1126                                            | 824             |
| 1137               | strake S3D                 | 1178                                            | 772             |
| 1138               | strake S3D                 | 1095                                            | 855             |
|                    |                            |                                                 | Error (years ±) |
|                    |                            |                                                 | 40              |
|                    |                            |                                                 | 54              |
|                    |                            |                                                 | 40              |
|                    |                            |                                                 | 51              |
|                    |                            |                                                 | 76              |
|                    |                            |                                                 | 38              |
|                    |                            |                                                 | 37              |

\* bp = before present (A.D. 1950)

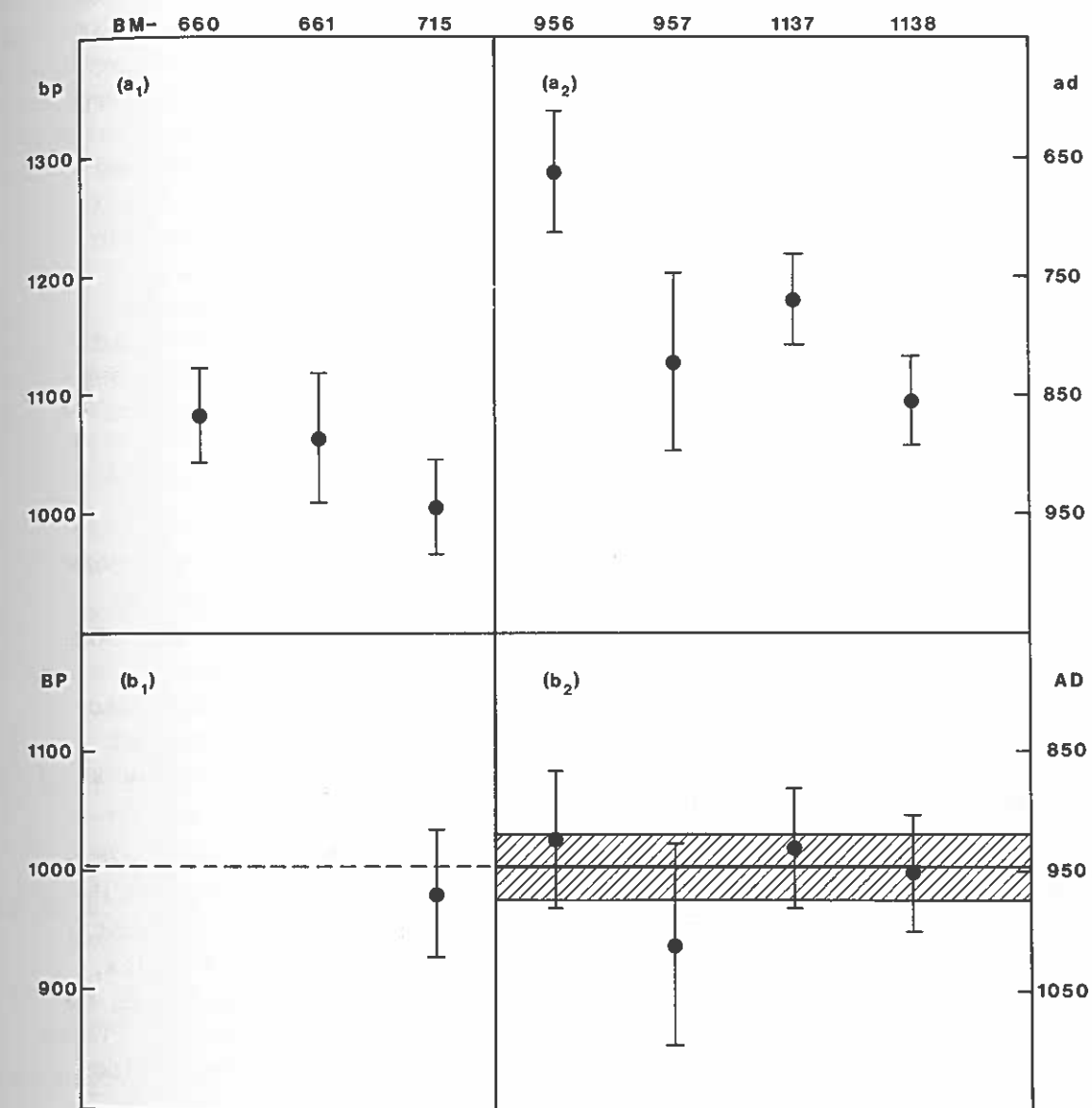


Fig. 4.1.1

## RADIOCARBON AND CALENDAR DATES

In sections a<sub>1</sub> and a<sub>2</sub> uncalibrated dates in radiocarbon years given in Table 4.1.2 are plotted, those in a<sub>2</sub> being for samples with known growth allowances (based on felling year 240). Sections b<sub>1</sub> and b<sub>2</sub> show equivalent dates in calendar years (see text for explanation of corrections). In b<sub>2</sub> the mean calendar date derived from these of A.D. 944 ± 30 is represented by a line through points (and shaded error band). The date for the sticks from beneath the hull (b<sub>1</sub> no growth allowance needed) compares closely with this. Diagram illustrates how the distribution of the four individual corrected values contributes to the mean date.

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dealing with waterlogged wood, the dry weight of which (i.e. the amount of material available for radiocarbon measurement) will often be very low even for bulky samples. The measurement of a small but relatively recent sample poses essentially the same problem as the measurement of a larger old sample, since the carbon-14 activity is low in both and economic considerations limit the length of time for which any given sample can be counted. For younger material this results in a date having an inconveniently large associated error and, as Fletcher has pointed out (Fletcher, 1975), the usefulness of such a date is greatly reduced. The figures given in Table 4.1 underline the need submission of enough sample material to overcome this limitation at the outset. At the same time, for pretreatment purposes, it is greatly preferable that waterlogged wood samples should be received undried by the dating laboratory; they should be sealed in heavy-duty polythene bags in their original wet state. All the Graveney samples except BM956 and BM957 had been kept in their waterlogged condition. BM956 and BM957, which had been slowly air-dried at ambient temperature in the laboratory, were soaked in water for two weeks or so before pretreatment began.

### RESULTS

The radiocarbon dates obtained are given in Table 4.1.2 with the positions which the individual samples were taken. They are based on the 5570 year half-life for carbon-14 as recommended by the journal *Radiocarbon*, but using the lower-case bp/ad notation to indicate raw dates in radiocarbon years (*Antiquity*, XLVI:265). All the results have been corrected for isotopic fractionation, so that the errors are derived from counting statistics alone and are equivalent to one standard deviation (1 sigma). This is the normal mode of presentation of radiocarbon dates at the present time.

As no other direct dating evidence was available at the time of the boat's discovery, samples BM660 and BM661 were measured at an early stage in the investigations to give a reasonably close idea of the period to which the boat might belong (Evans and Fenwick, 1971:94; Fenwick, 1972a:119; Fenwick, 1972c:9). Dendrochronological work on the hull had not begun at that time, so that no timber growth allowances<sup>2</sup> were recorded for these two samples. Taken at their face values, these two dates would, therefore, give a misleading idea of the date of the boat's construction, but the sticks lying beneath the hull (BM715) provided evidence for the date of its abandonment (Fenwick, 1972a:9), as they were all small branches representing at most about ten years of growth. Animal hair used as luting between the planks of the hull, which would otherwise have been almost ideal from the point of view of contemporaneity, was impregnated with tar and was therefore not considered suitable for dating.

The remaining four samples of wood from the boat (BM956, BM957, BM1137 and BM1138) were provided after tree-ring analysis and all had known growth allowances (chap. 4.2). These four radiocarbon measurements were used to derive a calendar date for the boat by a, making corrections for the new (5730 year) half-life for carbon-14 which is considered to be a more accurate value; b, allowing for the now well-attested natural carbon-14 variations (Olsson, 1971), using the data of Damon *et al.* (1972) to convert the radiocarbon measurements into dates in calendar years; and c, correcting the resulting

calendar dates for the individual timber growth allowances. Fig. 4.1.1 summarizes the results of these various corrections which led to a weighted mean date for the construction of the boat of c. A.D. 944  $\pm$  30 years. This date still has the normal uncertainty associated with all radiocarbon measurements, i.e. there is a fixed probability (of 1 chance in 3 at the 1 sigma level) that the true value lies outside the error limits quoted. No definitive relationship for conversion of radiocarbon dates into calendar dates has yet been agreed and various alternative calibration curves or tables are in current use,<sup>3</sup> which, if applied to these results, would give a closely similar calendar date for the boat.<sup>4</sup>

### NOTES

1. The radiocarbon samples were prepared and measured by Mr. N. D. Meeks and Mr. A. D. Hewson of the British Museum Research Laboratory. The author is indebted to Mr. Hewson, Dr. J. M. Fletcher and Mrs. Valerie Fenwick for much helpful discussion during the preparation of this report.
2. The years between the annual rings analysed and the time of felling and use of the tree: Fletcher, 1968.
3. For example the MASCA data of Ralph *et al.*, 1973.
4. Text submitted November 1975.

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## CHAPTER 4: DATING

### PART 2. TREE-RING STUDIES

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#### INTRODUCTION

The wooden hull of the Graveney boat provides evidence, detailed elsewhere (chap. 3.2), for its form and construction. Because the timbers are of oak, they should permit dendrochronology, a branch of applied science new to the maritime regions of northern Europe during the last decade, to fix the construction date of the boat more accurately than was previously possible.

In 1963-4 a few cores, 4 to 5 mm in diameter, were taken with an increment borer from the large oak cross-timbers of the Bremen cog, typologically of the 13th or 14th century, so that it was possible to chart the widths of the successive annual rings (Liese and Bauch, 1965). As there was no reference curve for the oaks that grew in the coastal region around Bremen, it was fortunate that the logs needed for some of the timbers of the cog were not of local origin but had been floated down the R. Weser from the hilly area (known as the Weserbergland) some 200 km to the S. in the vicinity of Kassel. A well established tree-ring reference curve for oaks in that region had been built up by Huber and his associates, as a result of research going back to 1938, first at Tharandt near Dresden, then at Munich (Huber, 1970). A ring-width sequence from the Bremen cog matched this reference curve, and as some of the timber included the sapwood and bark edge, it was possible to establish that one of the trees was felled in A.D. 1378 (Bauch, 1969). As there was evidence that the logs had not been seasoned, and allowing a year for the river transport, the cog must have been under construction in, or very close to, the year 1380. With such accuracy, there was certainly no need for larger samples or for the relatively costly physical and chemical techniques needed to measure the radiocarbon content of the timber and derive a radiocarbon age, often quoted with an uncertainty of a century.

Compared with the Bremen cog, the Graveney boat posed quite different problems:

- a. Only the keel was massive enough to drill; even this, owing to the softness from the extra decomposition of the cellulose in a boat that was 1000 years old, might not necessarily be suitable.
- b. The typological evidence for its date covered several centuries before 1100.
- c. There are as yet few suitable reference curves for areas around the North Sea, by which the tree-ring widths of the oak planks could be dated by dendrochronology.

For the Graveney boat, therefore, an approximate estimate of the date of construction was derived in the first place from radiocarbon measurements. The likely limits were confined to half a century by analysing several samples, each selected after tree-ring studies (Fletcher and Switsur, 1973). Each sample had to be of adequate weight, about 100 g if the wood is waterlogged, without which the uncertainty of a radiocarbon age may be substantially increased (chap. 4.1). As many cores would have been needed to provide even one such sample, it was decided to cut pieces from the planks which formed the strakes. For dendrochronology, such pieces from several planks were needed to obtain samples from different parts of the same tree or from more than one tree and thereby provide a better basis for dating the boat.

When a boat is subsequently to be reconstructed, there is a conflict between the desirability of having samples from several timbers for analysis, and of avoiding the cutting of timbers, which may be used in the reconstruction. The compromise reached with the Graveney boat has certainly added to the task of reconstruction, but the gain in knowledge, unequalled in work on other boats of the Viking period, should more than compensate. Whereas the construction of the Bremen cog was dated, by dendrochronology, in one step, there have been several stages after the initial typological estimate, for the Graveney boat:

1 (mid 1971). The 150 year period, a.d. 825-975, given by the uncorrected, raw, radiocarbon ages of two samples

2 (1975). The period, A.D.  $944 \pm 30$ , derived, after calibration, from radiocarbon analysis of four samples selected after tree-ring analysis

3 (early 1977). The period, A.D.  $930 \pm 20$ , based on the radiocarbon analyses for step 2 and on others (for samples from the Old Windsor mill and the North Elmham well) linked by dendrochronology with the Graveney boat (Fletcher, 1977)

4 (mid 1977). By dendrochronology, first by dating the overall sequence of annual rings, in this case 230, derived from the samples. Then by adding to the date of the latest ring two allowances: the first for absent sapwood rings, estimated at  $9 \pm 2$  years, the second, estimated at only one year, for construction of the boat within a year of the trees being felled. The dated chronologies at present available for SE. England and other areas around the North Sea are insufficiently early to provide a certain match but favour A.D. 917 for the latest ring of the sequence, and therefore A.D.  $927 \pm 2$  for the construction.

#### SAMPLES AND MEASUREMENTS

To avoid unnecessary cutting of planks, samples were taken in two phases, the second after the results on those of phase 1 had been assessed and further requirements determined.

From the wet strakes, four pieces, about 50 mm wide, were cut in phase 1, seven in phase 2. These eleven pieces included four pairs from different parts of the same plank. To reduce disfigurement of the vessel to a minimum, the samples chosen were in frame positions and excluded the hood-ends. They were .19 m to .26 m long, and in thickness tapered from about 25 mm at the

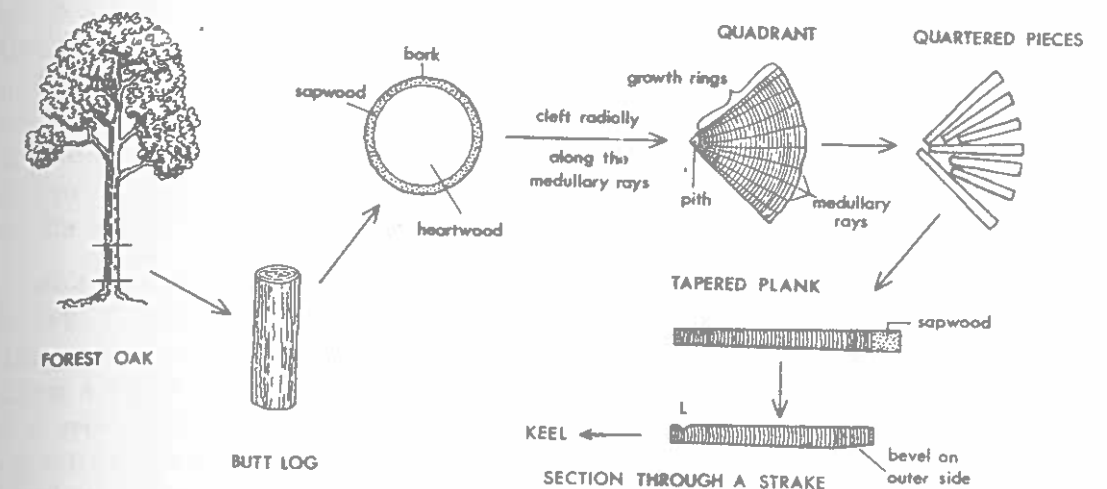


Fig. 4.2.1 Stages in the traditional method of converting trunks of oak trees into planks (up to 3.5 m long for Graveney boat). The bevel at the thicker (sapwood) end of the strake and the luting channel, L, helped to keep boat watertight  
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#### Widths of Successive Annual Rings

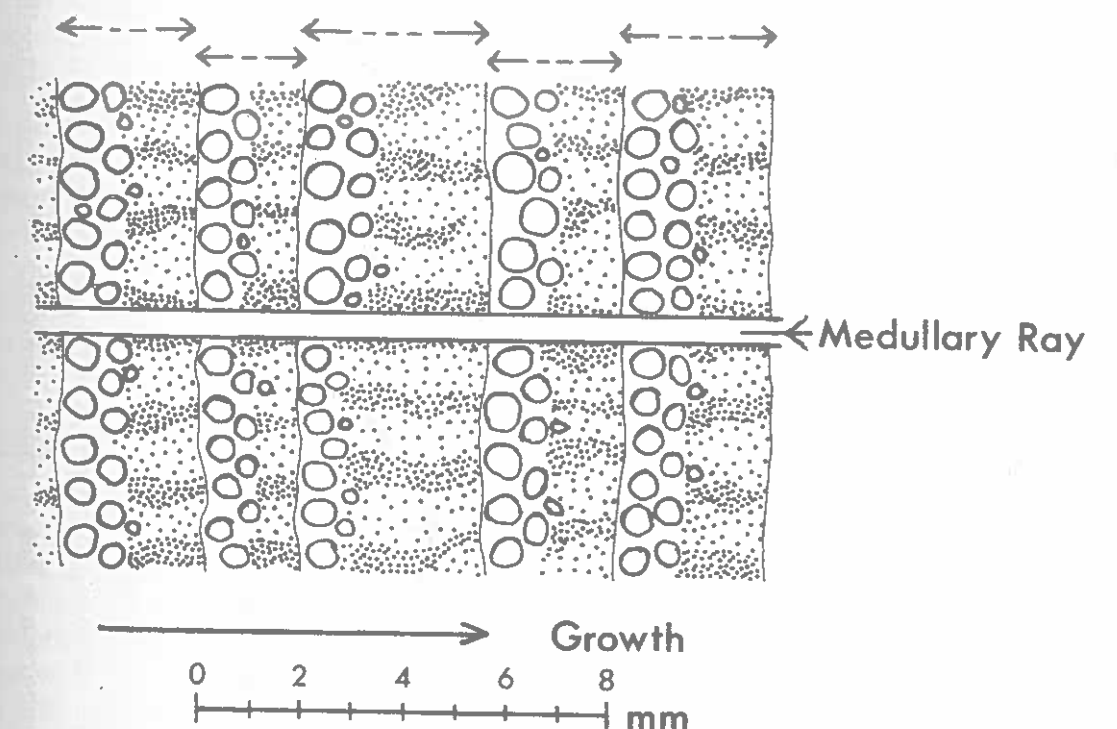


Fig. 4.2.2 Appearance, under magnification, of successive annual rings on a section of an oak plank  
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Table 4.2.1 Annual Rings of Samples

| Piece | Source strake         | Tree | No. of rings | Average width (mm) |            | Sapwood rings | Years spanned* | Sapwood begins at year |
|-------|-----------------------|------|--------------|--------------------|------------|---------------|----------------|------------------------|
|       |                       |      |              | All rings          | Last rings |               |                |                        |
| VI    | S6C                   | A    | 201          | 1.4                | c 0.5      | Nil           | 1-201          |                        |
| V     | P4D                   | A    | 203          | 1.15               | c 0.6      | 18            | 28-230         | 213                    |
| XII   | P4D                   | A    | 169          | 1.25               | 0.9        | Nil           | 28-196         |                        |
| XIII  | S3D                   | D    | 134          | 1.9                | 1.8        | 3             | 94-227         | 225                    |
| XIV   | S3D                   | D    | 110          | 2.3                | 1.8        | 7             | 117-226        | 220                    |
| XV    | P6D                   | B    | 209          | 1.3                | 0.8 to 1.4 | 4             | 9-217          | 214                    |
| XVI   | P6D                   | B    | 203          | 1.3                | 0.8 to 1.4 | 2             | 13-215         | 214                    |
| I     | P4C                   | B    | 171          | 1.3                | c 0.8      | Nil           | 36-206         |                        |
| X     | S1C                   | B    | 147          | 1.4                | 1 to 1.5   | Nil           | 37-183         |                        |
| XI    | S1C                   | B    | 133          | 1.4                | 1.2 to 1.7 | Nil           | 39-171         |                        |
| IV    | S6B                   | C    | 158          | 1.4                | c 2        | 2?            | 54-211         | 210?                   |
| III   | Frame R1 <sup>+</sup> | X    | 176          | 0.65               | 0.5        | 14            | 23-c 198       | c 185                  |
| II    | Frame R6 <sup>+</sup> | ?    | 210          | 0.6                | 0.4        | c 38          | ?              |                        |
| XX    | Post <sup>+</sup>     | ?    | 83           | 1.4                | 1.1        | 22            | ?              |                        |

\* On the dendrochronological scale; this starts with the first ring of piece VI.

+ These members are not of radial section. The frames include the pith.

inner rings (pith end) to about 30 mm at the outer rings (sapwood end), where the bevel occurs (Fig. 4.2.1). The arrangement of rings showed that the planks had been made by radial division of oak logs. Sapwood was present on five pieces, mostly only to the extent of a few millimetres. Pieces cut from frames R1 and 6 showed that each had been trimmed, presumably by axe, to the required section from the trunk of a slender tree of very slow growth. Such trees (often in these days removed during thinning operations) form a substantial proportion of the timber in natural oak forests. Little agreement between these narrow sequences and those of the strakes is to be expected.

Before exposing the annual rings for width measurements, the samples were kept (unwrapped so as to allow some evaporation of moisture from the surface) in deep-freeze for at least a day. The successive rings were exposed by using a razor blade or knife and their widths measured by the scale under a 10 X eye-piece (Fig. 4.2.2). Details about the annual rings on these pieces are given in Table 4.2.1, which also includes similar information about piece XX derived from a post found near the site of the boat. It was made from a halved block (probably from a pedunculate oak) and had too few annual rings to be dated by dendrochronology.

On the basis of good visual matching of the ring-width charts, supported by computer agreements greater than 70%, it was feasible to assign those strake planks from which the pieces had been cut to particular trees (two to Tree A, three to Tree B, one to Tree C and one to Tree D). The evidence is insufficient to decide whether Trees A and D were the same or different, as the visual and numerical agreement (68%, overlap 107 years) between their sequences could apply to either; the difference in their average ring-width and in their starting dates (Fig. 4.2.3) makes different trees somewhat more likely.

As all four samples for radiocarbon analysis (Table 4.2.2 and Fig. 4.2.3) were taken from pieces from Tree A and D, there is no uncertainty about any of the samples being reused wood or a replacement, i.e. they came from a tree (or two trees) felled at the same time and used in the initial construction of the boat. The growth allowance, that is the number of years between the rings sampled and the felling of the tree, were intentionally varied (Fletcher, 1975). They are shown diagrammatically in Fig. 4.2.3 and assume felling of the trees at year 240 on the dendrochronological scale used in Table 4.2.1 and Fig. 4.2.3.

#### Sapwood rings

The number of sapwood rings that remains on samples provides important evidence for dating an archaeological find by dendrochronology. They enable the felling year of a tree to be closely assessed even if the bark is absent. In mature oaks the sapwood forms a band of relatively constant width (20 to 30 m), and therefore the number of rings of sapwood varies considerably with their average width. Typical relationships derived from western Germany (Hollstein, 1965) and southern England (Fletcher, 1974) are as follows:

| Width of sapwood rings (mm) | Likely number of sapwood rings |
|-----------------------------|--------------------------------|
| 1.5 to 1.8                  | 15 to 20                       |
| 1.1 to 1.4                  | 18 to 25                       |
| 0.6 to 1.0                  | 22 to 33                       |
| < 0.6                       | > 25                           |

Table 4.2.2 Samples and Results from Radiocarbon Analysis (cf. chap. 4.1)

| British<br>Museum<br>Ref. No. | From<br>piece | Condition        | number of<br>annual Rings <sup>+</sup> | Weight (g) |      | Counting<br>time (min.) | Raw<br>radiocarbon<br>age | Date for felling of<br>the tree <sup>*</sup> |
|-------------------------------|---------------|------------------|----------------------------------------|------------|------|-------------------------|---------------------------|----------------------------------------------|
|                               |               |                  |                                        | Supplied   | Dry  |                         |                           |                                              |
| 956                           | VI            | Air dried at     | 21                                     | 30         | 13.4 | 1500                    | 1283 ± 51 b.p.            | 920 ± 57 A.D.                                |
| 957                           | V             | room temperature | 21                                     | 14         | 5.5  | 1600                    | 1126 ± 76                 | 1011 ± 85                                    |
| 1137                          | XIII          | Waterlogged      | 36                                     | 120        | 12.1 | 3200                    | 1178 ± 38                 | 926 ± 51                                     |
| 1138                          | XIV           |                  | 32                                     | 105        | 7.3  | 3000                    | 1095 ± 37                 | 942 ± 50                                     |
| Weighted Mean                 |               |                  |                                        |            |      |                         | 944 ± 30                  |                                              |

+ For position and growth allowance see Fig. 4.2.3.

\* Derived, see text, by calibrating the radiocarbon age and then adding the growth allowance to the date obtained.

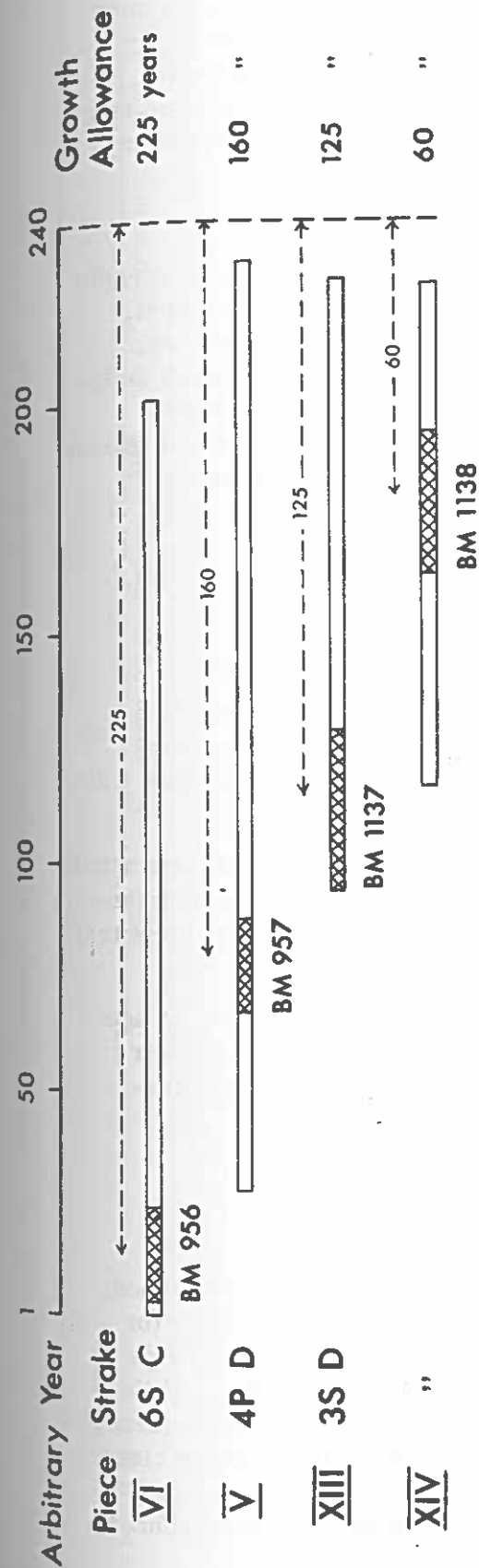


Fig. 4.2.3

Positions in the tree-ring sequence of four samples for radiocarbon analysis cut from strokes derived from Tree A. Note also how the growth allowances, rounded to the nearest five years, are estimated, year 240 being the estimated year of felling (cf. Table 4.2.2)

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Most of the sapwood had been removed in making the strakes but five pieces included some (Table 4.2.1). That on pieces XIII and XIV for Tree D is the most informative as the rings are relatively wide (average 1.8 mm) and the likely full complement is therefore only 15 to 20 sapwood rings. Sapwood begins on these pieces at years 220 and 225 respectively, so that the last sapwood ring on Tree D is estimated as being very close to year 239, with felling of the tree in year 240, the uncertainty ( $1\sigma$ ) being about  $\pm 2$  years.

Results from radiocarbon analysis for year 240

Each result (see final column of Table 4.2.2) is derived from the 'raw' radiocarbon age by making two corrections to obtain a more accurate age: first, that for the half-life of carbon-14 (5730 rather than 5570 years) and second, calibration for the fluctuations in the carbon-14 to carbon-12 ratio (by the tables of Damon *et al.*, 1973). In addition, the dendrochronologically determined growth allowance has to be included. For sample BM1137 these give a decrease in the age from 1178 to 1024 b.p., i.e. 154 years, derived as follows:

|                              |                |           |
|------------------------------|----------------|-----------|
| For the carbon-14 half life, | an increase of | 35 years  |
| For calibration,             | a decrease of  | 64 years  |
| For the growth allowance,    | a decrease of  | 125 years |
| Total                        |                | 154 years |

The date derived from radiocarbon analysis of this sample is therefore A.D. 1950-1024 = 926. The uncertainty of  $\pm 38$  years in the raw age is increased to  $\pm 51$  years because of a 3% increase associated with the revised half-life and by a further uncertainty of  $\pm 33$  years from the calibration.

In deriving the weighted mean,  $944 \pm 30$  (Table 4.2.2), each of the four results is weighted according to the reciprocal of its uncertainty term. The contribution from BM957 is thereby only 17% of the total because of its high ( $\pm 85$  years) uncertainty.<sup>2</sup>

When the same method of correction is applied to the raw radiocarbon age for the sticks found below the boat (BM715, 947  $\pm$  40 b.p.), the date of their cutting becomes A.D. 970  $\pm$  50 (no significant growth allowance being necessary).

RESULTS

Matching the ring-width sequences

Apart from the good agreement between Trees A and D already mentioned, it has been unusually difficult to derive self-consistent matching positions for the ring-width sequences of the other trees. This may be due to a maritime situation for the woodland in which they grew, e.g. the Forest of Blean, if the boat was built in the area in which it was found. Failure to match the sequences for the samples from frame R6 and from the post is not surprising as the rings of the former are all very narrow, while for the latter the number of rings (83) is too few for matching in a period as yet relatively unexplored by dendrochronology.

Between the mean of the sequences for pieces from Tree A and the mean of those from Tree B there is a visual match at a starting difference of nine

Table 4.2.3 Ring-width Sequences for Strakes: Agreement with other Sequences

|                                                   | Tree C    |                                | MC3 or NEG |                                |
|---------------------------------------------------|-----------|--------------------------------|------------|--------------------------------|
|                                                   | W%        | t <sup>+</sup> overlap (years) | W%         | t <sup>+</sup> overlap (years) |
| A. With a floating sequence of earlier date       |           |                                |            |                                |
| North Elmham well, 213 rings                      | 64*       | 136<br>66<br>3.4               | 62         | 145<br>96<br>4.6               |
| B. With a dated chronology or a constituent of it |           |                                |            |                                |
| REF 6, starts A.D. 778                            | Abs       | 119                            | 58         | 138                            |
| Westminster Abbey, chest 1 starts A.D. 850        | 73<br>65* | 47<br>54<br>2.1                | 66         | 57                             |
|                                                   |           |                                |            | A.D. 688-916                   |
| REF 6                                             | 60        | 156                            | 2.8        | 180                            |
| Westminster Abbey, chest 1                        | < 60      | 89                             | 1.8        | 102                            |
|                                                   |           |                                |            | A.D. 730-958                   |

+ Student's t values measure reliability of match. A value of  $> 3.6$  means probability, P, of random occurrence is  $< 0.001$ .  
\* Applies to mean curve for Trees B and C.

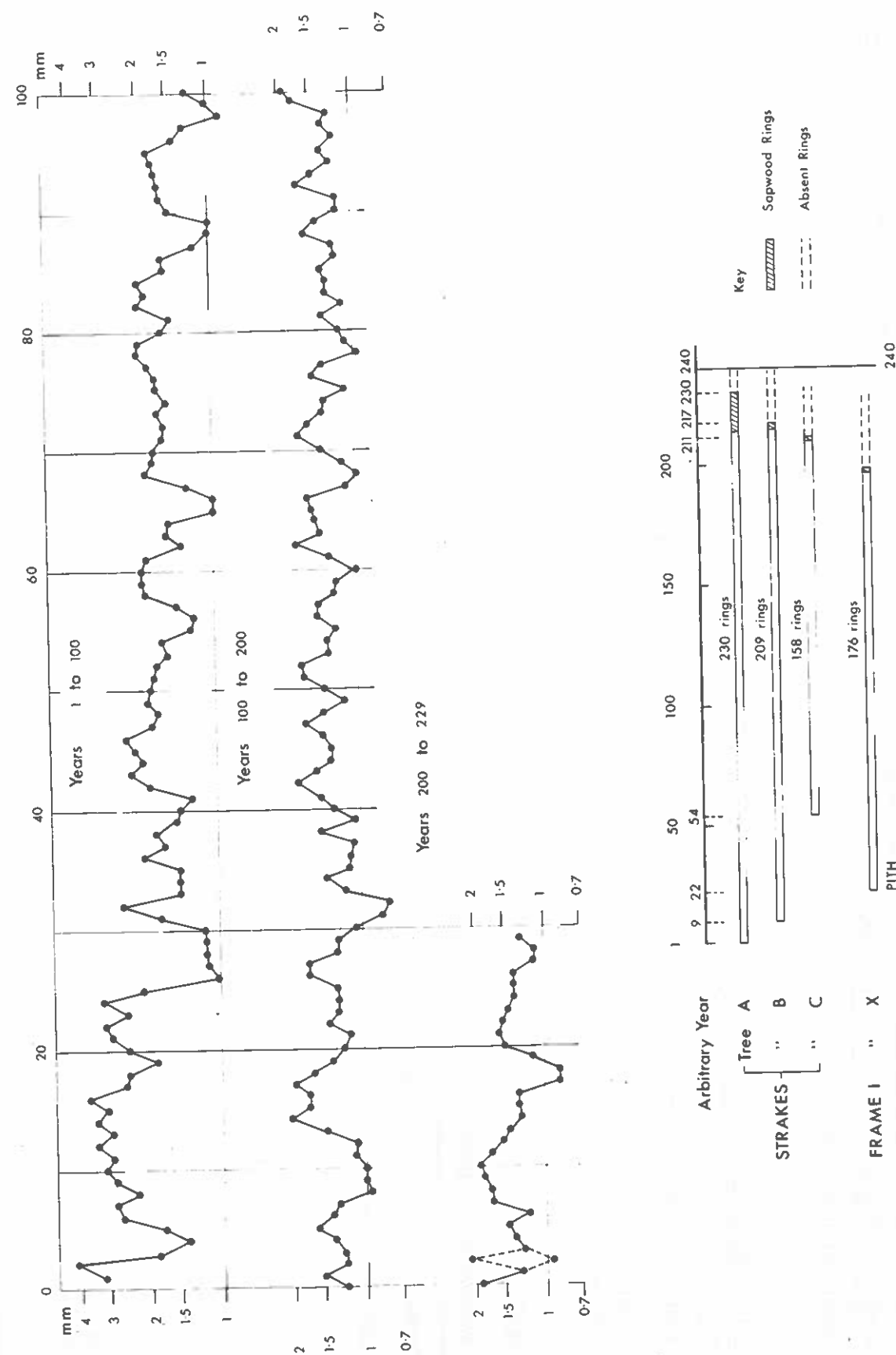


Fig. 4.2.4. Above, mean curve obtained by averaging the widths of the annual rings for the sequences in Trees A-C. Below, relative positions of the sequences of the annual rings for Tree A (pieces VI, V, XII, XIII, XIV); for Tree B (pieces XV, X, XI, I); for Tree C (piece IV).

years but the agreement over the complete sequences is low, about 60%. Both show groups of five to ten successive rings that are narrow, while the rings of Tree A are narrow after the first hundred.

The curve for the sample from Tree C maintains an average ring-width of about  $1\frac{1}{2}$  mm throughout its length and rather surprisingly the latest rings are the widest rings of all. With the mean curve for Trees A/D it has a matching position that is visually good and is supported by an agreement value of 63% by the Hamburg programme (Eckstein and Bauch, 1969) and of  $t = 3.8$  by the Belfast one (Baillie and Pilcher, 1973).

The relative positions of the matched sequences are shown in Fig. 4.2.4. The sapwood on the pieces from Tree B indicate it was felled at the same time as Tree A: evidence for the felling date of Tree C is lacking, since there is uncertainty about the presence or absence of sapwood in the final rings.

Various mean curves have been made from the whole and parts of the single-tree curves for Trees A, D, B and C. That called MC3 (Fig. 4.2.4) includes almost all of each sequence. Although the ring-widths for frame R1 are much narrower than those in MC3, its sequence is matched by MC3 in the position indicated in Table 4.2.1 and Fig. 4.2.4, the  $t$  value being 3.8 and value being 68% for an overlap of 93 years.

#### Dating the ring-width sequences

Because of the relatively poor agreement between the single-tree curves, each, as well as the mean curves from them, have been run and compared visually against all available reference curves for oak with which they are likely to be partly contemporary. These fall into three classes:

- Curves obtained in this laboratory for earlier English archaeological finds, the North Elmham well, the Portchester well and the Old Windsor mill, the latter two combined into a floating reference curve of 322 rings, known as REF 8 (Fletcher, 1977), which ends in the mid 9th century.
- A few sequences from Westminster Abbey chests and other English material from York and Essex that are later in date than the Graveney boat; the York material enables the reference chronology from these (REF 6) to start at A.D. 778 (Fletcher, 1977).
- Reference chronologies available at present for continental Germany back to A.D. 822 (Hollstein, 1965; Huber and Giertz-Siebenlist, 1969, from Schleswig and from S. Jutland.<sup>3</sup>

The sequences for Tree C and MC3 are matched (Table 4.2.3) by that North Elmham well, the sequence for which ends 84 years earlier. In turn, the mean curve from these two sets of archaeological material (which we call NEG) matches our earlier but floating chronology, REF 8, mentioned above (together REF 8 and NEG cover 415 years).

Thus, although some of the individual Graveney sequences may be unusual and much affected by site conditions, that for Tree C and the mean curve, MC3, show some features that are common to a large part of eastern and southern England. Since the dated chronology REF 6 applies to the same region, it

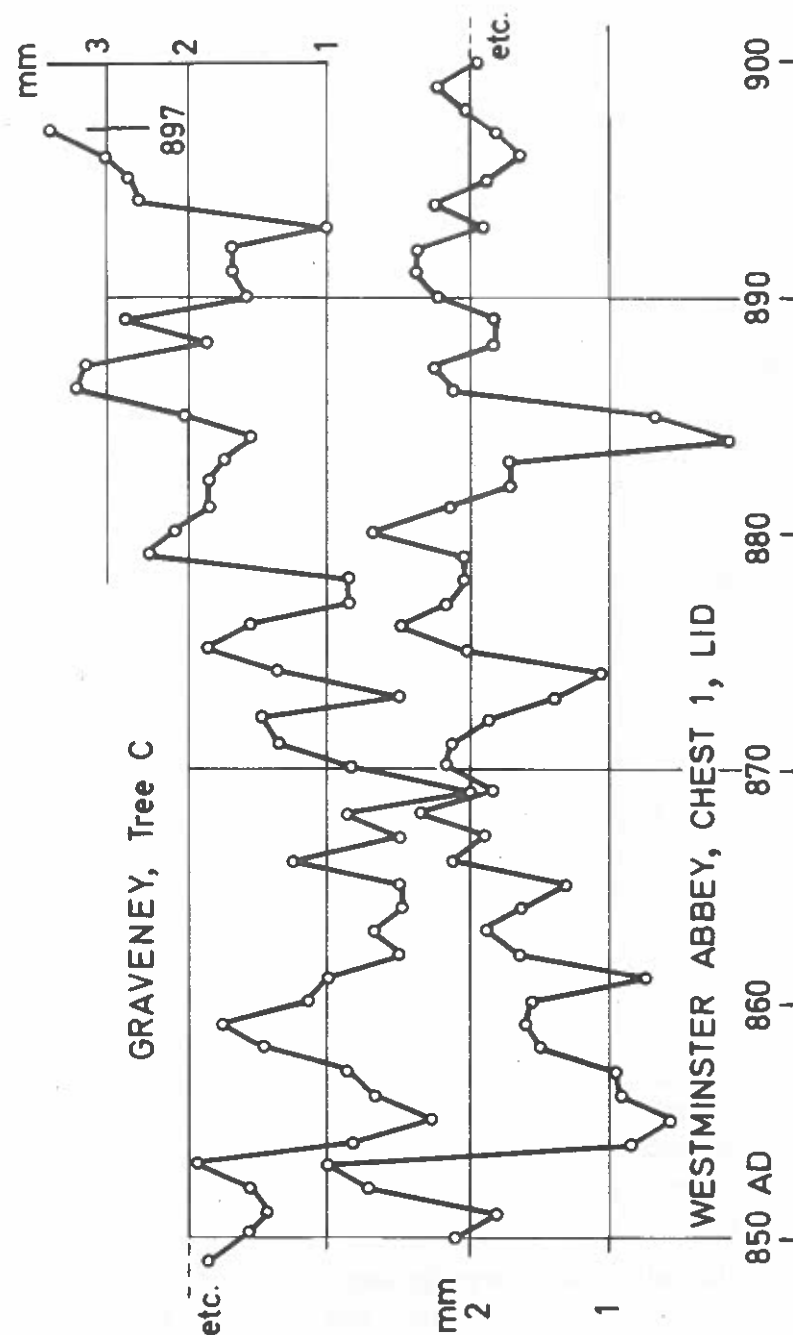


Fig. 4.2.5 Comparison of a Graveney ring-width sequence in likely matching position with dated Westminster Abbey sequence and making its final ring A.D. 897  
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offers some promise for dating one or more of the Graveney sequences. In fact it provides no certain match, only with the sequence for Tree C is there a  $t$  value greater than 3.5 and such values ( $t = 3.6$  and  $4.1$ ) occur in two positions separated by an interval of 42 years. They would make year 240 of the overall sequence either A.D. 927 or 969. Visual comparisons between the two sequences do not favour one in preference to the other. Other evidence as follows, favours the earlier as:

- i. The computer value (Table 4.2.3) and visual agreement (Fig. 4.2.5) between the sequence for Tree C and that for the Westminster Abbey chest is good in that position; where they overlap the average ring-widths are similar.
- ii. The mean curve (MC3) for the Graveney strakes gives favourable  $t$  values in that position with REF 6 and the chest (Table 4.2.3).
- iii. It makes the date of the North Elmham well A.D.  $834 \pm 2$ , which is consistent with the belief that it is earlier than 840.

There are, however, two other alternatives, A.D. 918 and 939 for year 240, suggested by computer comparisons with the sequences for Trees A and D, which cannot be definitely rejected at this stage.

#### CONCLUSION

The likely date for the construction of the boat from tree-ring analysis of eleven samples from the strakes is A.D. 927 with an uncertainty, because of the need to estimate the number of absent sapwood rings, of  $\pm 2$ . This date conforms closely to the radiocarbon estimate of A.D.  $930 \pm 20$ , based not only on four samples from the boat but on six others from earlier material cross-dated by dendrochronology with the boat. The date A.D. 927 is derived entirely from comparisons with limited overlap that start no earlier than 778 (whereas the Graveney sequence extends to  $c$  700 and others with which it is cross-dated to  $c$  500). Confirmation is therefore needed by comparison with earlier chronologies as they become available.

If the date of A.D. 927 is confirmed, the very good agreement between the sequence for Tree C and the Westminster Abbey chest suggests that the provenance of the boat may well have been SE. England.

#### NOTES

1. During the five years in which these tree-ring studies have been pursued, a number of persons to whom we are grateful have participated, in particular, Miss Hillam on the computer runs, Mrs. Mills on the typing of many drafts, and Mrs. Fenwick with guidance and help.
2. Indeed an alternative method of deriving the mean is to ignore the result for BM957. This gives  $930 \pm 30$ , the reliability in both results being the same.
3. We are grateful to D. Eckstein and K. Christiansen respectively for making these available.

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## CHAPTER 4: DATING

### PART 3. THE IMPORTED POT

by J. G. Hurst, Inspectorate of Ancient Monuments,  
Department of the Environment

Eight sherds (Gr44) comprise half the rim, part of the shoulder and body of a cooking-pot (Fig. 4.3.1). It is of a fine buff sandy fabric with small white grits, a few red inclusions and occasional flecks of mica. It was wheel-thrown and hard-fired with a metallic ring, but not so hard as some other wares of the same period. The upper part of the rim is reduced throughout; this is caused by the pot being fired upside-down with the rim surrounded by ash, so that it is not fully oxidized. The everted rim is slightly thickened, rounded but sharply cut outside and slightly hollowed inside with a slight, but sharp, bevel. The rim is not everted straight from the shoulder, but there is an upright vertical neck, with no break in the curve from the shoulder to the rim. The outer part of the body is smoothed, but the inner surface shows clear wheel-marks. On the lower part of the body there are marks of tooling inside and out. There is extensive fire-blackening, staining and some flaking of the outer surface.

This cooking-pot with its wide shoulder is quite unlike any of the Rhenish wares of the presumed period of the Graveney boat, either in shape or fabric (Hinz, 1965),<sup>1</sup> and is clearly from either Belgium or France. There are comparable sherds in France,<sup>2</sup> but none of them are in this exact fabric or in datable contexts,<sup>3</sup> nor can they be closely compared with any from known kiln sites (Chapelot, 1970; Hodges, 1976; Renimel, 1974). Likewise the sherds cannot be matched with any of the known Belgian fabrics.<sup>4</sup>

In England this fabric is typical of the wide range of pottery imported into the Anglo-Saxon town of Hamwih (Dunning et al., 1959:52, fig. 23; Addyman and Hill, 1969). There are not many examples, but single sherds have been found from most of the sites excavated over the past thirty years.<sup>5</sup> The Graveney sherds are visually identical with these in fabric and at least five comparable rims are known.<sup>6</sup> These are also similarly reduced in a way that is only otherwise known in this period on Stamford ware (Hurst, 1958:49). Most of the Hamwih rims are more everted than that from Graveney and lack a neck. Only one comes from a dated context, a pit of the mid 8th century; most of the others are likely to belong to the 8th and 9th centuries. The Graveney cooking-pot was probably made in the same area and possibly in the same kiln as these comparable examples, but as the rim is more developed it should be placed late in the series. The presumed 10th-century date of the Graveney boat extends the 8th and 9th-century date of the fabric at Hamwih. Many Anglo-Saxon fabrics have a date range of several hundred years without a very significant change in form (Dunning et al., 1959). Therefore a mid

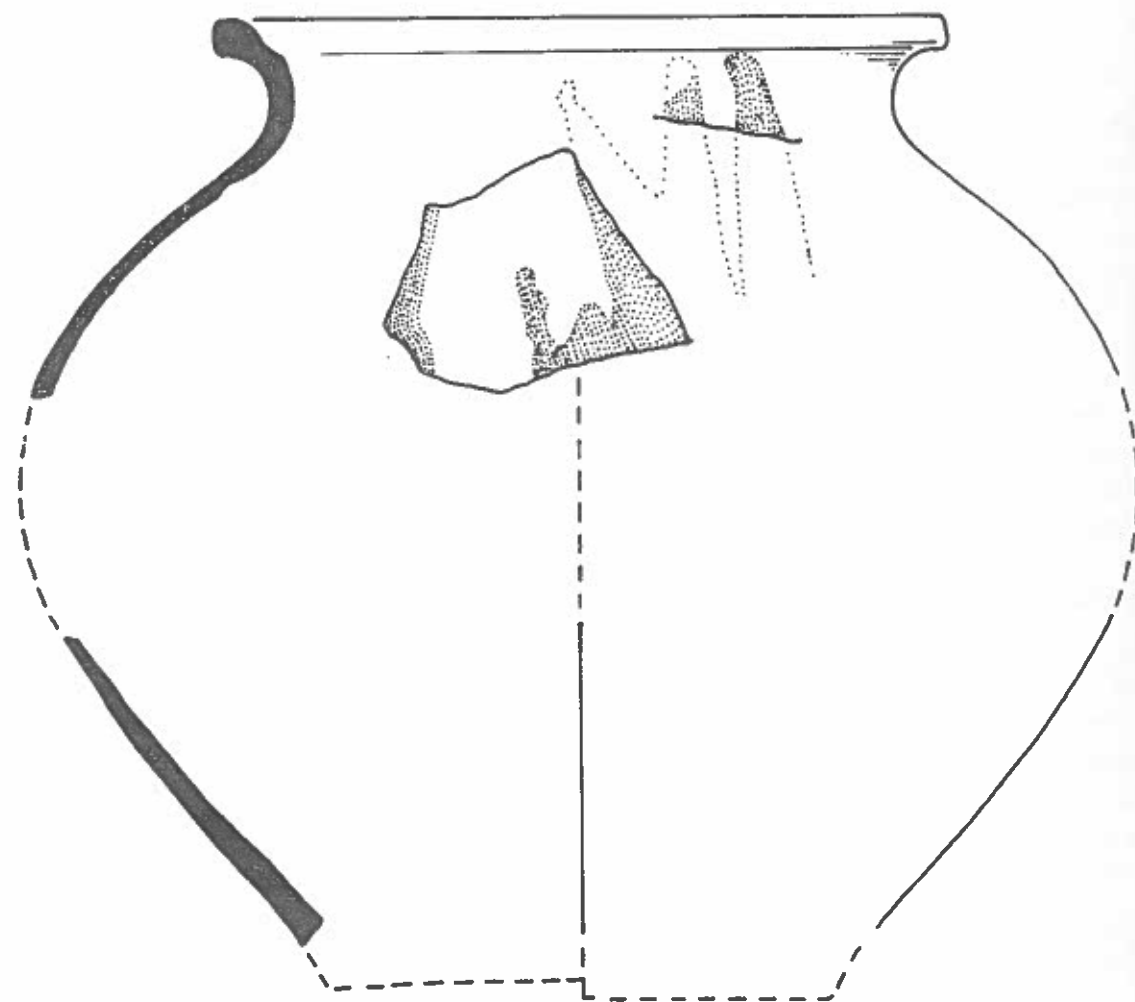


Fig. 4.3.1 Pot from the bottom of the boat. Scale 1:3. Drawn by J. Thorn  
© Dept. of Environment

10th-century date for the Graveney cooking-pot is quite consistent with the evidence. It is hoped that current work on the Hamwih fabrics<sup>7</sup> will help to identify the kiln sources, which are likely to cover a wide area of Belgium, northern and central France.

Until recently it was too readily assumed that all wheel-thrown late Saxon imported pottery was made in the Rhineland (Dunning *et al.*, 1959:21), but the tremendous amount of work carried out in France during the last few years has transformed the situation (Chapelot, 1970; Bottard and Guibert, 1969; Hodges, 1976; Leman, 1972; Renimel, 1974). It appears that wheel-thrown late Saxon wares were being produced at widely spaced centres, ranging from the Atlantic to the Loire and northern France to the Rhine (Hurst, 1976:311-12). Recent excavations at North Elmham, Norfolk (Wade-Martins, 1969, 1970, 1971, 1972) and Bonhunt, Essex (Wade, 1974) have produced several sherds of non-Rhenish fabrics which must also come from kilns in the Low Countries or France. Sherds from other sites, in addition to those which were first identified as middle Saxon (Dunning *et al.*, 1959:21), should now be looked at afresh, including many which were previously dismissed as Roman (for example, from Jarrow and Monkwearmouth: Hurst, 1969:59-64).

The discovery of this French cooking-pot together with fragments of Mayen lava quern blanks (chap. 4.4) in the Graveney boat raises the question as to whether they were being used on board or were part of a cargo, and also whether the vessel was engaged in local or coastal trade. The fragments of quern blanks cannot have been in use. They must have been either fragments broken from complete examples carried as cargo, or ballast. The cooking-pot is not so unusual that it could not have been in use on board a coastal trader; it need not have been purchased at a foreign port. It is unfortunate that neither the pot nor the quern fragments can identify the use or origin of the Graveney boat.

#### NOTES

1. Confirmed by W. Janssen of Bonn and W. A. Van Es of Amersfoort, who have not seen similar sherds either in the Rhineland or at Dorestad.
2. Information from J. Chapelot of Paris.
3. I have examined sherds from northern France (P. Leman and J. Cartier), Paris (J. Nicourt), Orléans (J. Chapelot) and Tours (H. Galinie), and am grateful for the help of those named.
4. Information from F. Verhaeghe of Ghent.
5. Information from R. Hodges to whom I am indebted for showing me the comparable material.
6. Waterman, 1946-51 excavations, P29, 6, 820; Addyman, 1968-9 excavations, P15, 10A, 745; Southampton Archaeological Research Committee (1972), TTII, P1, and VII P1, F21; (1973), F62, P818.

7. By R. Hodges and D. Peacock. Since the above was written Mr. R. Hodges has carried out more work on the Hamwih pottery and reports: 'The Graveney sherds are very like one of the commonest imports which we have termed Hamwih Class 11. It is a cooking-pot ware, the only exception being a pierced lid. The wire-cutting on the base is always very prominent. Thin-section reveals a light-olive brown (Munsell 2.5YR 5/6) anisotropic clay matrix with abundant inclusions of sub-angular quartz-sand and a few inclusions of quartzite and mica. This is hardly distinctive petrologically. I have seen this kind of fabric in the region of Troyes, Aube, and Tours (Indre et Loire), but a Normandy source is more likely. There are comparable vessels in the museums at Evreux and Dieppe from Merovingian cemeteries along the Seine, suggesting a source for this ware near Rouen. This Hamwih pottery of Class 11, with the few sherds of Beauvais ware (Hamwih Class 9) and another Class 25, is the only archaeological material, other than coins, which indicate mercantile activity of the upper Seine in the Carolingian period.'

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## CHAPTER 4 : DATING

### PART 4. THE LAVA QUERNS

by Daniel Smith, University of Nottingham \*

Two large circumferential fragments and many small chips of lava quern<sup>1</sup> from the Mayen area (p. 153)<sup>2</sup> were found in the Graveney boat, whether from one quern or several it is impossible to be certain. The two large fragments are in an unfinished state and had a diameter of 0.46 m when reconstructed. This seems to be the standard size in late Saxon times.<sup>3</sup> There have been other finds of quern blanks at Hedeby (Jankuhn, 1963:165), Linford, Essex (Barton, 1961-5:68), and Wanzenu (Forrer, 1935:185), showing that from at least the 3rd century A.D. it was usual to transport querns as blanks; this was no doubt because the stone was weakened when the central hole was cut.

The export of unfinished querns invites consideration of the nature of the finishing industry; was it centralized, with coastal re-exportation, or was it local? There is very little information on this but Hassall (1962:43-4) quotes documents referring to payment made to millwrights for finishing a pair of millstones. If the finishing was local, then research into the standardization of millwrights' tools might be possible on the basis of tool marks.

At present there is no information on the extent of coastal trade in lava querns at this period, although work begun on their distribution may in time shed a little light on this aspect.

\* I am indebted to Dr G. C. Dunning, Mr J. G. Hurst and Mr J. T. Smith for their help in preparing this note.

#### NOTES

1. Gr84, 112, 136, 146, 150 (20 fragments in all). I am indebted to Dr G. C. Denning, Mr J. G. Hurst and Mr J. T. Smith for their help in preparing this note.
2. Dr J. Röder believes all the material before about 1500 to have come from Mayen; this is on archaeological evidence only, since there is no petrological difference between Mayen and Niedermendig material: Biddle, 1964: 82-3.
3. Addyman, 1972:89, suggests this; it is supported by evidence from Southampton; Addyman and Hill, 1969:79; and Golpho, Lincs. (personal knowledge).

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## CHAPTER 5: ENVIRONMENTAL STUDIES

### PART 1. PLANT REMAINS INCLUDING THE EVIDENCE FOR HOPS

by D. Gay Wilson,<sup>1</sup> Botany School, University of Cambridge,  
and

Ann P. Conolly, Department of Botany, University of Leicester

### INTRODUCTION

Work on the plant macro-samples, financed by the Natural Environment Research Council, was begun by D. G. W. at an early stage in the excavations when it seemed that the boat might be Roman. Four of the samples had been examined for plant remains, and a pollen analysis of one of them had already been made by the time radiocarbon dates became available. The results from these samples have been discussed in greater detail elsewhere (Wilson, 1975). The remaining macro-samples have now been studied. Data from the earlier samples are included for completeness.

### METHODS AND RESULTS

Each sample was immersed in liquid to disperse the clay particles and organic fragments, and then washed through a fine sieve (in most cases 100 or 85 meshes per in., i.e. aperture 152  $\mu$ m or 180  $\mu$ m). The bulk of each sample consisted of fine-grade particles which passed through the sieve. Organic debris and particles of medium-grade sand and coarser were retained by the sieve. Each residue was sorted in water under a binocular microscope at magnifications x 25 or x 20. Plant remains were extracted for examination at higher magnifications and for detailed comparison with modern reference material. Some hundred plant taxa were identified (Table 5.1.1). Table 5.1.2 shows the position and the preliminary immersion treatment of each sample; Table 5.1.3 gives the wood identifications.

### DISCUSSION

There is little doubt that the Graveney clays are of estuarine origin. They closely resemble modern and fossil samples from elsewhere in Britain, both in sediment type and in species content. Besides remains of typical salt-marsh plants, there are in all samples such fossils as fern sporangia, Sphagnum leaves, mica fragments, the remains of colonial Coelenterata, and Foraminifera including Jadammina macrescens, which is a species that lives in brackish water. All are typical of estuarine sediments.

The fossils represent material carried downstream as well as material from the immediate locality of the samples. Sometimes it is easy to tell

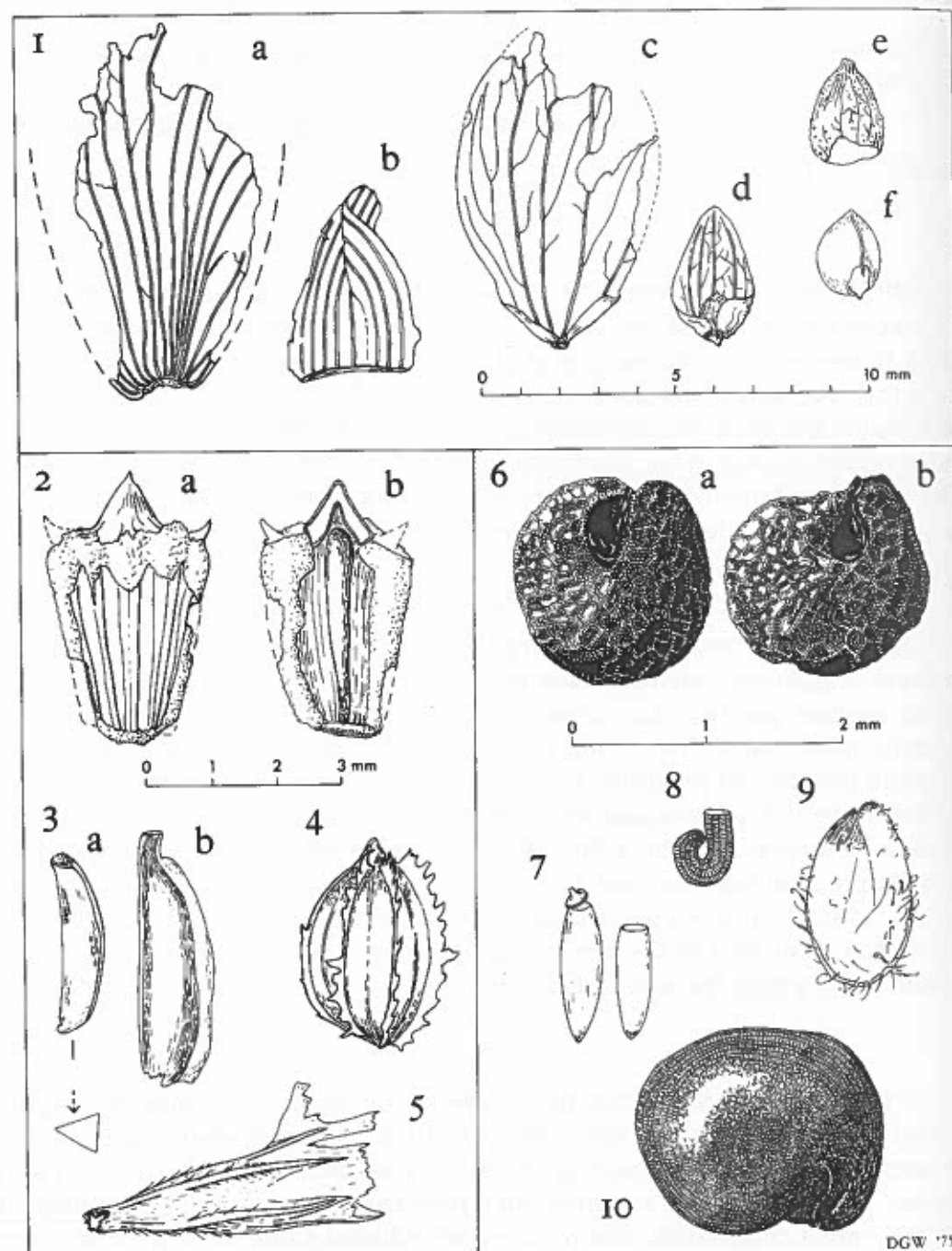


Fig. 5.1.1

# PLANT MACROFOSSILS

1. Humulus lupulus: a, b, bracts; c, bracteole; d, bracteole enclosing fruit; e, pericarp; f, nut
2. Fruit of Oenanthe fistulosa: a, dorsal view; b, ventral view
3. Triglochin maritima: a, seed, with cross-section and restored cross-section; b, empty fruit
4. Fruit of Daucus carota
5. Calyx of Armeria or Limonium
6. Seeds of Chenopodium hybridum: a, modern; b, from Graveney
7. Fruits of Typha
8. Seed of Elatine hydropiper
9. Seed of Salicornia
10. Seed of Suaeda maritima var. macrocarpa

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Table 5.1.1.1 Macro-fossils identified from Samples 1-8 (Fig. 5.1.1)

Table 5.1.1 MACRO-FOSSILS RECORDED IN CORE

| Species identified<br>(nomenclature after Dandy, 1958)  | Sample number (see Table 5.1.2) |   |    |   |   |    |    |   | Common name of species       |
|---------------------------------------------------------|---------------------------------|---|----|---|---|----|----|---|------------------------------|
|                                                         | 1                               | 2 | 3  | 4 | 5 | 6  | 7  | 8 |                              |
| <b>A. Miscellaneous</b>                                 |                                 |   |    |   |   |    |    |   |                              |
| cf. <i>Chaetomium</i> sp., perithecium                  | -                               | - | -  | - | 1 | -  | -  | - | a fungus                     |
| charcoal fragments less than 2 mm                       | +                               | + | -  | + | - | +  | +  | - |                              |
| coal fragments less than 2 mm                           | -                               | - | +  | + | - | -  | +  | - |                              |
| colonial Coelenterata fragments                         | +                               | + | -  | + | - | +  | +  | + |                              |
| Foraminifera                                            | +                               | - | +  | + | + | +  | +  | + |                              |
| Foraminifera ( <i>Jadammina macrescens</i> Brady, 1870) | +                               | - | +  | - | - | +  | +  | - |                              |
| insect fragments                                        | -                               | - | +  | + | + | +  | +  | + |                              |
| mica fragments                                          | +                               | + | +  | + | + | +  | +  | + |                              |
| Ostracoda                                               | -                               | - | +  | + | - | -  | -  | - |                              |
| shell fragments (marine)                                | +                               | - | +  | + | - | -  | -  | + |                              |
| shell fragments (fresh water)                           | -                               | - | +  | + | - | -  | -  | - |                              |
| small-animal bones                                      | -                               | - | -  | + | + | -  | -  | - |                              |
| <b>B. Lower plants</b>                                  |                                 |   |    |   |   |    |    |   |                              |
| <i>Azolla filiculoides</i> Lam., megaspores             | -                               | + | +  | + | - | -  | +  | - |                              |
| Characeae, oospores                                     | +                               | 4 | 8  | 6 | - | -  | 2  | - |                              |
| Dryopteris-type, sporangia                              | +                               | 6 | 13 | 1 | - | -  | 2  | - |                              |
| Megaspores (Mesozoic, derived)                          | -                               | 4 | 2  | 7 | - | 5  | 10 | - |                              |
| mosses, leafy stems                                     | +                               | + | +  | + | + | +  | +  | + |                              |
| mosses ( <i>Sphagnum</i> spp.) leaves                   | +                               | + | +  | + | + | +  | +  | + |                              |
| <i>Osmunda regalis</i> L., annuli from sporangia        | -                               | 1 | 8  | 4 | - | -  | 2  | - | Royal Fern                   |
| <i>Pteridium aquilinum</i> (L.) Kuhn leaf frags.        | 1                               | - | -  | 3 | - | 28 | -  | - | Bracken<br>(Table continued) |

Table 5.1.1 (contd.)

| Species identified                                                       | 1 | 2  | 3 | 4    | 5 | 6 | 7    | 8 | Common name of species              |
|--------------------------------------------------------------------------|---|----|---|------|---|---|------|---|-------------------------------------|
| <i>Selaginella selaginoides</i> (L.) Link megaspores                     | - | 1? | 2 | -    | - | - | -    | - | Lesser Clubmoss                     |
| <b>C. Higher plants (Part found = fruit or seed except where stated)</b> |   |    |   |      |   |   |      |   |                                     |
| <i>Achillea millefolium</i> L.                                           | - | -  | - | 4    | - | - | -    | - | Yarrow                              |
| <i>Aegopodium podagraria</i> L.                                          | - | -  | - | -    | - | 3 | -    | - | Goutweed                            |
| <i>Agrostemma githago</i> L.                                             | + | -  | - | -    | - | 8 | -    | - | Corn Cockle                         |
| <i>Alisma plantago-aquatica</i> L.                                       | - | -  | 2 | -    | - | - | -    | - | Water Plantain                      |
| <i>Alnus glutinosa</i> (L.) Gaertn.                                      | - | -  | - | -    | - | 2 | -    | - | Alder                               |
| <i>Anthemis cotula</i> L.                                                | - | -  | - | 2    | - | 2 | -    | - | Stinking Mayweed                    |
| <i>Arctium</i> cf. <i>lappa</i> L.                                       | - | -  | - | -    | - | 1 | -    | - | Burdock                             |
| <i>Arenaria</i> sp.                                                      | - | -  | - | 1    | - | - | -    | - | Sandwort                            |
| <i>Armeria</i> sp. or <i>Limonium</i> sp. (Fig. 5.1.1.1, no. 5) (calyx)  | - | -  | - | -    | - | 1 | 1    | - | Thrift, or Sea Lavender             |
| <i>Aster tripolium</i> L.                                                | - | -  | 1 | -    | - | - | -    | - | Sea Aster                           |
| <i>Atriplex</i> sp.                                                      | - | -  | 3 | -    | - | - | 1cf. | - | Orache                              |
| <i>A. cf. hastata</i> L.                                                 | - | -  | 3 | -    | - | - | -    | - | Hastate Orache                      |
| <i>A. littoralis</i> L. or <i>A. glabriuscula</i> Edmondst.              | - | -  | - | -    | - | - | -    | 2 | Shore Orache, or Babington's Orache |
| <i>A. cf. patula</i> L.                                                  | - | -  | - | -    | - | 4 | -    | - | Common Orache                       |
| <i>Betula</i> sp.                                                        | - | -  | - | 1    | - | - | 1    | - | Birch                               |
| <i>Bidens tripartita</i> L.                                              | - | -  | - | 1    | - | - | -    | - | Tripartite Bur-marigold             |
| <i>Brassica</i> sp.                                                      | - | -  | - | 1cf. | - | 1 | -    | - | Marsh Marigold                      |
| cf. <i>Caltha palustris</i> L.                                           | - | -  | - | -    | - | 1 | -    | - | Sedges                              |
| <i>Carex</i> sp. or spp.                                                 | - | -  | 2 | 3    | - | 1 | -    | - | (Table continued)                   |

Table 5.1.1.1 (contd.)

| Species identified                                                 | 1   | 2 | 3 | 4   | 5 | 6    | 7 | 8 | Common name of species     |
|--------------------------------------------------------------------|-----|---|---|-----|---|------|---|---|----------------------------|
| <i>C. cf. divisa</i> Huds.                                         | -   | - | - | -   | - | 1    | - | - | Divided Sedge              |
| <i>C. cf. hirta</i> L.                                             | -   | - | - | -   | - | 1    | - | - | Hammer Sedge               |
| <i>C. cf. otrubae</i> Podp.                                        | -   | - | - | -   | - | 1    | - | - | False Fox Sedge            |
| <i>Centaurea</i> sp.                                               | -   | 1 | - | -   | - | -    | - | - | Knapweed or Cornflower     |
| <i>Cerastium holosteoides</i> Fr.                                  | -   | - | - | 2   | - | -    | - | - | Common Mouse-ear Chickweed |
| <i>Chenopodium album</i> L.                                        | -   | - | - | -   | - | 4    | - | - | Fat Hen                    |
| <i>Chenopodium hybridum</i> L. (Fig. 5.1.1.1, no. 6)               | -   | - | - | -   | - | 1    | - | - | Sowbane                    |
| <i>Chenopodium</i> sect. <i>Pseudoblitum</i>                       | -   | - | - | 2   | 1 | -    | - | - | Goosefoot                  |
| <i>Cirsium</i> sp.                                                 | -   | - | - | -   | - | 1    | - | - | Thistle                    |
| <i>Conium maculatum</i> L.                                         | -   | - | 1 | 1   | - | 16   | - | - | Hemlock                    |
| <i>Corylus avellana</i> L. (fragments of nuts)                     | -   | - | - | -   | - | 15   | - | - | Hazel                      |
| Cruciferae                                                         | -   | - | - | -   | - | 1    | - | - | Cress family               |
| <i>Daucus carota</i> L. (Fig. 5.1.1.1, no. 4)                      | -   | - | - | 1   | - | 3    | - | - | (Wild) Carrot              |
| <i>Dipsacus fullonum</i> L.                                        | -   | - | - | -   | - | 1    | - | - | Teazel                     |
| <i>Elatine hydropiper</i> L. (Fig. 5.1.1.1, no. 8)                 | -   | - | - | 1   | - | -    | - | - | no common name             |
| <i>Eleocharis palustris</i> (L.) Roem. et Schult.                  | -   | - | - | -   | - | 1    | - | - | Common Spike Rush          |
| <i>Epilobium</i> sp.                                               | -   | - | - | -   | - | 2    | - | - | Willow Herb                |
| <i>Eupatorium cannabinum</i> L.                                    | -   | 3 | 6 | -   | - | 1cf. | 7 | - | Hemp Agrimony              |
| <i>Filipendula ulmaria</i> (L.) Maxim.                             | -   | - | - | -   | - | 1    | - | - | Meadowsweet                |
| <i>Galium cf. aparine</i> L.                                       | -   | - | - | -   | - | 1    | - | - | Cleavers                   |
| Gramineae                                                          | +   | 1 | 3 | 6   | - | 7    | 3 | - | Grasses                    |
| Gramineae (cf. <i>Parapholis strigosa</i> (Dum.)<br>C. E. Hubbard) | -   | - | - | 1   | - | -    | - | - | Sea Hard Grass             |
| <i>Heracleum sphondylium</i> L.                                    | -   | - | - | -   | - | 2½   | - | - | Hogweed                    |
| <i>Humulus lupulus</i> L. (Fig. 5.1.1.1, no. 1)<br>fruits          | 102 | 9 | - | 300 | 9 | 4363 | - | - | Hop                        |
| bracts and bracteoles                                              | 23  | 8 | - | 100 | 8 | 192  | - | - | Hop                        |

(Table continued)

Table 5.1.1.1 (contd.)

| Species identified                                            | 1 | 2  | 3  | 4 | 5    | 6 | 7  | 8 | Common name of species                 |
|---------------------------------------------------------------|---|----|----|---|------|---|----|---|----------------------------------------|
| <i>Hydrocharis morsus-ranae</i> L.                            | - | 1  | -  | - | -    | - | -  | - | Frogbit                                |
| <i>Juncus</i> sp. or spp.                                     | + | 27 | 80 | - | 1    | 1 | 27 | 1 | Rushes                                 |
| <i>J. acutiflorus</i> Ehr. ex Hoffm. or <i>J. bulbosus</i> L. | - | -  | 1  | - | -    | - | -  | - | Sharp-flowered Rush or<br>Bulbous Rush |
| <i>J. compressus</i> Jacq.                                    | - | -  | 2  | - | -    | - | -  | - | Round-fruited Rush                     |
| <i>J. gerardii</i> Lois.                                      | - | -  | 16 | 1 | -    | - | -  | - | Mud Rush                               |
| <i>J. maritimus</i> Lam.                                      | - | -  | 4  | - | -    | - | -  | - | Sea Rush                               |
| <i>J. subnodulosus</i> Schrank.                               | - | -  | 3  | 1 | -    | - | -  | - | Blunt-flowered Rush                    |
| <i>Lapsana communis</i> L.                                    | - | -  | -  | - | -    | 1 | -  | - | Nipplewort                             |
| Leguminosae (pod fragment)                                    | - | -  | -  | - | -    | 1 | -  | - | Pea family                             |
| <i>Linum usitatissimum</i> L.                                 | - | -  | 1  | - | -    | 1 | -  | - | Flax                                   |
| <i>Mentha cf. aquatica</i> L.                                 | - | 1  | -  | - | -    | - | -  | - | Water Mint                             |
| <i>Oenanthe aquatica</i> (L.) Poir.                           | - | -  | -  | - | 1cf. | 1 | -  | - | Fine-leaved Water Dropwort             |
| <i>O. fistulosa</i> L. (Fig. 5.1.1.1, no. 2)                  | - | -  | -  | - | -    | 1 | -  | - | Water Dropwort                         |
| <i>O. silaifolia</i> Bieb.                                    | - | -  | -  | - | -    | 1 | -  | - | no common name                         |
| <i>Polygonum aviculare</i> L. <u>sensu lato</u>               | - | -  | -  | - | -    | 6 | -  | - | Knotgrass                              |
| <i>P. convolvulus</i> L.                                      | - | -  | -  | 1 | -    | 1 | -  | - | Black Bindweed                         |
| <i>P. lapathifolium</i> L.                                    | - | -  | -  | - | -    | 3 | -  | - | Pale Persicaria                        |
| <i>P. cf. lapathifolium</i> L. (perianth skeleton)            | - | -  | -  | - | -    | 1 | -  | - | Pale Persicaria                        |
| <i>Potamogeton</i> sp.                                        | - | -  | 1  | - | -    | - | -  | - | Pondweed                               |
| <i>Potentilla</i> sp.                                         | - | -  | -  | - | -    | 1 | -  | - | Tormentil, Cinquefoil                  |
| <i>Prunella vulgaris</i> L.                                   | - | -  | -  | - | -    | 1 | -  | - | Self-heal                              |
| <i>Ranunculus lingua</i> L.                                   | - | -  | -  | - | -    | 1 | -  | - | Great Spearwort                        |
| <i>R. subgenus Ranunculus</i>                                 | - | -  | -  | 1 | -    | 1 | -  | - | Buttercup                              |
| <i>R. sardous</i> Crantz                                      | - | -  | -  | - | -    | 5 | -  | - | Hairy Buttercup                        |
| <i>R. sceleratus</i> L.                                       | 1 | 1  | -  | 2 | -    | - | -  | - | Celery-leaved Crowfoot                 |

(Table continued)

Table 5.1.1.1 (contd.)

| Species identified                                                                                                       | 1  | 2 | 3  | 4  | 5 | 6 | 7  | 8 | Common name of species  |
|--------------------------------------------------------------------------------------------------------------------------|----|---|----|----|---|---|----|---|-------------------------|
| <u>Rubus idaeus</u> L. or <u>R. fruticosus</u> L. s.l.                                                                   | 1  | - | -  | 1  | - | - | 1  | - | Raspberry or Blackberry |
| <u>Rosa</u> sp. (thorns)                                                                                                 | -  | - | -  | -  | - | 2 | -  | - | Rose                    |
| <u>Rumex</u> sp.                                                                                                         | -  | - | -  | -  | - | 2 | -  | - | Dock or Sorrel          |
| <u>R. angiocarpus</u> Murb. (nut-and-pericarp)                                                                           | -  | - | -  | 1  | - | 1 | -  | - | Sheep's Sorrel          |
| <u>R. cf. crispus</u> L. (nut and perianth)                                                                              | -  | - | -  | -  | - | 1 | -  | - | Curled Dock             |
| <u>Sagina</u> sp.                                                                                                        | -  | 1 | -  | -  | 1 | - | -  | - | Pearlwort               |
| <u>Salicornia</u> sp. (Fig. 5.1.1, no. 9)                                                                                | 10 | 8 | 31 | 40 | - | 1 | 11 | - | Glasswort               |
| <u>Salix</u> sp. or spp. (bud scales)                                                                                    | -  | - | -  | 1  | 1 | 8 | -  | - | Willow, Osier           |
| <u>Sambucus nigra</u> L.                                                                                                 | -  | - | -  | -  | - | 7 | -  | - | Elder                   |
| <u>Samolus valerandi</u> L.                                                                                              | -  | - | 1  | -  | - | - | -  | - | Brookweed               |
| cf. <u>S. valerandi</u> L.                                                                                               | -  | - | 1  | -  | - | - | -  | - | Brookweed               |
| <u>Scabiosa columbaria</u> L.                                                                                            | -  | - | -  | -  | - | 1 | -  | - | Small Scabious          |
| <u>Silene</u> sp.                                                                                                        | -  | - | -  | -  | - | 1 | -  | - | Campion                 |
| <u>Sonchus asper</u> (L.) Hill                                                                                           | -  | - | -  | -  | - | 2 | -  | - | Spiny Sowthistle        |
| <u>Spergularia</u> sp.                                                                                                   | -  | - | -  | 1  | - | - | -  | - | Spurrey                 |
| <u>S. cf. marina</u> (L.) Griseb.                                                                                        | 1  | - | 1  | -  | - | - | -  | - | Spurrey                 |
| <u>Stellaria graminea</u> L.                                                                                             | -  | - | -  | 1  | - | 2 | -  | - | Lesser Stitchwort       |
| <u>S. media</u> (L.) Vill.                                                                                               | -  | - | -  | 1  | - | - | -  | - | Chickweed               |
| <u>Suaeda maritima</u> (L.) Dum. var. <u>maritima</u><br>and var. <u>macrocarpa</u> (Desv.) Moq. (Fig.<br>5.1.1, no. 10) | 9  | 3 | 21 | 24 | - | 8 | 5  | 3 | Seablite                |
| <u>Torilis japonica</u> (Houtt.) DC.                                                                                     | -  | - | -  | -  | - | 3 | -  | - | Upright Hedge-parsley   |
| <u>T. cf. japonica</u> (Houtt.) DC. (fragments)                                                                          | -  | - | -  | -  | - | 5 | -  | - | Upright Hedge-parsley   |
| <u>Triglochin maritima</u> L. (Fig. 5.1.1, no. 3)                                                                        | -  | - | -  | 1  | - | 1 | -  | - | Sea Arrowgrass          |
| <u>Typha</u> sp. or spp. (Fig. 5.1.1, no. 7)                                                                             | +  | 5 | -  | 30 | - | - | 14 | - | Reedmace, Bulrush       |
| <u>Typha angustifolia</u> L.                                                                                             | -  | 1 | -  | -  | - | - | -  | - | Reedmace, Bulrush       |

(Table continued)

Table 5.1.1.1 (contd.)

| Species identified               | 1 | 2 | 3  | 4  | 5 | 6  | 7 | 8 | Common name of species |
|----------------------------------|---|---|----|----|---|----|---|---|------------------------|
| <u>Typha latifolia</u> L.        | - | - | 28 | -  | - | -  | - | - | Reedmace, Bulrush      |
| <u>Umbelliferae</u>              | - | - | -  | -  | - | 1  | - | - | Parsley family         |
| <u>Urtica dioica</u> L.          | 5 | - | -  | 15 | 1 | 20 | 2 | - | Stinging Nettle        |
| <u>Urtica urens</u> L.           | - | - | -  | -  | - | -  | 1 | - | Small Nettle           |
| <u>Zannichellia palustris</u> L. | - | - | -  | 1  | - | -  | - | - | Horned Pondweed        |

which fossils have been transported a long distance; for instance, the category 'derived megaspores' refers to Mesozoic fossils obviously redeposited by the river, and the minute coal fragments have a similar origin. The megaspores of *Azolla filiculoides* must also have been redeposited. This aquatic fern is not native in Britain today, having been introduced only very recently from America. It used to grow in Britain, however, until the Hoxnian Interglacial period; its presence at Graveney suggests that the river was eroding Hoxnian or earlier deposits upstream. All the secondarily derived fossils are easily transported, and all those in the Graveney samples are abraded (especially the *Azolla* megaspores). Most of the remaining fossils are well-preserved and are unlikely to have been carried far by water.

It is not easy to be precise about the plant communities represented in the Graveney lists, because many of the species can occur in any of several plant communities. The lists, do, however, give a general indication of the vegetation around the site.

The samples contain at least four species highly characteristic of salt-marshes, and many other maritime species. The presence of *Salicornia* (Glasswort; Fig. 5.1.1, no. 9) may represent the first stage of colonization of the mudflats, but the additional presence of *Suaeda maritima* (Seablite; Fig. 5.1.1, no. 10) and *Aster tripolium* (Sea Aster) suggests a somewhat later stage of colonization. Remains of *Triglochin maritima* (Sea Arrowgrass; Fig. 5.1.1, no. 3) were also found. If these four species are considered together, they indicate a still later stage. In fact several salt-marsh communities must be represented, since Glasswort only grows where it is submerged by the tide for most of the time, whereas others such as *Juncus maritimus* (Sea Rush) only grow above high water mark. Such species as *Chenopodium botryodes* (Goosefoot) and *Spergularia marina* (Spurrey) are found in the upper levels of salt-marshes (Tansley, 1949). The Graveney boat was found during the widening of the Hammond Drain, part of an ancient natural watercourse. The plant remains indicate that in Anglo-Saxon times this watercourse was within the range of high tides, and near mudflats which were usually covered by the tide. At present, the high water mark is 1 km distant, in Whitstable Bay.

Some of the aquatic and semi-aquatic species in the Graveney lists require fresh water, but are nonetheless found most often by the sea. Others can tolerate salt influences or brackish water, for instance *Ranunculus sceleratus* (Celery-leaved Crowfoot) which can grow on estuarine muds, and *Bidens tripartita* (Bur-marigold) and *Oenanthe fistulosa* (Water Dropwort; Fig. 5.1.1, no. 2) which may be found in marshes near the sea. The calyces (Fig. 5.1.1, no. 5) of *Armeria* (Thrift) or *Limonium* (Sea Lavender) also indicate maritime species. Several *Limonium* species grow in muddy coastal places, which would evidently have been available at Graveney, and others are characteristic of drier or sandier habitats on the shore. Thrift can grow either on mountains inland, or by the sea; its upland habitats do not concern us here.

Sample 4 gives the best idea of dry-land vegetation in the vicinity. The brushwood for the platform was presumably collected beyond the mudflats but within relatively easy reach of the boat. Trees and shrubs include *Alnus glutinosa* (Alder), *Rubus* sp. (Blackberry or Raspberry), *Salix* sp. (Willow),

*Quercus* sp. (Oak), and *Betula* sp. (Birch). A number of the herbaceous terrestrial species in this sample are species which occupy disturbed ground inland and which also find suitable habitats near the sea. Some of them are most familiar as weeds, for instance *Achillea millefolium* (Yarrow), *Cerastium holosteoides* (Common Mouse-ear Chickweed), *Stellaria media* (Chickweed), and *Polygonum aviculare* (Knotgrass). Others such as *Atriplex hastata* and *Daucus carota* (Wild Carrot; Fig. 5.1.1, no. 4) occur all round Britain on the coast, although they do occur inland in parts of lowland Britain. The pollen counts from Sample 4 are given elsewhere (Wilson, 1975). The non-tree pollen has rather a high value, which is usual for estuarine deposits. The tree pollen indicates mixed oak forest, pollen zone VIII, with quite a high percentage of beech, which is appropriate for a 10th-century site in SE. Britain. It need not, however, imply that the immediate vicinity of the site was wooded. Much of the pollen is likely to have come from 'Andredesweald' or the Old Forest, which lay some 25 km S. of Graveney. Historical sources show that parts of this forest had not long been cleared or settled at this period (Darby and Campbell, 1962). There will also have been lesser woods nearer Graveney.

The samples from within the boat have much in common with the brushwood sample, but it is likely that they include more plant remains transported in the cargo as well as from the site itself. Sample 6 in particular yielded a long species list (partly because it was a bigger sample than most of the others), and it includes more weeds. *Agrostemma githago* (Corn Cockle) and *Conium maculatum* (Hemlock) occurred in much greater abundance than in the other samples. Corn Cockle is very typically a weed of rye crops, and Hemlock is a species strongly associated with human settlement although it may be found in damp places and on shingly strand-lines. *Aegopodium podagraria* (Goutweed), *Torilis japonica* (Hedge Parsley) and *Heracleum sphondylium* (Hogweed) are all species of rough grassy places or disturbed ground, often associated with human activity. The single seed of *Chenopodium hybridum* (Fig. 5.1.1, no. 6b) is of particular interest. It is not a common species in Britain today, and its distribution is distinctly south-eastern (Perring and Walters, 1962). Like many members of its family, it grows in waste places and cultivated ground. It is not known how long it has been in Britain, but it is likely to have been introduced as an agricultural weed or a 'camp follower'. The seeds are highly distinctive, with a coarse pattern of large hollows arranged in fairly regular polygons. This layer is black and shiny. Beneath it lies a layer of small rectangular cells, which is only visible in immature specimens or in mature seeds which have had the outer layer removed. The embryo of *Chenopodium* seeds is curled or bent, according to species. Those with curled embryos have seeds that show a curved groove running more or less parallel to the rounded edge of the seed; those with bent embryos have a radial groove. *Chenopodium hybridum* normally has a radial groove. In the Graveney fossil the groove is poorly marked and definitely not properly radial, but we found an exactly similar young seed of *C. hybridum* (Fig. 5.1.1, no. 6a) in Leicester University Herbarium.

In sample 6 *Dipsacus fullonum* (Teazel) and *Linum usitatissimum* (Flax) are noteworthy. Both species are cultivated, but they are not present in sufficient quantity to require further comment. *Scabiosa columbaria* (Small

Table 5.1.2 Position and Preliminary Treatment of Samples 1-8

| Sample no. | Graveney no. | Position                                                                                         | Volume (ml) | Sediment type                                     | Treatment                       | Notes                                                                                                                               |
|------------|--------------|--------------------------------------------------------------------------------------------------|-------------|---------------------------------------------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| 1          | -            | Between planks on port side near base of frame R4                                                | 250         | Sticky grey clay                                  | Hot water and Decon (detergent) |                                                                                                                                     |
| 2          | GM70/2       | Immediately above keel amidships; lower of two samples taken from temporary baulk c. 0.15 m high | 250         | Clay with shell fragments                         | Nitric acid                     | Detergent not effective                                                                                                             |
| 3          | Gr57         | Amidships below keel and brushwood platform                                                      | 500         | Homogeneous black clay                            | Hot water and Decon             | Natural surface on which boat settled; least likely of all samples to have been disturbed, either in antiquity or during excavation |
| 4          | Gr138        | Brushwood platform on starboard side                                                             | 500         | Contorted blue clay with pieces of wood and twigs | Hot water and Decon             | Sub-sampled for pollen analysis                                                                                                     |
| 5          | Gr72         | Beneath frame R1                                                                                 | -           | Clay                                              | Water                           | Accumulated in later part of boat's life (p. 171)                                                                                   |
| 6          | Gr92         | Beneath frame R6                                                                                 | 700         | Clay                                              | Hot water                       | Detergent not effective.                                                                                                            |
| 7          | Gr53         | Outside hull on starboard side                                                                   | 600         | Clay                                              | Nitric acid                     | Modern bud found in sample                                                                                                          |
| 8          | Gr93         | Level of 'painter' Gr164                                                                         | c. 5        | Gritty clay                                       | Water                           | With unidentifiable cast. Virtually sterile; no wood                                                                                |

Table 5.1.3 Wood Identifications

| Sample no.* | Description of unnumbered sample                                                   | Identification                                                                                                                                          | Notes                                                                               |
|-------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| 4           |                                                                                    | Oak and <u>Corylus</u> (hazel) with few twigs of <u>Alnus</u> sp. (alder)                                                                               |                                                                                     |
| 5           |                                                                                    | Not identifiable                                                                                                                                        |                                                                                     |
| 6           |                                                                                    | Mostly <u>Salix</u> sp. (willow) and <u>Quercus</u> sp. (oak) with a few pieces of <u>Corylus</u> (hazel)                                               |                                                                                     |
| 7           |                                                                                    | Numerous slivers of <u>Fraxinus</u> sp. (ash)                                                                                                           | Resembling flat splinters that result from splitting ash log along grain with wedge |
|             | Rope fragments: a, Gr164 ('painter'), fixed to stern; b, ARC.S.4016 from port side | a, disintegrated; b, impregnated with resin; not identifiable but not <u>Humulus</u> (hop); one section showed features of Dicotyledon stem 3 years old | In poor condition. Looked like osier rope <u>in situ</u>                            |
|             | Frame fragments including Gr91                                                     | <u>Quercus</u> sp. (oak)                                                                                                                                |                                                                                     |
|             | Strake fragments, including 1 port aft, Gr81                                       | <u>Quercus</u> sp. (oak)                                                                                                                                |                                                                                     |
|             | Keel, Gr80                                                                         | <u>Quercus</u> sp. (oak)                                                                                                                                |                                                                                     |
|             | Trenails, Gr25 and Gr365                                                           | <u>Salix</u> sp. (willow)                                                                                                                               |                                                                                     |
|             | Plugs Gr285 and Gr287 (ARC.S.4087/88)                                              | Identifiable fragments <u>Quercus</u> sp. (oak)                                                                                                         | Uncertain whether from plugs or from planks into which they were driven             |

(Table continued)

Table 5.1.3 (contd.)

| Sample no.* | Description of unnumbered sample                    | Identification                                     | Notes                            |
|-------------|-----------------------------------------------------|----------------------------------------------------|----------------------------------|
|             | Stern fragments                                     | <u>Quercus</u> sp. (oak)                           |                                  |
|             | Post 3 on port side                                 | <u>Quercus</u> sp. (oak)                           |                                  |
|             | Brushwood on starboard side beneath frame R1, Gr138 | Cf. <u>Salix</u> sp. (possibly willow)             |                                  |
|             | Pegs                                                | <u>Quercus</u> sp. (oak)                           |                                  |
|             | Caulking GM57                                       | Pad of animal hair 35 mm x 25 mm, horseshoe-shaped | No plant remains in adherent mud |

\*Position as in Table 5.1.2.

*Scabious*) is a species of dry calcareous pasture or grassy places, a habitat not otherwise clearly indicated by the Graveney lists. Only one 'involucl' or epicalyx was found.

The only species whose abundance is seriously out of keeping with the rest of the Graveney fossils is Humulus lupulus L., the hop (Fig. 5.1.1, no. 1). There can be little doubt that the boat was carrying a cargo of hops and that some were spilt on to the brushwood platform. Hops were not found in the undisturbed sample from beneath the keel, nor in the sample from outside the hull on the starboard side, nor in the sample from the level of the 'painter' at the stern (i.e. samples 3, 7 and 8). They occurred abundantly inside the boat (Fig. 6.5), and in quantity in the brushwood sample. No pollen of hop was found in the brushwood sample, despite particular attention to the possibility and despite the fact that male hops produce abundant wind-borne pollen. One male plant is now considered adequate to pollinate an acre of females, and twelve males per acre were formerly recommended (Lance, 1838:103-4). If hops had been gathered with the brushwood, some pollen, twigs or leaves would have been found with the fertilized nuts and other parts of the inflorescence. If hops had been growing upstream beyond the pollen catchment area, the fossils would have been less well-preserved, and they would have occurred also in the clays beneath the hull.

The use and cultivation of hop in Britain has been supposed to be relatively recent, and the question is complicated by the fact that wild hops have been part of the British flora since long before the adoption of agriculture (Godwin, 1956). Their natural habitat is in wet alder and oak woods, and the apparently wild hops to be seen in hedgerows today are only relicts of these habitats, or escapes from cultivation. Hops have many uses besides the most familiar one of preserving and flavouring beer. The stems provide a strong fibre, but no stems were found at Graveney. The young shoots can be eaten like asparagus, but as the Graveney fossils were mature nuts, hop shoots would have been long out of season. The leaves and inflorescences provide a yellow dye, but not one that was sufficiently valuable to warrant bulk transport. Hops have long been used in medicine, as a tonic and as a sedative, but again the sheer quantity of hops at Graveney suggests industry on a larger scale than pharmacy. The multitude of fossils can only represent a small proportion of the cargo which had been split on the platform or had found its way into crevices in the boat's timbers.

There is no inherent improbability that the hops were destined for brewing. From the 9th century onwards there is good evidence that French monasteries were making beer with hops, and that they required their tenants to provide hops for the purpose.<sup>2</sup> At first it seems that wild hops were gathered from the woods, as at the diocese of Freising (Bitterauf, 1967:I, 666-715). 1878:97), but by A.D. 859-875 there are numerous references to hop-gardens, notably in the annals of the abbey of Freisingen (Bitterauf, 1967:I, 666-715). The evidence for hopped beer in Britain at this date is indirect. Anglo-Saxon leech books and glossaries show that hops were known, and in one recipe there is a note commenting that hyme is such a useful herb that men put it in their usual drinks (Cockayne, 1864:172). This recipe is to be found in the Anglo-Saxon manuscript known as the Herbarium of Apuleius. A Latin version of

the text does not mention hops (Hunger, 1935), which suggests that hopped beer was not usual in the Mediterranean region.

In Kent documents exist which refer to hoptavel. This term refers to pre-conquest land tenure and proves that hops used to be a customary due or rent-in-kind payable by certain tenants. Similarly, in hoplands dues had been payable in respect of hops no matter what the status of the tenant was (Neilson, 1910; Ballard, 1920). These hops must surely have been for brewing, just as on the continent. Most references to hoplands and to hoptavel are to be found in documents belonging to the abbey of St Augustine in Canterbury, and concern manors in Thanet. At the time of Domesday (the date of the relevant documents) Graveney belonged to Christ Church, Canterbury. It may be accidental that the manor of Graveney is not mentioned as a 'hop' manor. At this time the brewery at Canterbury was famous for the excellence of its beer, and the monks did not stint themselves (Brewer, 1861:51). The provost, Brimannus, was in dispute with the community, because he kept for himself the fines levied on any who brewed beer 'in any other way than in ancient times' (Ballard, 1920:8). This might well refer back to the days of hoptavel and suggest that traditional brewing methods included the use of hops. Certainly the monks at Canterbury were in contact with European communities, and would have known how to make hopped beer. Perhaps the Graveney boat was part of a transport system supplying hops for the brewery in Canterbury. We cannot tell whether the hops were grown in Kent, but what evidence there is suggests that they were not grown at Graveney itself. Trade links between Europe and Britain were strong at this time (Stenton, 1934), and there may well have been hops among the commodities carried across the Channel. Goods would have included tithes being taken to continental monasteries holding land in Britain; Odo of Bayeux held land in Kent in the eleventh century, as did the monastery of St Peter in Ghent (V.C.H. Kent, II:238; *ibid.*, III:214; Stenton, 1934).

At about this time, too, there was rivalry in Europe between the makers of hopped beer and those who held monopolies in 'gruit' manufacture, i.e., mixtures of herbs and spices for beer flavouring (see Arnold, 1911). Since these monopolies were specifically intended to oust the use of hops, it is clear that hops were still popular. Indeed, it is reported that an 11th-century document in Westminster Abbey refers to 'hoppis de brasio' (Skeat, 1910); it is not until more than a century later that English ale was the subject of an assize which precluded the use of hops or other herbs in its manufacture (Sharpe, 1912:211-12 and 295).

The hop fossils in the Graveney boat are not explicable in terms of the ecology of the site, but they do provide the first concrete evidence for the early use of hops in British brewing.

#### NOTES

1. We gratefully acknowledge the cooperation of Miss Louise Millard of the Royal Museum, Canterbury, G. de G. Sieveking of the Department of Prehistoric Antiquities in the British Museum, and members of the Graveney Boat Unit, in securing samples. We would like to thank Miss R. Andrew for the pollen analysis of the brushwood sample, Dr H. H. Birks and Miss K. Guyton for identifying fragments of a frame and a plank, and R. E. Moore of the Jodrell Laboratory, Kew, for examining

a rope fragment. We particularly thank Mrs. V. Fenwick for the enthusiasm and encouragement which made this report possible.

2. See, for instance, the abbey of Corvey's statutes of A.D. 822 (Levillain, 1900:384).

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## CHAPTER 5: ENVIRONMENTAL STUDIES

### PART 2. REPORT ON THE EXAMINATION OF MISCELLANEOUS SAMPLES

by A. E. Werner and W. A. Oddy,  
Research Laboratory, British Museum

1. Samples Gr139 and 222. Gr139 consisted of twisted caulking which seemed to be mixed with 'putty' to act as a stopper. Gr222 consisted of a 'concretion' from the top of an iron rove on Gr216. The 'concretion' and the 'putty' were analysed by quantitative emission spectroscopy. The spectra were compared with those of a sample of mud from the site and no detectable difference was observed. Hence there is no evidence for the use of a 'stopper' with either the twisted caulking or on top of the rove.

2. Sample Gr344. This is a sample of white material which was observed during the excavation (Fig. 8.29). Opinions differ as to whether it is the remains of paint or of a mould growth. It was examined by X-ray diffraction analysis but as it proved to be amorphous, no identification was possible. A spectroscopic analysis revealed essentially the same pattern of elements found in samples Gr139 and 222 (above), and thus no conclusions can be drawn about the nature of this white material. Further samples were submitted to the Commonwealth Mycological Institute and Dr D. L. Hawksworth reports as follows:

'The whitish film on your sample no. 1 (IMI 157237) is not fungal but seems most likely to be paint. Some bacteria were present on this sample and more on your sample no. 2 (IMI 157238). In addition to the paint-like film on your sample no. 1, the minute black sporocarps of a fungus are present, but this is quite unrelated to the film in question. Extensive investigations of this fungus involving examination of most of the sporocarps present failed to reveal any in a sufficiently good condition to give the fungus concerned a name.'

3. Sample Gr47. Gr47 consisted of red brick or tile on which a blue material was deposited. This has been identified by X-ray diffraction analysis as vivianite, which is a hydrated ferrous orthophosphate, and, no doubt, formed naturally.

4. Samples Gr255, 264 and 265. Gr255 and 264 are samples of felted luting and Gr265 is a sample of twisted caulking. All have been impregnated with a black material. Samples of this black material were extracted with chloroform and tentatively identified as wood tar by paper chromatography, by comparison with modern materials (Stockholm Tar and Archangel Pitch). The identification was confirmed by infra-red analysis of extracts from all three samples.

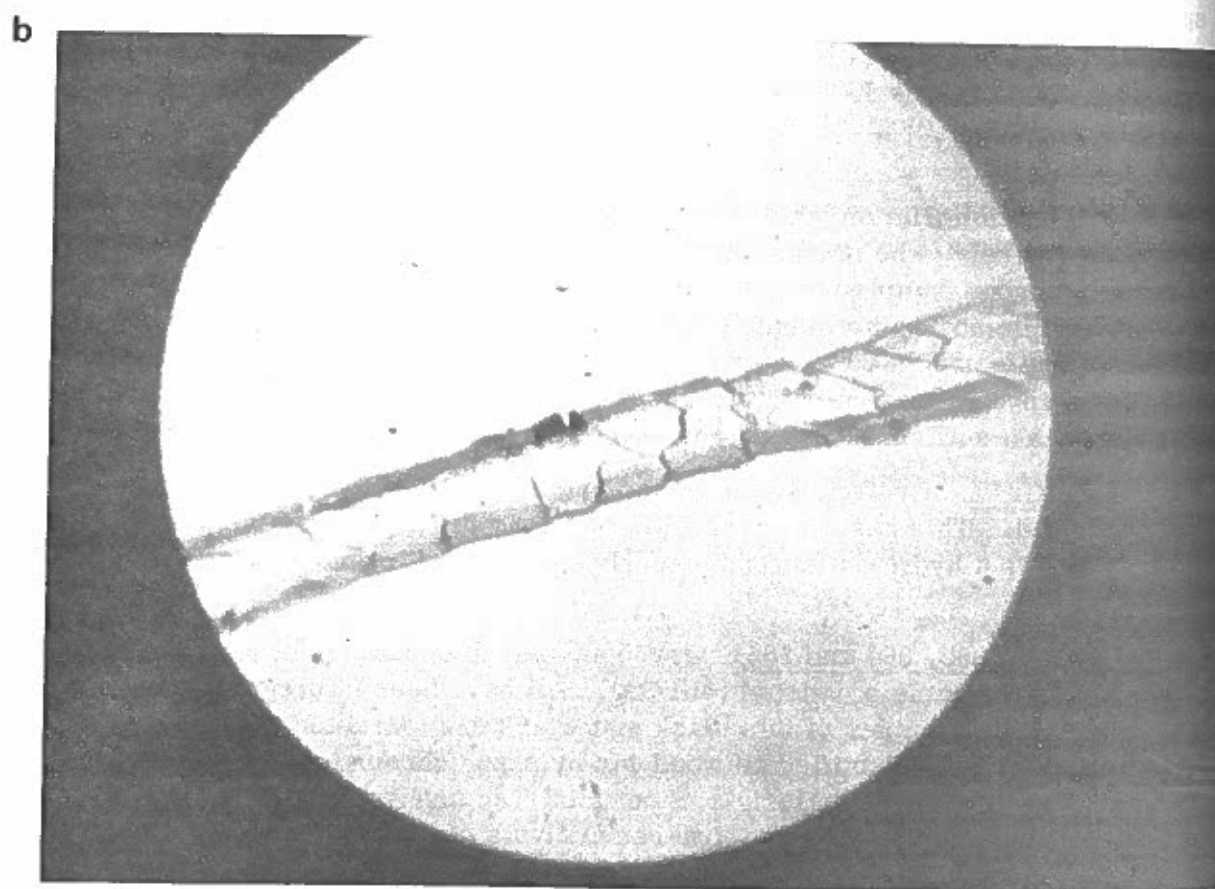
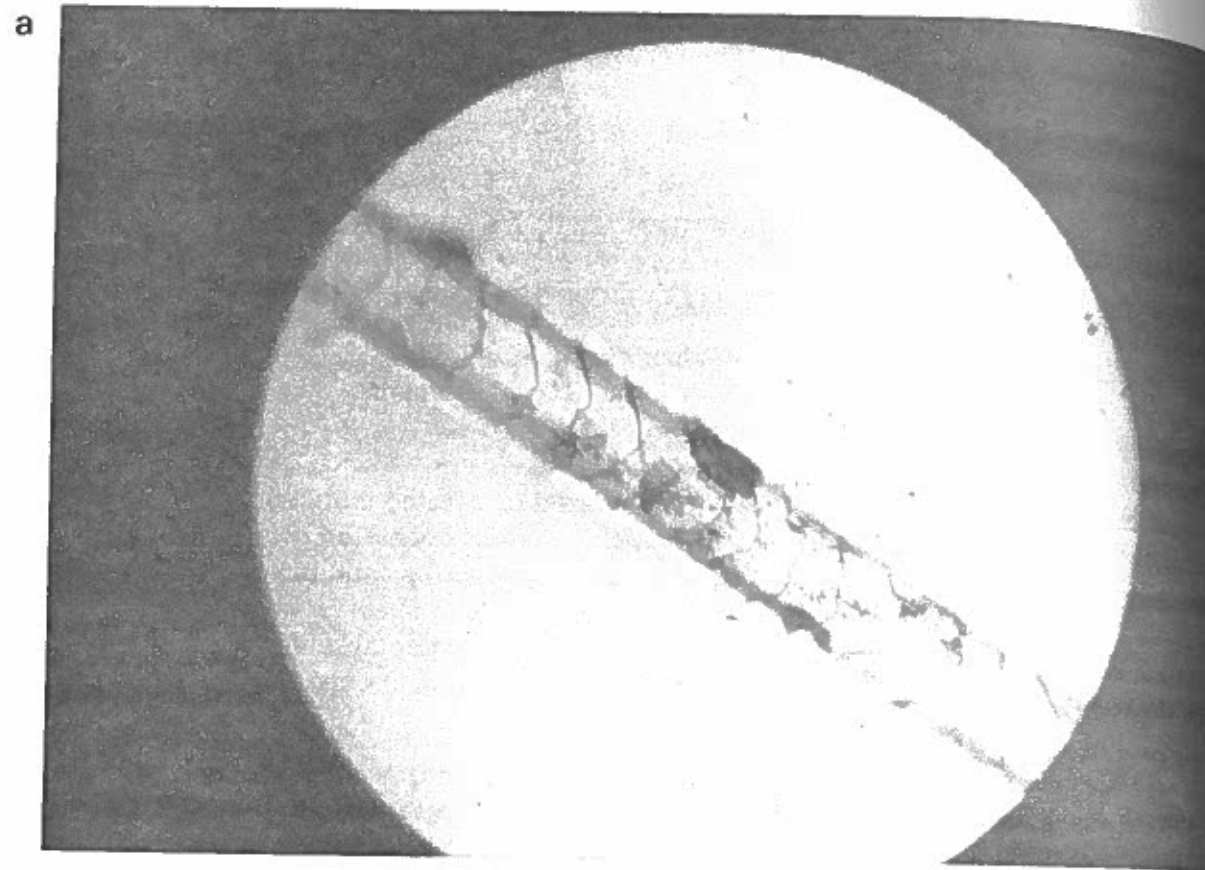


Fig. 5.2.1 Poly(vinylacetate)-resin casts magnified x 500 of surface details of fibrous materials: a, luting between planks (Gr255); b, grommet around trenail (Gr21)  
© Laboratory of Government Chemist

Samples of the fibre from Gr264 and 265 were examined microscopically and shown to be of animal origin, most probably from a sheep. This identification was confirmed on other samples by the Laboratory of the Government Chemist, whose report appears below.

5. Timber. Samples of wood from various parts of the boat submitted to Dr D. F. Cutler of the Royal Botanic Gardens, Kew, were identified as follows:

|    |                                         |   |                            |
|----|-----------------------------------------|---|----------------------------|
| A. | Strake P5A                              | } | <u>Quercus robur</u> (oak) |
|    | Strake S5B                              |   |                            |
|    | Sticks Gr118 (two samples)              |   |                            |
|    | Frame, unnumbered                       |   |                            |
|    | Posts in vicinity of boat (two samples) |   |                            |
|    | Trenail Gr365                           |   |                            |
|    | Keel                                    |   |                            |
| B. | Trenail Gr363                           |   | <u>Salix</u> (willow)      |
| C. | 'Osier painter' Gr164                   | } | <u>Alnus</u> (alder)       |
|    | Sticks Gr118 (two samples)              |   |                            |

#### Report on stone samples

by S. E. Ellis,  
Department of Mineralogy, British Museum (Natural History)

1. 'Clinker' Gr83. This is probably clinker resulting from fire. The earthy coating contains blue iron phosphate vivianite, which in recent deposits is often associated with material of organic origin, such as calcined bones.
2. Quern Gr112. This is undoubtedly millstone lava of the Niedermendig district of the Rhineland. The blue mineral visible is probably hatyne which occurs sporadically in this lava.

#### Report on fibrous samples

by H. A. Hunt, Laboratory of the Government Chemist

1. Large wet sample Gr255, between clinker planks
2. Small wet sample Gr21, twisted round trenail
3. Small dry sample Gr217, in sternpost scarf with keel

The samples were extremely dirty and normal microscopic examination revealed little except that they were of animal hair. Casts of the fibres were made in poly(vinylacetate) resin and when micrographs of these were examined the scale pattern was more readily identifiable (Fig. 5.2.1). All three samples are animal hair. The cross-section is apparently circular and the hairs do not

appear to be medullated. The general appearance strongly suggests that it is sheep's wool; the scale pattern and cross-section are consistent with a long-wool breed.

#### NOTE

1. We are grateful to the following whose reports are included in this section: Dr D. L. Hawksworth of the Commonwealth Mycological Institute; Dr D. F. Cutler of the Royal Botanic Gardens, Kew; Mr S. E. Ellis of the Department of Mineralogy, British Museum (Natural History); and Mr H. A. Hunt of the Laboratory of the Government Chemist.

## CHAPTER 5: ENVIRONMENTAL STUDIES

### PART 3. THE MOLLUSCS

by Kenneth Thomas, Institute of Archaeology, University of London

This report on the molluscs found in and around the boat is divided into three sections. The identity and numbers of the different species present in the various samples are described (Table 5.3.1). The significance of the molluscs found inside, and in the immediate vicinity of, the boat is considered. The shells from the 13th-century horizon down-stream are also discussed.

#### Interpretation of the molluscs around the boat

Scrobicularia, Mytilus, Ostrea and Cerastoderma are bivalved molluscs which quite commonly live in estuaries. The gastropod Buccinum undatum occurs in the sub-littoral zone, as does Ostrea. Cerastoderma edule may be found in the inter-tidal zone in clean sand, muddy sand, muddy gravel or muds. It can tolerate low salinities and is often very abundant in estuaries. Only three valves were recovered, perhaps indicating that conditions in this part of the estuary were not at their best for this species. Mytilus edulis is also common in estuaries, extending from high in the inter-tidal zone to depths of a few fathoms (where such depths exist in estuaries). It requires a suitable place for attachment (rocks, piers, etc.); perhaps this was provided by the posts of the supposed jetty. Scrobicularia plana is found in great abundance in the inter-tidal zone of estuaries with soft bottoms of clay and mud rich in organic matter.

The species found in and around the boat are those which one would expect to find in the inter-tidal zone of an estuary with a muddy bottom. It is likely that they occur naturally in their context and that the few deeper-water specimens had been washed up after death. Particularly compelling evidence for this comes from the valves of S. plana. This species lives in mud and when it dies it remains buried in it. The valves are therefore likely to remain together, although some may become separated if uncovered by wave action. Of the thirty-five reasonably complete valves of S. plana recovered, more than 50% (eighteen valves) could be exactly fitted together to form complete shells. This strongly suggests that the shells were found in situ and had not been derived from elsewhere by wave action. As S. plana is rather distasteful, it is not likely that its shells represent human food debris. It feeds on muds rich in decaying organic matter and associated bacteria.

The environment around the boat before and possibly after its abandonment consisted of richly organic, inter-tidal, estuarine muds.

#### Shells from 13th-century layer

The shells were found c. 100 m downstream in a layer exposed by the cutting of the ditch. This layer was transitional between the estuarine muds and a

supposed land surface (Evans and Fenwick, 1971:91).

Most are of the oyster, *Ostrea edulis*. The inequality of the numbers of left and right valves in the sample has no statistical significance. The valves are remarkably clean and fresh with the exception of one right valve which is stained black and has very smooth edges. The outer growth lines of this valve are smooth and the inner surface bears encrustations of Bryozoa and the left valve of a juvenile oyster. Since both Bryozoa and oysters settle as larvae from the plankton on to a suitable surface on which they can metamorphose and grow, it seems that this particular valve was exposed under water for some time after the death of the oyster. The outer surface of this valve bears a growth of barnacles (*Balanus balanoides*), but this is not unusual even on living oysters. All the other valves were very clean on their inner surfaces, suggesting that they had not been in water for a long time (if at all) after the deaths of their occupants. The valves were therefore either washed up soon after the oysters had died or they represent dumped food debris.

All are medium to large, perhaps indicating some selection by man (if they had been derived naturally one might have expected to find some very small valves). The lower edges of ten right valves and seven (perhaps eight) left valves show consistent patterns of damage which suggest that they were forcibly opened by an implement. The consistency of the damage is such that one would not expect it to be natural, especially since the other parts of the valves show little damage (Fig. 5.3.1). On the other hand the fact that such damage was not evident in some of the valves does not necessarily prove that they were not opened for food; a knife could have been inserted with sufficient skill to cut the adductor muscle, so that the valves did not have to be forced apart. Against this, it should be noted that only two of the valves could be fitted together to form a complete shell (and then only tentatively). However, the shells were samples only, and taken from a thin layer.

Most of the other molluscs found are very worn and broken and one specimen of *Buccinum* had been extensively bored by a sponge (*Clione*). These shells were clearly washed around in water for some time after death. However, the adult specimen of *Nassarius incrassatus* was in good condition. This species bores holes in the shells of other molluscs and feeds on the enclosed soft tissues. Possibly it was collected with the oysters. If the oysters were dredged from the bed of the estuary, the rest may also have been brought up and later discarded.

#### REFERENCE

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Table 5.3.1 / Identifications of Molluscs

| Graveney No. of sample | Position                  | Identification                                       | No. of shells<br>(l. = left; r. = right) |                   |
|------------------------|---------------------------|------------------------------------------------------|------------------------------------------|-------------------|
| 104 (ARC.S.4048)       | Beneath boat              | 1. <i>Scrobicularia plana</i><br>(da Costa)          | 4 l. valves<br>3 r. valves               | 1 complete shell  |
|                        |                           | 2. <i>Mytilus edulis</i> (Linn.)<br>(common mussel)  | 1 r. valve                               |                   |
| 133 (ARC.S.4049)       | Beneath boat              | <i>Scrobicularia plana</i>                           | 1 l. valve<br>3 r. valves                | 1 complete shell  |
| 140 (ARC.S.4050)       | Inside boat               | <i>Scrobicularia plana</i>                           | 2 l. valves<br>1 r. valve                | 1 complete shell  |
| 145 (ARC.S.4045)       | Beneath boat on port side | 1. <i>Scrobicularia plana</i>                        | 3 l. valves<br>2 r. valves               | 1 complete shell  |
|                        |                           | 2. <i>Mytilus edulis</i>                             | 1 r. valve<br>3 fragments                |                   |
| 134 (ARC.S.4047)       | Beneath boat              | <i>Scrobicularia plana</i>                           | 6 l. valves<br>4 r. valves               | 3 complete shells |
| 149 (ARC.S.4051)       | Beneath keel              | 1. <i>Scrobicularia plana</i>                        | 2 l. valves<br>2 r. valves               | 1 complete shell  |
|                        |                           | 2. <i>Mytilus edulis</i>                             | 2 r. valves                              |                   |
|                        |                           | 3. <i>Ostrea edulis</i> (Linn.)<br>(European oyster) | 2 l. valves<br>1 r. valve                |                   |

(Table continued)

Table 5.3.1 (contd.)

| Graveney No. of sample | Position                     | Identification                                                 | No. of shells<br>(l. = left; r. = right)                                                                            |
|------------------------|------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 152 (ARC.S.4046)       | Near sternpost               | 1. <u>Scrobicularia plana</u>                                  | 1 l. valve<br>1 r. valve<br>1 complete shell                                                                        |
| 367                    | Residue after excavation     | 2. <u>Mytilus edulis</u>                                       | 1 l. valve                                                                                                          |
| 387 (GM70/4)           | In grey clay                 | <u>Ostrea edulis</u><br>1. <u>Scrobicularia plana</u>          | 1 l. valve<br>4 l. valves<br>3 r. valves<br>Broken, identified from umbonal frags                                   |
|                        |                              | 2. <u>Ostrea edulis</u>                                        | 2 l. valves<br>2 r. valves                                                                                          |
|                        |                              | 3. <u>Cerastoderma edule</u> (Linn.)<br>(Common edible cockle) | 1 l. valve<br>2 r. valves                                                                                           |
|                        |                              | 4. <u>Buccinum undatum</u> (Linn.)<br>(Common whelk)           | 1 broken                                                                                                            |
| 388 (GM70/6)           | Inside boat                  | 1. <u>Scrobicularia plana</u><br>2. <u>Mytilus edulis</u>      | Fragments                                                                                                           |
| 147 (ARC.S.4052)       | 13th-cent. layer down-stream | 1. <u>Scrobicularia plana</u><br>2. <u>Ostrea edulis</u>       | 1 l. valve<br>13 l. valves +<br>1 non-umbonal frag.<br>20 r. valves +<br>1 umbo and 1 non-umbonal frag.<br>(contd.) |

Table 5.3.1 (contd.)

| Graveney No. of sample | Position                     | Identification                                                       | No. of shells<br>(l. = left; r. = right)                                   |
|------------------------|------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------|
| 147 (ARC.S.4052)       | 13th-cent. layer down-stream | 3. <u>Littorina littorea</u> (Linn.)<br>(Common periwinkle)          | 1 badly worn apical fragment                                               |
|                        |                              | 4. <u>Nassarius incrassatus</u> (Ström.)<br>(Thick-lipped dog whelk) | 1 damaged juvenile<br>1 whole adult                                        |
|                        |                              | 5. <u>Buccinum undatum</u>                                           | 1 broken juvenile<br>1 broken worn adult (heavily bored by <u>Clione</u> ) |

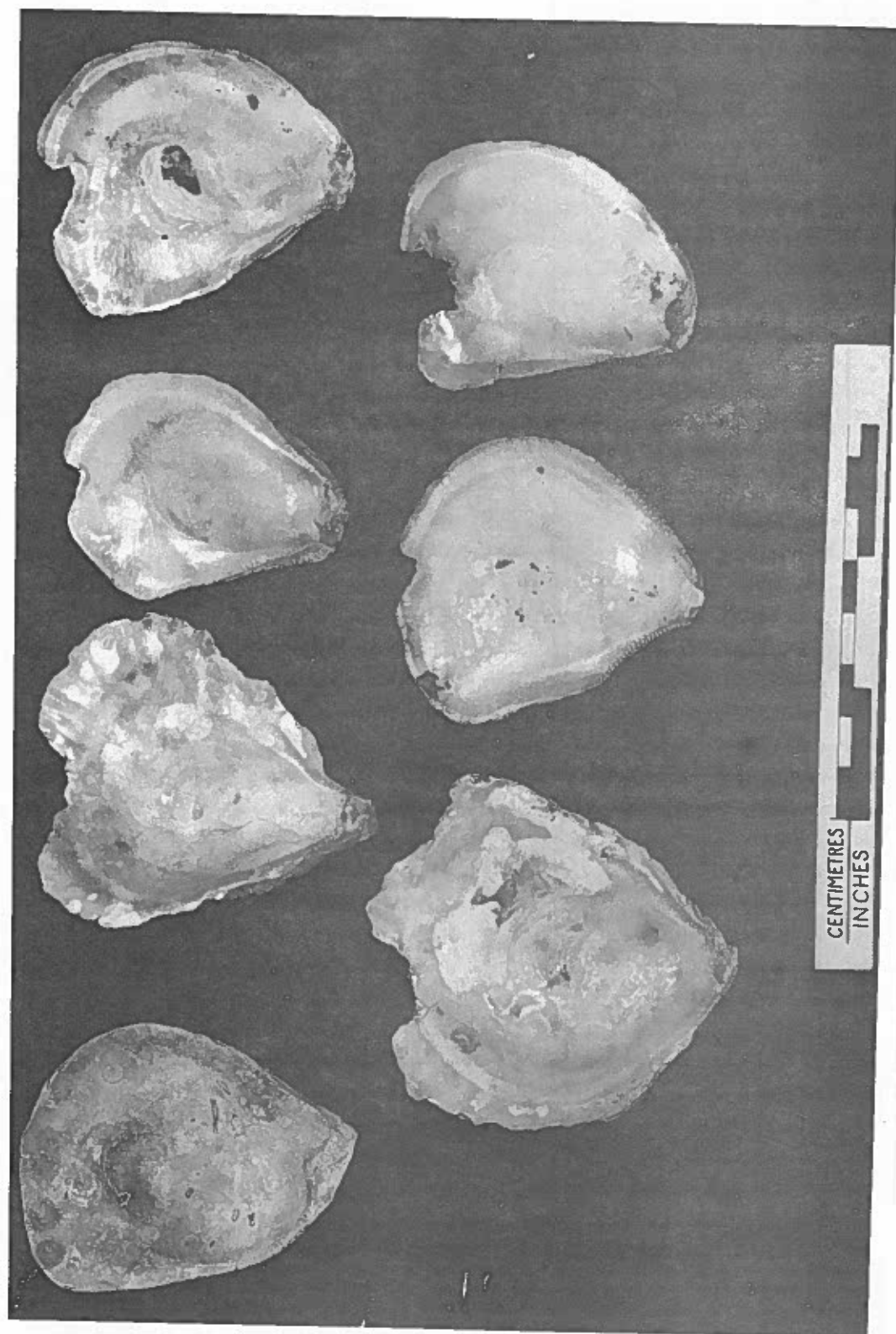


Fig. 5.3.1 Oyster valves from a 13th-century layer downstream of the boat, probably dumped food debris  
© K. D. Thomas

## CHAPTER 5: ENVIRONMENTAL STUDIES

### PART 4. ANIMAL BONES

by Barbara Noddle, Department of Anatomy, University College, Cardiff

As the bones were well-preserved, it is unfortunate that there were so few of them. With this small number it is only possible to give identifications; (Table 5.4.1); economic interpretations and comparison of livestock from the different find-spots would not be valid.

The proportion of abnormalities is high; in most osteological collections it is about 0.1%. The bovine metapodial is the smallest I have ever seen, yet the bone is not of the quality found in a newborn animal. Heifers accidentally allowed to breed in their first year of life produce extremely small calves; alternatively this might be from a dwarf animal. Comparison was made with an 18th-century context in Orkney; this deposit also included very young calves, which had metacarpals (without distal epiphytes) about 130 mm in length.

Table 5.4.1.1 Identifications of Animal Bones

| Graveney no. of sample | Position                                        | Identification (l. = length, w. = width)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Notes                                                                               |
|------------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Gr116                  | Inside boat beneath frame R8                    | Sheep or goat, 1 rib                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                     |
| Gr112 and 137          | Inside boat                                     | Pig, 2 lumbar vertebrae, immature exhibiting spondylosis with small exostosis (Fig. 5.4.1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | As spondylosis is normally result of old age, probably due to injury in this animal |
| Gr119                  | Beyond broken end of boat, probably once inside | <ol style="list-style-type: none"> <li>1. Cattle, metacarpal, distally immature (Fig. 5.4.2), l. 94 mm, proximal w. 27 mm, midshaft w. 13 mm rib tibia fragment } could be of horse</li> <li>2. Sheep or goat, 10 ribs scapula fragment femur distal epiphysis thoracic vertebra mature } larger than lumbar vertebra mature } Soay type</li> <li>3. Pig, sacrum mature thoracic vertebra mature pelvis fragment tibia proximal fragment, w. 39 mm 2 lateral metapodials mature l. 44.5 and 60.6 mm 1st phalanx mature, max. l. 40 mm 1st phalanx lateral mature</li> </ol> |                                                                                     |

1. Sheep and goat bones are not easily distinguished from each other.



Fig. 5.4.1 Lumbar vertebra of a pig from inside the boat, exhibiting spondylosis with some exostosis  
© National Maritime Museum



Fig. 5.4.2 Tiny bovine metapodial, perhaps from a dwarf animal. Actual size 94 mm  
© Barbara Noddle

## CHAPTER 6

### GEOGRAPHICAL AND HISTORICAL BACKGROUND

by Valerie Fenwick

#### CHANGES IN N. KENT COASTLINE

The southern shores of the estuary of the R. Thames are characterized by large tracts of alluvial mud. The chief of these are Cliffe marshes and the isles of Grain and Sheppey. Sheppey is separated from another extensive tract of marsh clay on the S. by the R. Swale. The river provides an alternative route to the main estuary for craft sailing along this treacherous coast. Graveney lies on the marsh immediately S. of this ancient shipping lane (Fig. 6.1).

Today the spread of high tides over the low-lying marsh clay is restricted by sea-walls. N. of Graveney the sea-wall lies on the line, or slightly S., of a wall first built between 1325 and 1340. Since that time, except for rare periods of flooding, the sea has been kept out (Thompson, 1956:47-9). Until the 14th century there was no physical boundary between the Seasalter Level, the name on the first Ordnance Survey map for the whole tract of marsh, 1.6 m by 3.25 km, which stretches from Graveney to Seasalter, and the large tract on the N. known as the Whitstable Flats. Indeed, evidence for the early Anglo-Saxon period, collected by Sonia Chadwick Hawkes, shows that the high-water line was farther N. than it is today (Hawkes, 1969:fig. 1).<sup>1</sup>

The northern coast of Kent has undergone major changes in the last two thousand years. These have been the result of three main factors: erosion of the London clay outcrops; rise in sea-level; fall in land-level. Although none of these factors has been as dramatic as was once thought, in combination their effect has been considerable. Recent measurements at Warden Point, Sheppey (d'Olier, 1972:129), have shown that it is now eroding at the rate of about 8 m a year, while farther E. along the coast at Reculver half of the Roman fort guarding the entrance to the Swale has disappeared into the sea, at least 500 m of land on the N. having been eroded since 1540 (Philp, 1969:3).

In her thesis on changes in sea-level in SE England Anne Akeroyd observes: 'Changes in relative levels are apparently greater in London and the Thames estuary than in other parts of the country, yet the history of the region has been subjected frequently more to speculation than to hard reason.' She concludes that in general the physiographical and archaeological data from the Thames estuary, Canvey Island and the Thames and Essex marshes show a mean sea-level rise of some 1.6 to 2.6 m since the Roman period (Akeroyd, 1972:157). On the other hand the rate of subsidence in the Thames estuary since Roman times is estimated at between 0.10 and 0.16 m a century. These estimates are modest compared with some which have been advanced, but if they are

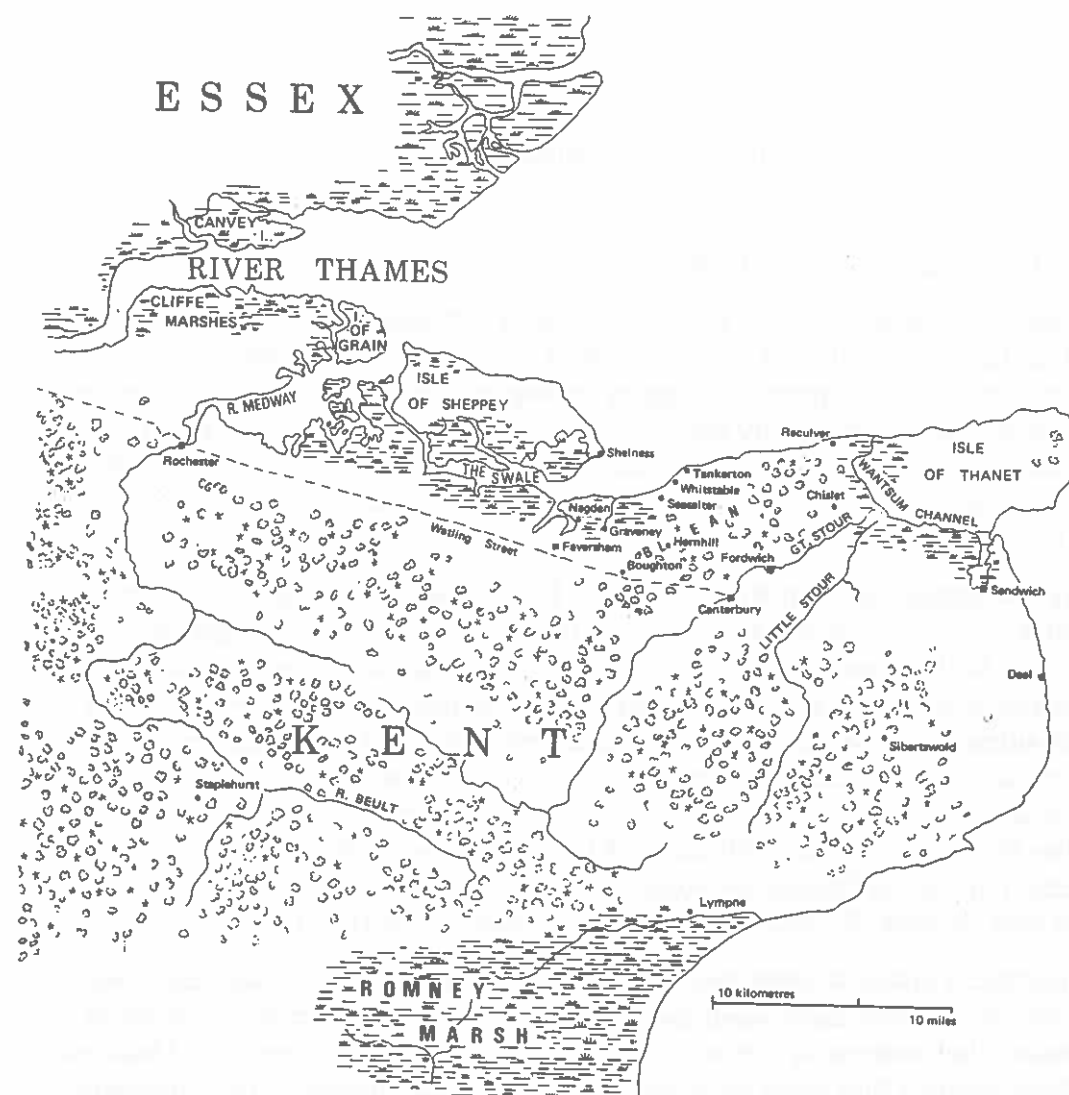


Fig. 6.1 Map of Kent showing places mentioned in text  
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they are applied to the low-lying area under consideration, it is apparent that a sea-level some 2 m lower and a land-level some 2 m higher would make the sea-wall unnecessary and would, moreover, convert the flats N. of it into salt-marsh. In addition erosion has reduced the London clay headland stretching eastwards from Seasalter, so that this too once extended farther N.

The picture which emerges then is of the ship actually being farther from sea when she was abandoned than when she was found. She lay at 0.167 ft (0.85 m) below Ordnance Datum (Newlyn) beside a meandering watercourse which has its sources near Watling Street at Dunkirk. It was during the later medieval period that, as the literary and archaeological evidence shows (summarized by Thompson, 1956), storms and high tides increasingly swamped the large tract of low ground between Graveney and Seasalter, although freak storms, one of which destroyed the first church at Seasalter, are recorded as early as the 11th century (Goodsall, 1938:73; Evans, 1953:140).

#### SALT-WORKS

The present level of Graveney marsh, inned by 1340, is c. 5.4 ft (1.64 m) above Ordnance Datum (Newlyn) near Mound B (see below) and 6.4 ft (1.95 m) near the ship (Fig. 6.7). Some of the mounds scattered over the marsh have been proved to be of artificial construction and to be earlier than the sea-wall. They are between 2.13 and 4.5 m high, oval or kidney-shaped and between 500 and 1400 m inland of the sea-wall. Mounds A, B, C and F have been dated to the 13th century by pottery and Thompson's emergency excavation in 1955 showed that they had been salt-works (*wychwerke*) (Thompson, 1956).

Salt-works are among the most sensitive indicators of changes in relative land and sea-levels (Akeroyd, 1972:160). They are usually sited below high water to avoid the need to transport the brine, yet close to the high-water mark to facilitate the carting of wood to fire them. They were placed on sheltered inlets and estuaries to prevent destruction by the sea. The distribution of marine salt-works in the Domesday Survey is associated with coastal alluvium, parts of which must have been regularly flooded in the 11th century (Darby and Campbell, 1962:fig. 154). In Kent the three main areas of salt-works were around the rivers Wantsum and Swale and on Romney marsh. Chislet, on the Wantsum, seems to have been the biggest single producer with forty-one salt-works. Graveney is listed as having four and neighbouring Boughton, one (Darby and Campbell, 1962: 539). Seasalter, which so obviously took its name from the trade, strangely has none.<sup>2</sup> We do not know the location of these early salt-works at Graveney (Fig. 6.3). However, the easternmost groups of mounds on the marsh have not been dated by excavation and there are traces, visible from the air (Fig. 6.4), of mounds nearer the sea-wall than Thompson's Mound M. Mounds which may have lain in close landward proximity to the sea-wall would almost certainly have been utilized in the construction of this and of the earlier wall N. of it (Goodsall, 1938:31), unless they had already been swept away by sea; this of course would apply equally to any beyond them.

Three hundred years before Domesday there is documentary evidence to show that salt was an important industry in N. Kent. These Anglo-Saxon charters<sup>3</sup> do not give precise locations, but they describe places situated between Faversham and Tankerton, and, as can be seen from Fig. 6.1, the ship lay in the middle of this area. The charters show that in the later Anglo-Saxon

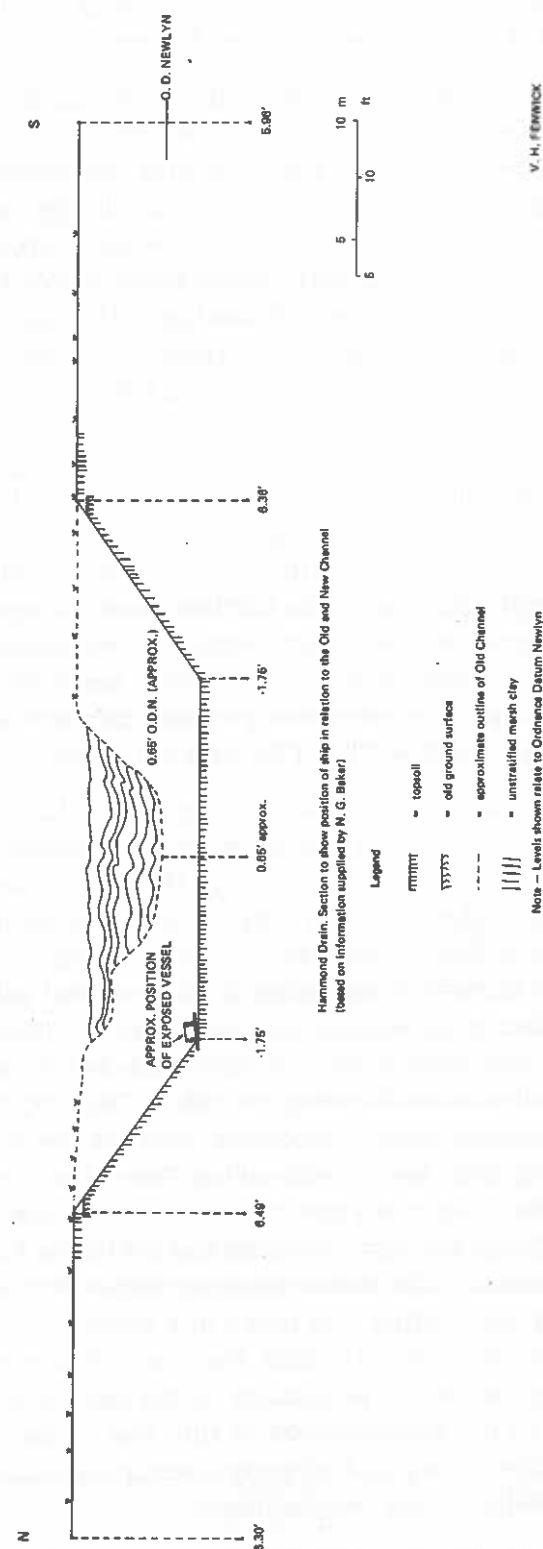


Fig. 6.2 Section of the Hammond Drain showing the position of the ship in relation to the Old and New Channel. Based on information supplied by N. G. Baker  
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period salt was being artificially evaporated by burning wood. They make it possible to visualize the cottages and the smoke rising from the salt-works, while carts loaded with wood toiled from the forest of Blean, which lay between Canterbury and the coast. Another charter, this time relating to salt-works at Lympne, implies that '120 loaded waggons of wood for boiling the salt' are required to service a salt-works on a small piece of land - 'a quarter of one ploughland' (E.H.D.:no. 65). From this cause alone an estimate can be made of the deforestation which must have been taking place in the vicinity of the Seasalter Level before the Conquest.<sup>4</sup>

Production of salt by natural evaporation of brine was in S. England a seasonal activity, limited to four months of a dry summer (Bradley, 1975:21). Artificial evaporation increased output and extended the season. The wood-lined pits found by Thompson (Thompson, 1956), together with signs of burning, suggest that the evaporation technique used on the Seasalter Level in medieval times involved lighting fires round shallow wood-lined pits filled with brine. Fire-hot stones may have been put into the brine to speed evaporation. This was not such an inefficient method as may be supposed.<sup>5</sup> Pieces of lead found in two of the mounds suggest that lead pans like those used in Lancashire might have been used as receptacles for the final boiling and, in view of their size, they were probably assembled and mended on site (Thompson, 1956:54). The use of lead for another purpose is known from 19th-century salterns in Hampshire, where hemispherical pieces of wax, loaded with lead, were so graduated that workmen could calculate the strength of the brine according to the size of the one which just floated in it (St. Barbe, quoted in Lloyd, 1969:10).

## CARGO

### Salt

Although the Graveney ship lay between two main concentrations of salt-works, and although salt was certainly an important industry here at the time of her abandonment, the only evidence to connect her with the salt trade is circumstantial. No fragments of suitable containers, such as the wooden bowl from Mound C, or barrels, baskets or pottery containers were found on board, nor were parts of tools, such as the 'rutra' and 'batillum' fragments from Mounds B and F (Thompson, 1956:fig. 5). The latter are perhaps not items which would have been carried, since she was clearly too large to have been a 'supply' boat. Her connexion, if any, with salt-works would have been in the collection of their output,<sup>6</sup> and also in the products, pickled in brine, of 'piscariae', or fisheries, which were also numerous in the vicinity of the Seasalter Level (Darby 1962:fig. 153).

### Fish

The fish caught are rarely specified in the Domesday Survey,<sup>7</sup> but the eight fisheries listed for Seasalter would certainly have included oysters, for which Whitstable (not mentioned in the Survey) later became so famous. Oysters were a cheap article of diet in SE England. For instance, there was a petition in 1598 (Goodsall, 1938:225), in which it was said of the poor inhabitants of Canterbury and E. Kent that they 'in these dear times are not able to buy flesh for their sustenance, but live altogether or for the most part on such victuals as by daily travaille is brought from there [Whitstable]'.

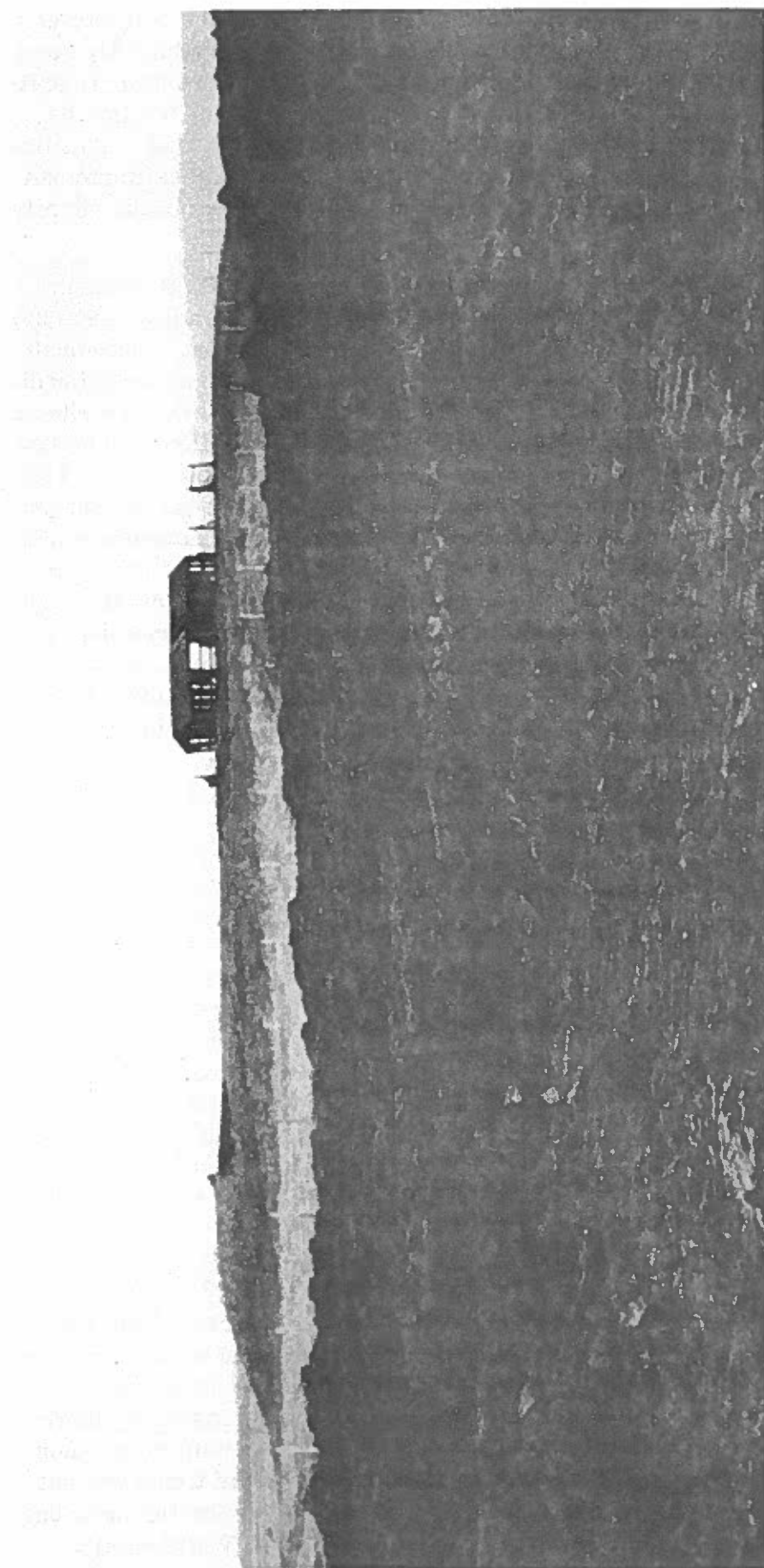


Fig. 6.3 Artificial mound near the ship, probably a medieval saltern, later used as a refuge for sheep (shepherd's hut on top). In foreground is the upcast from the watercourse recut in 1970.

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The quantity of oyster shells found in levels of all periods in London, Canterbury and elsewhere seems to confirm this, and the N. coast of Kent was a main source of supply.

There were oyster shells in and around the ship as she lay in the mud. Mussels, together with other molluscs, were present immediately beneath the hull, in considerably greater numbers than the samples suggest (pp. 155, 157-8). They were detected in the mud during excavation, for they frequently tore the fingers of those undercutting planks. No other shells were found in the upcast from the channel, with the exception of a shelly layer, c. 100 m downstream from the ship, which was dated to the 13th century by pottery. This consisted mainly of oyster shells; from the damage to them (Fig. 5.3.1) they were judged to be food debris in contrast with the shells round the ship. The latter, in Dr Thomas's view (chap. 5.3), are likely to have occurred naturally in their context; the few deep-water specimens had been washed up after death (p. 156).

### Hops

While the shells sieved from the mud samples failed to provide a connexion with the local industry, the mud itself provided evidence of a quite unexpected kind to link the trade ship with a specific cargo (Fig. 6.5). It contained pollen which had been blown from plants growing near by and some distance away (pp. 142-3). Mixed oak forest with quite a high percentage of beech indicated by the tree pollen confirms the plentiful evidence from elsewhere for the former extent of the forest of Blean (e.g. Southouse, 1671:121). Plant remains found in the mud around the ship reveal the nature of the local environment. Seeds and other plant remains had also been washed with the mud into the hull (pp. 143, 147). The immediate environment was, as expected from the geographical situation, estuarine in the period before the marsh was inned. Species from the brushwood platform again supported the general picture of dry-land vegetation in the vicinity, which included weeds perhaps from cultivated ground round the manor of Graveney on the W. or Hernhill on the S. This is consistent with evidence for eustatic change and with documentary evidence for pasture land before the Conquest (pp. 165, 167, 179).

There were no traces of hop in any of the samples taken from outside the hull, with the exception of the brushwood immediately beyond the broken starboard side. In view of the heavy concentration of hop seeds inboard these latter have probably spilled from beneath frames R4 and 5 when the ship broke up. The sample from beneath frame R6 produced the greatest proportion of hop remains. As this frame lay amidships, it would have collected sludge containing fragments of its cargo beneath it. It is interesting that this frame also trapped many plant remains not found in other samples. These must have been collected on voyages, or in the place where it was built. Samples from beneath frame R1 did not have the same quantity of hop seeds (this frame was certainly removed at a late stage in the vessel's life in order to repair the keel, p. 221); the other main collection of seeds came from a sample taken from between overlapping strakes on the port side near frame R4. This again came from low down in the hull, where dirt derived from its cargo could well have collected.



Fig. 6.4 Air-photograph of the Seasalter Level showing the older drainage patterns and the modern network of straight ditches. The arrow indicates the position of the ship among a cluster of artificial mounds.  
© Aerofilm Ltd.

The implications of hop remains in England at a hitherto unexpectedly early period are assessed above (chap. 5.1). It is suggested that the ship may have been carrying hops for brewing. The absence of hop in the pollen samples makes a local source unlikely and it is therefore argued that the hops may have been imported from abroad. While this is most useful supporting evidence for the carriage of mixed cargoes and hops have been found at the entrepôt of Hedeby (Foote and Wilson, 1970:212), it does not help to identify the nature of the principal cargoes for which the ship was built. It is quite clear that she was designed to transport heavy cargo.

#### Quernstones

In the silt in the bottom of the ship, together with beach pebbles and fragments of Roman roof tile (*tegula*) and of local Kentish ragstone, to some of which mortar still adhered, there was basalt lava, certainly deriving from the Middle Rhine (chap. 4.4). The presence of this material, together with the other items mentioned above, might be explained as residual ballast, taken, for instance, from the immediate foreshore (where Roman tile can still be found), or the remains of a Roman building near the boat and washed into it. The latter hypothesis can perhaps be discounted, since the river is unlikely ever to have been fast-flowing and there were no other remains of this character found in the upcast from the channel, despite a thorough search. The former hypothesis seems more likely; the material on the foreshore may have included the remains of a cargo of Eifel basalt lava, especially as Whitstable Bay is a notoriously dangerous part of the coast for sailing ships. On the other hand it is unlikely that friable lava would have survived on the shore in such large fragments. They are larger than any of the other fragmentary material and were not abraded when found.

They derive from one or more querns (chap. 4.4). Two large fragments are unfinished and were originally 0.46 m in diameter and 0.08 m thick, probably the standard size in late Saxon times. Quern fragments have been found at every coastal settlement in Germany, but only at Hedeby in an unfinished condition.<sup>8</sup> As Hedeby was above all an entrepôt, it is possible that ships such as this sailed there or to Tiel (Clarke, 1978) instead of going to the source of supply, to take on a mixed cargo including querns and hops.

On the other hand the wide distribution of Mayen lava querns in England and their occurrence in many contexts seems to show that they were imported in quantity and therefore perhaps in bulk.<sup>9</sup> Fragments have been found in 7th to 11th-century levels in Canterbury and Hamwih and in early medieval London and Thetford (Dunning, 1956:232). Three wrecked vessels which carried millstone cargoes are known from elsewhere. The first, of the late 3rd century, was carrying thirty unfinished quernstones up the Rhine when she sank at Wanzenau, near Strasburg. She was a small vessel with a beam of c. 2 m (Ellmers, 1972a:no. 34).<sup>10</sup> The second wreck was found at Lüttingen, Kr. Moers (Nordrhein-Westfalen), during gravel dredging in 1957. Only part of the cargo was recovered; it consisted of globular jars of the 9th century and quernstones, both Mayen. It was described as coming from a 'rather large ship'.<sup>11</sup> The third discovery was also made in the Upper Rhine, at Salmorth, Kr. Kleve, in 1964, and, again, gravel dredging only brought up part of the cargo. This consisted of about a dozen quernstone blanks; they



Fig. 6.5 Hop seeds from inside the ship  
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Fig. 6.6 Scene on Bayeux Tapestry showing wine being carried in tun  
F. M. Stenton (ed.), *The Bayeux Tapestry* (Phaidon Press)

were 'rather small, which indicates an early medieval date' (Ellmers, 1974: 142). On the other hand the thick broad oak planks recorded as being dredged up are indicative of a sizable vessel.

The Graveney hull seems to have been eminently suited for carrying a cargo of quernstones from the Middle Rhine to the Thames, as Dr Corlett's analysis of its sea-keeping qualities shows (chap. 10.2). The estimated capacity of the minimum Graveney, or conservative reconstruction, is 7 tons, equal to a cargo of about 280 quernstones (Forsythe, 1964:292). Since lava blanks are fragile, allowance has to be made for dunnage and for this a secondary cargo of hops would be well suited. On the assumption that the main hold area was between frames R1 and 11 (Fig. 2.1.2), two pairs, totalling c. 0.32 m in thickness, stacked on end and perpendicular to the keel, fit comfortably between each frame. Basalt lava has a density of 2.7 to 2.72 (Forsythe, 1964: 292). With an increase in deadrise and consequent addition of further strakes (p. 275) the ship's theoretical capacity becomes much greater. In the conservative reconstruction twenty-eight could be fitted without difficulty in each of the ten cargo spaces. The frame-space was an important division of the hull at this period. It formed the basis for classification of ships and for the estimate, for instance, of harbour dues and requirements, and customs. Scandinavian ships were classified by the number of *rum* (Foote and Wilson, 1970: 235). The Old English word for toll was *hlaesting*, based on a lading (*hlaest*) of 2 tons. In customs taken by the abbot of St Augustine's, Canterbury, at Fordwich (the medieval port of Canterbury) the term '*lastus molarum*' ('last of millstones') occurs to confirm its use in Kent (Woodruff, 1895:33).

#### Commodities in barrels

However, the Graveney *hlaest-seip* was equally suited for carrying barrels of wine, the bulk of which also came from the Rhine in the later Anglo-Saxon period (Grierson, 1941:89). Aethelred's tolls show that wine was also imported from Rouen in the late 10th century, perhaps in the huge tuns used for this purpose at the time of the Norman invasion (Fig. 6.6). It may have been in the course of a voyage to northern France that the cooking-pot found on board was acquired; it was most probably made in the neighbourhood of Rouen, although it could have been shipped on board through an English trading centre, such as Hamwih (chap. 4.3).

The return cargoes may also have been packed in barrels. The requirements of the Church stimulated trade in fish as well as wine in medieval Europe, as the rise of the great herring market at Falsterbo and the export of stockfish from Dergen show. The combination of salt-works and fisheries in the vicinity of Graveney makes it not improbable that the ship exported pickled herring, oysters, mussels, and possibly salt, in barrels. Certainly, despite Viking dangers, trade actually increased in the 10th century (Ellmers, 1972a:23). In 1956 Gerald Dunning observed (Dunning, 1956:232): 'Connexions by trade between England and the Continent were closely maintained in the late Anglo-Saxon period. The extent of the trade from the Rhineland to Holland and thence oversea to north Germany and beyond is proved by a wealth of archaeological material, but the participation of England in this trade has only become evident from recent excavations at Thetford, Canterbury and Hamwih.' Since 1956 there have been many archaeological discoveries to support the first

statement; the discovery of the ship at Graveney provides the first tangible evidence of the vehicles of that trade.

#### NOTES

1. And personal communication. Mrs Hawkes's map, it should be noted, shows the Graveney watercourse considerably larger than it is today.
2. The Domesday Survey describes Seasalter as a small borough which belongs to the archbishop's private kitchen ('proprie pertinet coquinae'). No doubt it was the oysters, herring and other fish yielded by its eight fisheries which the scribe had in mind, since no salt-works are mentioned.
3. A.D. 786 (B.C.S. 248) 'sealterna steallas thaer bi uban et in Blean uidiung thaer to' ('the salt place stalls there to the north and in the Blean wooding for them').  
A.D. 783 (B.C.S. 247) 'silvam afundanter ad coquendum sal' ('wood sufficient for evaporating salt')  
A.D. 858 (B.C.S. 496) 'et Febresham i sealtern et ii wena gang mid cyninges wenum to Blean them wiada' ('at Faversham one salt-works and two wain-goings with the king's wains to Blean wood')  
A.D. 863 (B.C.S. 507) 'unamque salis coquinariam hoc est i sealtern-steall et ther cotato in illa loco ubi nominatur Herewic et iiii carris transductionem in silba regis sex ebdomades a die pentecosten hubi alteri homines silbam cedunt hoc est in regis comunione' ('one salt evaporator, that is, one salt-works and its cottage in the place called Herewic and the leading of four carts in the king's wood for six weeks after Pentecost, where other men go into the wood, that is, in the king's commoning')  
A.D. 946 (B.C.S. 459, 854) 'loco in quo sal adipisci potest et cum gressu trium carrorum in silva que dicitur Blean' ('a place at which it is possible to obtain salt, with entry for three carts in the wood called Blean')  
A.D. 946 (B.C.S. 874b, 1345) 'et seo wudu reden the ther mid rihte to gebirede....et the sealttaern steal aet here pit' ('and the wood clearing that therewith rightly belongs....and the salt-works at Herewic').  
The borough of Herewic is covered by modern Tankerton (Ward, 1944: 52).
4. Deforestation as a result of salt-boiling must have started in Roman times. Although no briquetage of this period has been located on the Seasalter Level, it is known from a large number of N. Kent sites (listed by Miles 1975).
5. 100 gallons were heated in 35 minutes by these means (Foote and Wilson, 1970:163-4).
6. This would have been in the form of gravel-like granules. Mitta ('load') was the main unit of measurement for salt in medieval Kent and is found as early as the 9th century (Prior, 1924:36). The term suggests that the salt was transported in loose form.
7. A rare instance in which an Anglo-Saxon fisherman's catch is listed occurs in Aelfric's Colloquy (Garmonsway, 1967:105-7). Herring take first place in the list of salt-water fish, and there is confirmation that both oysters and

mussels were fished in the 9th century. On line 102 'sprote' (sprats) are glossed by the word 'saliu', which, if derived from sal, provides a reference to salt fish in an Anglo-Saxon context (Garmonsway, 1967:28, note 102):

'Haerinczas 7 leaxas, merespyn 7 stirian, ostran 7 crabban, muslan, pinepinclan, saecoccas, fazc 7 floc 7 lopystran 7 fela spylces. Alleces et isicios, delfinos et sturias, ostreas et caneros, musculas, torniculi, neptigalli, platesia et platissa et polipodes et similia.'

I am most grateful to Dr R. I. Page for help in obtaining this reference.

8. Personal communication from D. Ellmers.
9. The worn stumps of adult teeth sometimes found in Anglo-Saxon cemeteries explain why lava querns, which produced flour without hard grits, were so much sought after.
10. The quernstones, with the exception of that illustrated by Ellmers, fig. 181, were unperforated and undressed.
11. i.e. not a small boat (Ellmers, 1974:140-1).

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## CHAPTER 7

THE SITE AT GRAVENEY AND ITS POSSIBLE USE  
AS A LANDING-PLACE

by Valerie Fenwick

## OWNERSHIP OF LAND

The owner of the ship cannot, of course, be identified, but it may perhaps be possible to identify the owner of the land on which she lay. Ward mapped the topographical relationships of some Anglo-Saxon charters relating to the Faversham district and suggested that the royal manor of Faversham once extended over the Whitstable area and was slowly split up as a result of bribes and gifts to powerful courtiers and nobles (Ward, 1934:1944:53). The picture he assembled explains how Graveney came to combine five scattered holdings. An important result from a nautical archaeological point of view is Ward's tentative location of Cilling, the original port of Faversham (where Nagden is now marked on the O.S. 2½ in. map), and also the course of the road already described as old in 814—'*antiqua strata quae jacet ad portum*'. Its course is shown running eastwards to Graveney and Hernhill (Ward, 1934:fig. 1). Graveney is clearly a large manor with cow pasture ('*cua lond*') below the 25ft contour. That this, the portion of Graveney marshes W. of the Graveney watercourse (Grafon Aea), was first-class grazing in the 9th century is shown by the fact that it was royal cattle pasture ('*Cynincges cua lond*') before King Coenwulf gave it to Archbishop Wilfred in 814. On the E. the boundary of the manor is probably marked by the parish boundary,<sup>1</sup> and it was in the water-course on the Seasalter side of the parish boundary that the ship was abandoned (Fig. 1.1.1).

Graveney village took its name from a stream (Ekwall, 1928:185). It is first mentioned in a charter of 811 (B.C.S. 335) and Ekwall observed that '*Grafanea*' would mean 'a stream that feeds a canal'; alternatively *Grafon* might be the past participle of *grafan* and, if so, the name 'dug river'. Both derivations have equally important implications for associating Graveney specifically with an artificially constructed or maintained channel by the early 9th century at the latest.<sup>2</sup>

As early as this Graveney belonged to Christ Church, Canterbury, and it was farmed by a priest named Werhard (B.C.S. 402). The lands reverted to Christ Church on his death in 832. 'But', Ward observes, 'there was evidently a break in ownership, a very usual happening with Church property, for King Edmund restored it again to the Church in 941 (B.C.S. 766, 811). In 1006 it is returned as still belonging to Christ Church....and so it seems to have remained until it was leased to Richard the Constable soon after the Conquest' (Ward, 1934:127). Downstream from Graveney the Seasalter bank of the watercourse may also have belonged to Christ Church at this time.

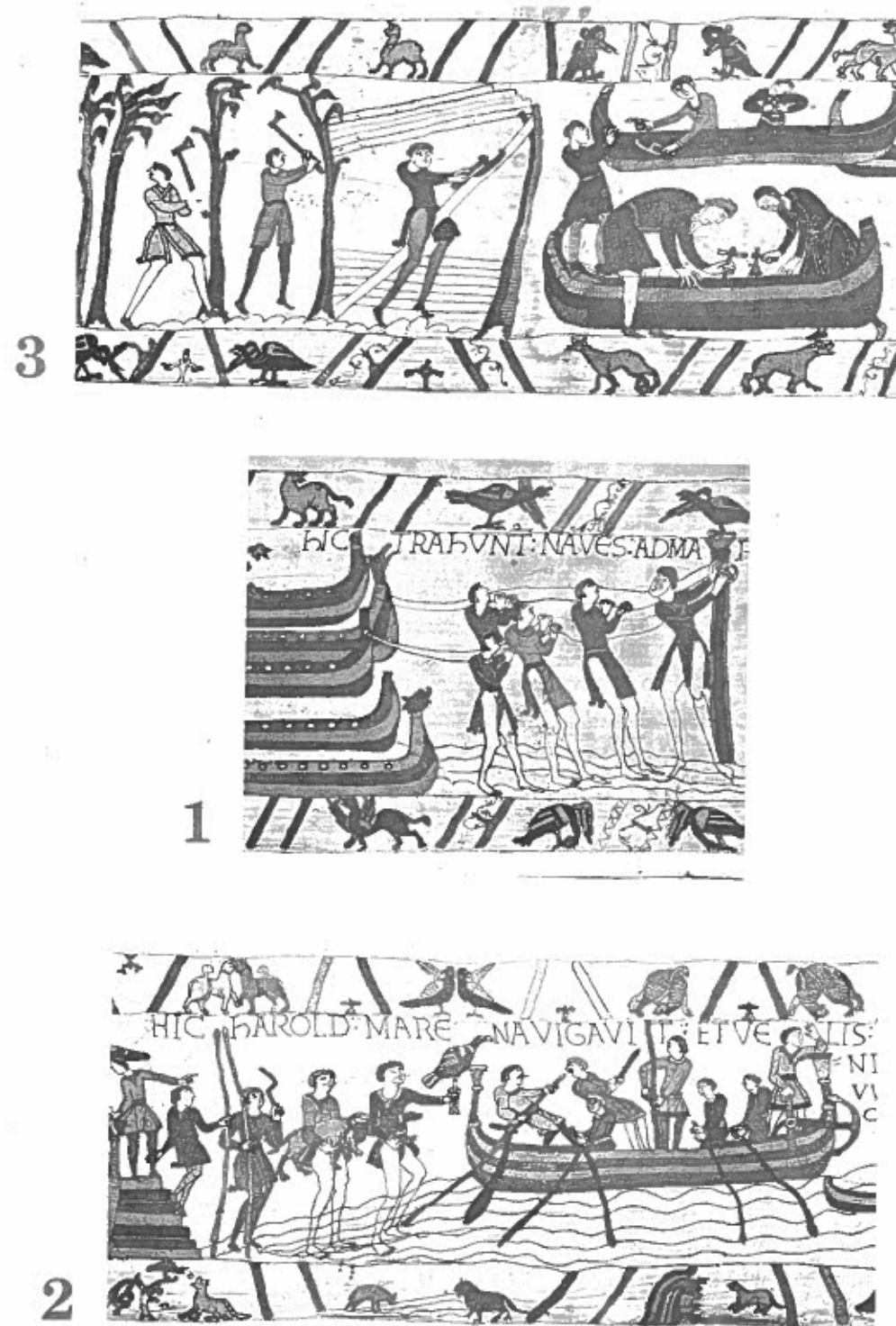


Fig. 7.1-3 SCENES FROM BAYEUX TAPESTRY  
 1, Mooring post in shallow water; 2, Harold embarking at Bosham; 3, ship-building  
 F. M. Stenton (ed.), *The Bayeux Tapestry* (Phaidon Press)

Hasted records that the manor of Seasalter was given before the Norman Conquest to the priory of Christ Church in Canterbury, 'but by whom I have nowhere found' (Hasted, 1790:505). The Hernhill bank may also have been in ecclesiastical ownership; it seems to have formed part of the archbishop's manor of Boltune, of which Graveney also formed a part, according to the Domesday Monachorum.

The importance of this information for the present study is that it indicates that at the time of the ship's abandonment, determined as c. 947 by the carbon-14 date of the sticks beneath it, p. 106 (a date not inconsistent with the evidence of wear on the hull, which was probably constructed c. 927 ± 2, p. 123) the manor of Graveney belonged to Christ Church and the bank on which she was deliberately berthed was probably also in church ownership.

#### LANDING-PLACE

The evolution of deep-draught trading ships in later medieval northern Europe necessitated the widespread construction of wharfs and quays. Before this most trading vessels were small enough to put in at places other than ports (Fenwick, 1978a). They were either unloaded from the shallows or dragged ashore. The structures used scarcely merit the term 'harbour installations' and until recently have seldom been noted by scholars. Such evidence as there is for early *Landeplätze* and *Schiffsländen* has been recently discussed by Ellmers (Ellmers, 1972a:123ff.; 1975) and for ports by Clarke (Clarke, 1978).

From an early period it seems to have been the practice to lay beds of branches on muddy foreshores to serve as hards and boat mooring-places. There are examples at North Ferriby on the R. Humber (Wright and Churchill, 1965:7, pl. 2), Bentumersiel on the R. Ems, and Flögel, N. of Bremerhaven (Ellmers, 1975:336). At the important trading-post of Kaupang, Norway (Fig. 8.30), the installations consist of jetties resting on bundles of brushwood and horizontal logs extending into the water at right angles to the bank with mooring-posts offshore (Clarke, 1978). Ropes were still tied round some of them when they were found. Ropes are shown in one of the ship-building scenes on the Bayeux Tapestry; several vessels are tied up to a large mooring-post in shallow water (Fig. 7.1). The Tapestry shows that the normal procedure for boarding ship or landing was to wade through the water barefoot. If such an important man as Duke Harold had to hitch up his tunic and wade out to his ship at Bosham (Fig. 7.2), it was surely because there was no quay or jetty there in the 11th century. Other scenes depict a similarly informal approach to boarding and landing.

The substantial mooring-posts and remains of a timber standing at Graveney are evidence for a *Landeplätze* in the 10th century (Fig. 1.2.9). It may have served the manor alone, but there are reasons for thinking that a landing-place here could have been useful to Christ Church. The silting of the northern arm of the R. Wantsum may have made Graveney a useful alternative to Sandwich for goods coming both from London and into the Thames estuary.<sup>3</sup> Rivalry between the monastery of Christ Church and the monks of St. Augustine's, who were seeking to control Canterbury's port of Fordwich, only 3.2 km distant, must have made holdings on the N. coast more attractive

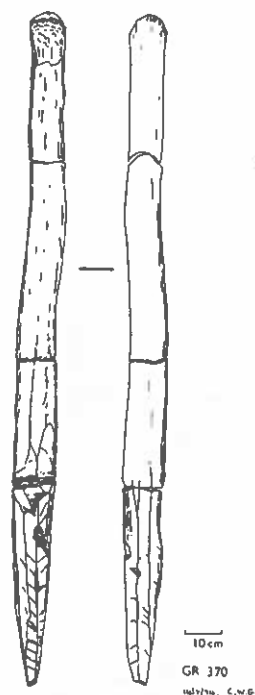


Fig. 7.4 Post 1, driven into mud on starboard quarter, Gr370.  
Drawn by C. W. Gregson  
© National Maritime Museum

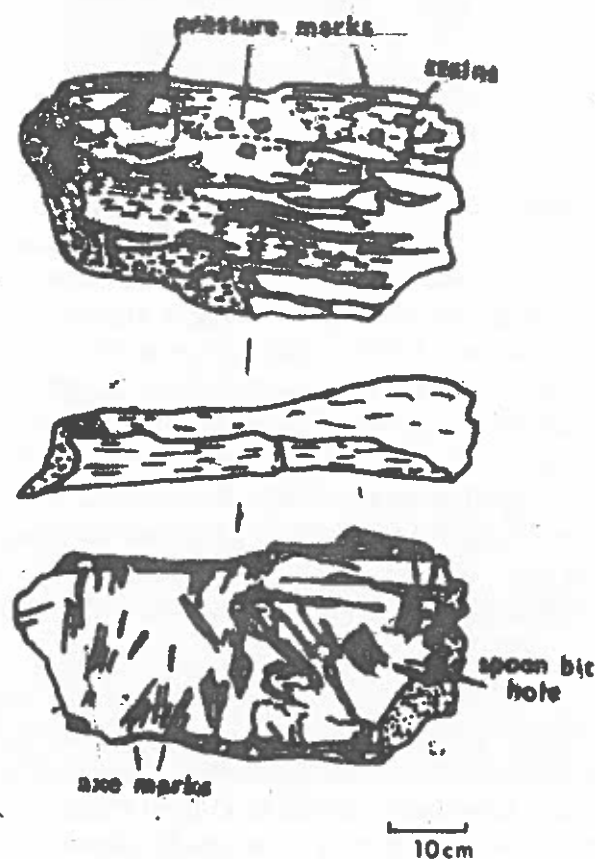


Fig. 7.5 Half of a tree-trunk with numerous tool marks, perhaps used as a work surface, Gr373. Scale 1:10. Drawn by C. W. Gregson  
© National Maritime Museum

to Christ Church. The alternative port, Sandwich, was 17.5 km from Canterbury by road and was, moreover, exposed to Danish attacks. It is possible that the advantages of Graveney as a landing-place made it worth maintaining the dug channel implicit in the name.

#### BOAT-BUILDING AND REPAIR

There was, however, evidence near the vessel that at the time of her abandonment she was berthed not to unload cargo but for repair. The hull itself, in other respects showing little sign of wear and tear, had been subjected to a major repair, which had involved the removal of at least one of its frames and possibly the replacement with through-fastenings of some of the spikes securing its hood-ends and the removal of a mast-partner (p. 246).<sup>4</sup> Before she silted over, there seems to have been an attempt to cut her up (Fig. 8.19e).

The vessel lay on a platform of brushwood, in which, from the samples taken, oak predominated (pp. 145-6, 153). This was not brushwood in the usual sense of the term, since it consisted of made sticks of oak laid parallel and in a, mainly, single layer (Fig. 8.29). Among them were ash chips from a log of some girth (p. 145) and willow sticks. Although the ship had what at first appeared to be a painter, it became clear that she was secured by a series of stakes (Fig. 7.4) round her hull, while the so-called painter trailed loosely and had been secured low down on her sternpost probably to assist in dragging her on to the platform of sticks. An additional piece of evidence of wood-working was a split oak trunk (Gr373), c. 0.35 m in diameter (Fig. 7.5), which had on its flat face dozens of axe-cuts, as though it had been used as a chopping block, and also a blind hole, 30 mm deep and 25 mm in diameter, made by a spoon-bit.

This seems to be slight enough evidence for boat-building or repair, but it must be remembered that ship-building was not yet a specialized profession<sup>5</sup> and that like 'harbour installations', 'boat-yards' at this period were of the simplest kind. In 1949 at Hessens, Kr. Wilhelmshaven, Niedersachsen, a ship-yard was discovered which contained a pair of runners. Many wood shavings were found near by. This slipway was for a flat-bottomed boat more than 2 m on the chine and can be dated to the 7th century stratigraphically (Ellmers, 1972a:fig. 103; 1974:138). Boat-houses have been traditionally used from the Iron Age in Western Norway.<sup>6</sup> On the other hand in other parts of northern Europe there are traditions of boat-building in the open air. Constable's painting of an early 19th-century boat-yard in Suffolk (Fig. 7.6) shows how vessels as large as that at Graveney were built without elaborate facilities or boat-sheds, quite informally on the banks of rivers, as close as possible to the trees used in their construction. In the Constable painting, which is closely based on a life-drawing made in 1814, a small inlet has been dug in the side of the river, so that it can be flooded to float the completed barge. Few tools are needed: axe, adze, hammer, auger and a chisel or two, while the pitch-pot stands ready. Until recently vessels such as these clinker-built barges continued to be constructed by eye and rule of thumb (often by men who were illiterate and certainly innumerate) and without the aid of measured drawing and the mould-loft floor (Christensen, 1972).



Fig. 7.6 'Boat Building' by John Constable, showing an early 19th-century boat-yard in Suffolk  
© Victoria and Albert Museum

The ship-building scenes on the Bayeux Tapestry (Fig. 7.3) show a similar technique in the 11th century. Indeed it has particular relevance for the Graveney ship, since of the three probable centres for the production of the embroidery, the Kentish one, Canterbury, is the most likely.<sup>7</sup> But whether it was made in London, Winchester or Canterbury the Bayeux Tapestry depicts the clinker boat-building technique current in southern England a century after the Graveney ship was repaired. Forest-grown trees with tall straight trunks are chosen and cut down with axes. While still in the forest they are cleft into planks. The oak is evidently used while still green, the advantage being that it is easily cleft at this stage with the aid of wedges. The trunk is split into halves and then split again; the halving continues until sixteen or thirty-two parts are obtained.<sup>8</sup> The resulting wedge-shaped planks are stronger than tangentially cut ones,<sup>9</sup> which are laborious to produce with a saw. An additional advantage of cleaving is economy; Olsen and Crumlin-Pedersen have calculated that a knot-free oak log, 0.75 m in diameter, yields about 5.5 to 6 m<sup>2</sup> per linear metre when radially cleaved, as against about 1.2 m<sup>2</sup> per linear metre when tangentially cut (Olsen and Crumlin-Pedersen, 1967:158-9). The Graveney hull appears to have been built in this way; few trees were cleft to produce her planking (p. 115), and her frames were axed into shape from slender mis-shapen forest oak stems. As on the Bayeux Tapestry (Fig. 7.3) axes of different kinds were the chief tools, while an auger made holes for her trenails (p. 99). From the marks left in blind holes it is possible to say that the spoon-bit used was of a form known from both Anglo-Saxon and Viking contexts (Figs. 7.7-8). The trenails were not shaped with a mute—a tool apparently unknown at this period—since they have irregularly faceted shafts and swelling faceted heads (Fig. 8.31); trenails of a strikingly similar form are produced today by a Portuguese *xavega* builder with the aid of a knife and a wooden disc pressed against his chest (Fig. 7.9).<sup>10</sup> Sheep's wool and pitch made the hull watertight; a caulking iron may have been used (Fig. 8.19a). No evidence of either hard or soft stopping was detected chemically, although it is possible that she was painted (p. 151). However, the white deposit found covering the woodwork during excavation (Figs. 8.13b, 29) may be the remains of something applied during construction, perhaps a wood-preservative rather than a paint.<sup>11</sup>

From internal evidence it is not possible to be certain that on her last voyage the ship returned to the yard where she was built. The same materials were used to repair her and, although the repairs show signs of rougher workmanship, they are not indicative of a different boat-building tradition.

#### NOTES

1. 'The two usually being the same in Kent until well into the Norman period' (Ward, 1934:136).
2. Channels were excavated specifically for shipping in the Anglo-Saxon period (Toller, 1972: sub *scip-ryne*). The neighbouring creek of Faversham was artificially maintained in medieval times before the construction of a sluice in 1558, and documents give an idea of what was involved (Jacob, 1774:64-5): 'in the earliest accounts, I find, that according to antient usage and custom, every owner of a vessel of ten tons and upwards, found a man

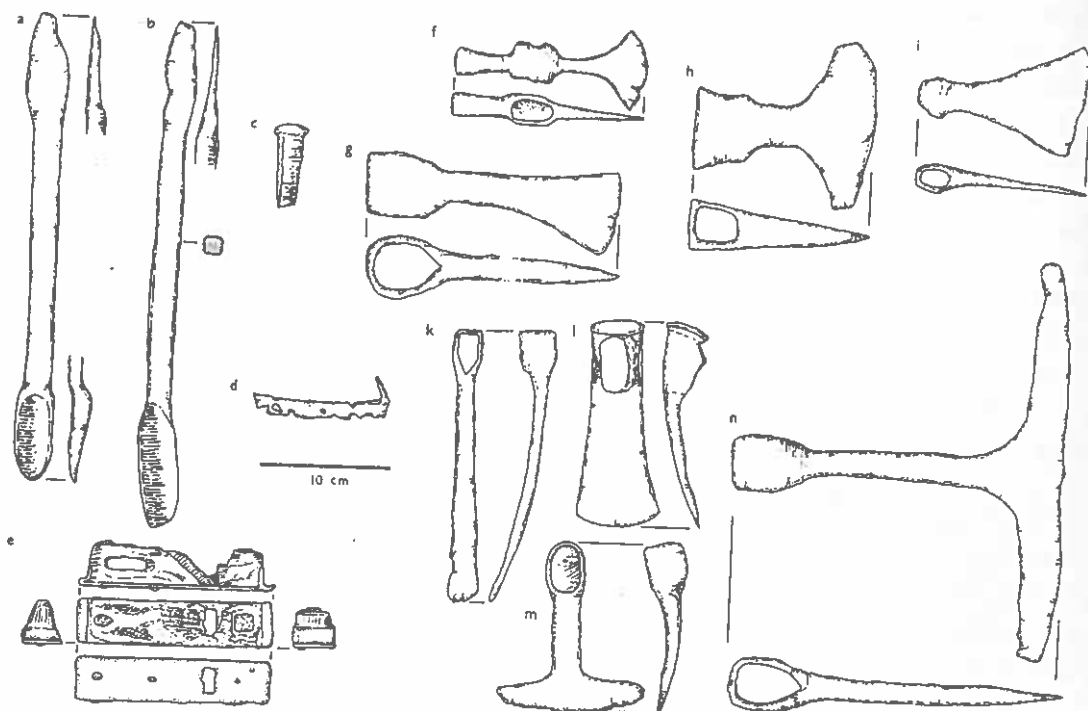


Fig. 7.7 ANGLO-SAXON CARPENTERS' IRON TOOLS, 8TH TO 10TH CENTURY

a-b, spoon-bits, for holes c. 27 mm diam., a, Westley Waterless, Cambs., b, Hurbuck, co. Durham; c, wedge for splitting green timber, Brundall, Norfolk, 57 mm long; d, draw-knife for surface dressing (left tine missing), Sandtun, Kent, 103 mm long; e, small plane with antler stock and bronze base-plate, Sarre, Kent; f-j, axes, f, Horton Kirby, Kent, g, i, Hurbuck, h, Sarre, j, Crayke, Yorks.; k-m, adzes, k, m, Hurbuck, l, Thetford, Norfolk, with much-hammered butt  
Based on drawings by David Wilson

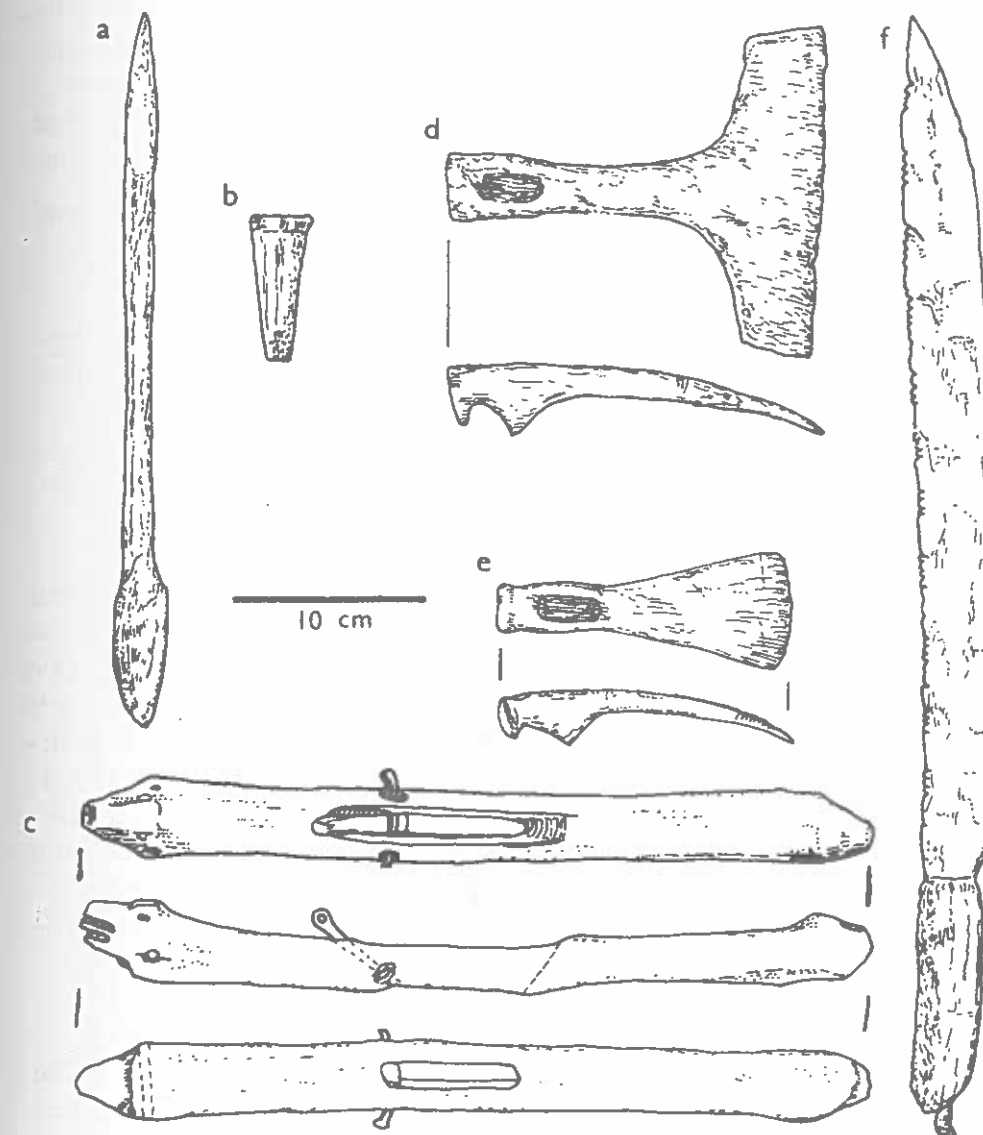


Fig. 7.8 VIKING CARPENTERS' IRON TOOLS, 11TH CENTURY

a, spoon-bit for holes c. 28 mm diam.; b, wedge for splitting green timber; c, wooden grooving (?) plane; d, axe; e, adze; f, saw-knife  
a-b, d-f, Mästemyr, Gotland, c. 1000 (Based on drawings by David Wilson); c, Dublin, 11th-century (National Museum, Dublin)

with an iron rake and shovel, to work therein for six days in a year, and the owners of smaller vessels found a man with the same implements, to work three days, under the direction of the overseers of the creeke or channel, appointed by the corporation.'

3. Silting of the R. Wantsum: Hardman and Stebbing, 1941:46, have observed that the Danish attacks seem to have been made through the Sandwich entrance. 'Perhaps this was because the main object of the Danes was to reach Canterbury which was more conveniently approached from the Sandwich side, but it also throws light on the condition of the Ebbsfleet channel.'
4. Gr232, a plank in strake 6 starboard, appears to have been felled fifteen years before the other planks sampled (Ch 4.2) but does not show signs of being a repair or a reused component.
5. The boat-builder was known in Kent at this time as a 'treewright' (*treow-wyrhta*) and turned his hand equally to houses, wooden utensils and ships in Aelfric's *Colloquy*, 229-30 (Garmonsway, 1967).
6. B. Myhre, 'Boat-houses from the Iron Age in western Norway'; paper read at 24 Symposium der Arbeitsgemeinschaft für Sachsenforschung, London, Sept. 1973; Hinsch, 1960.
7. In addition to the stylistic evidence there are reasons for thinking that the Bayeux Tapestry was embroidered in Canterbury. Domesday lists Odo as the fifth largest landowner in Kent and he is the most likely person to have commissioned the Tapestry (E.H.D.:no. 5). Wadard seems to be Odo's right-hand man, since he holds large Kentish estates from him. In addition Wadard is a tenant of the church of St Augustine in Canterbury and it is certain that ecclesiastical talents were needed for the execution of the needlework. Wadard, specifically named, appears in the central section of the Tapestry. He is organizing supplies for the Norman army at Hastings. Were these organizing talents later used by Odo when he delegated the huge task of weaving and embroidering the Tapestry? If so, what more likely than that Wadard would have taken the opportunity of working his own name into a prominent position in the design and of including the names of other members of Odo's retinue in it, some of whom were also given Kentish lands? This seems to provide additional support for the view that the production of the Tapestry was organized in Kent.
8. In 1968 pioneer experimental work on the techniques used to build a Viking ship were undertaken by the Danish scouts of Greater Arhus under the guidance of Ole Crumlin-Pedersen. The report of the building of the replica of the Ladby ship, which they named *Imme Aros*, makes fascinating reading (Hjorth, 1970): 'Oak wood has silver grain, i.e. radial lines running perpendicular to the grain, so that it is easy to split along them. It really sounds silly when a little boy stands there with a little woodman's wedge in his hand and says that he is going to split the trunk which is beside him, when it is half as thick as he is high. But he can do it easily, for it is more a question of knack than of strength. First the direction of splitting must be decided upon and then the wedge driven in until the sap oozes out of the green oak. This makes the trunk split a little and one simply follows up the split with fresh wedges. When 3-5 wedges have



Fig. 7.9 Unused trenail with faceted expanded head, produced by a 20th-century *xavega* builder with a knife pivoting on his right thigh and a wooden disc held against his chest. Scale 1:2  
© Jane Weeks

have been driven in at the correct places, the first wedges which were driven in fall out and are replaced one by one by wooden wedges as the work proceeds.

'If the trunk is free from knots and shakes, one can manage with this technique all the way through it, but such a trunk is almost impossible to find. Therefore, we have to work with the holding-axe and cut 'runners', that is to say, nicks in the wood which go diagonally from one side of the shake to the other, and over small knots....it takes only a few hours to split a trunk about 5 m long.'

9. I.e. planks produced by parallel longitudinal cuts through the section of the log.
10. Xavega: I am most indebted to the late Mr Paul Johnstone for information on the construction of this remarkable Portuguese fishing boat and for the loan of the trenail and photograph, from which Fig. 7.9 was drawn by Miss Jane Weeks.
11. According to medieval accounts for the building of the Common Bote at near-by Fordwich lime may have been used for this purpose, since, together with pitch, it is itemized at an early stage in the construction (Mayor's Accounts, 1474; Woodruff, 1895:82):

|                                                    |     |                          |                     |
|----------------------------------------------------|-----|--------------------------|---------------------|
| Itm for a steme                                    | ... | ...                      | iiij <sup>d</sup>   |
| Itm for carryage of bords from Sandwich            | ... | ...                      | viiij <sup>d</sup>  |
| Itm for a bosschel of lyme                         | ... | ...                      | ij <sup>d</sup> ob. |
| Itm a quarter of a barell of pytch                 | ... | ...                      | xviiij <sup>d</sup> |
| Itm a quarter (?) of planks                        | ... | ...                      | vj <sup>d</sup>     |
| Itm a piece of tymber for a bord logge             | ... | } iijs viij <sup>d</sup> |                     |
| Itm a pece for ye kele of ye bote                  | ... |                          |                     |
| Itm for another bord logge sett owte of his place' | ... |                          |                     |

Lime mixed with dung was used in recent times, for instance, on Arab dhows (information from Major David Goddard).

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## CHAPTER 8

### STRUCTURAL EVIDENCE FOR THE ORIGIN OF THE SHIP AND COMPARISON WITH OTHER EARLY N.EUROPEAN SHIP-FINDS

by Valerie Fenwick

#### INTRODUCTION

The portion of the vessel that survives (Fig. 1.2.9) exhibits the main features of construction found in N. European clinker boat-building. That is to say, the ship was shell-built, with a backbone of keel and stems, to which planks were attached in an overlapping sequence before frames were inserted. Strake-fastenings beneath the frames confirm this. Vessels sharing the same technique of construction and as old, or older, than the Graveney ship have been found over a wide area of northern Europe, stretching from the eastern Baltic to the British Isles and from Iceland to the mouth of the R. Loire.

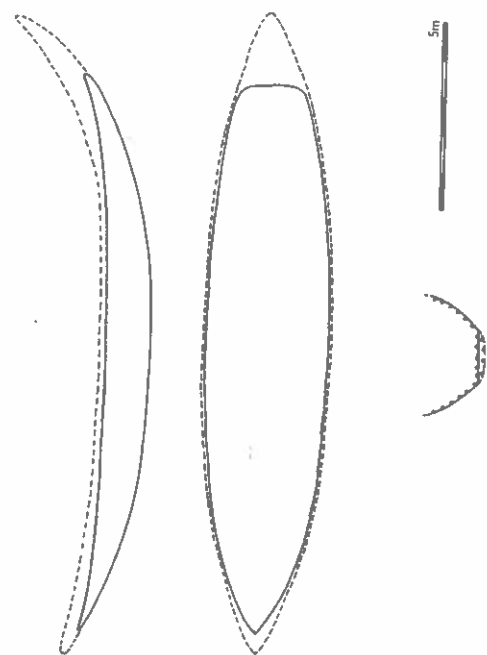
The remains fall into two categories:

1. Wrecks and derelicts
2. Vessels deliberately buried in graves and bogs as offerings.

The Graveney vessel comes into the first category, clearly abandoned and not wrecked.

Recent surveys of the published material by Ellmers, 1972a and Müller-Wille, 1970, have shown that very few of the ships so far found can provide definite evidence as to where they were built. The accumulation of evidence, far from simplifying the picture of the way ship-building has developed in the last two millennia, has taught nautical archaeologists to be cautious in drawing evolutionary patterns; each new discovery tends to confound an old theory and to furnish new problems of interpretation. Then, too, despite the discoveries of the last twenty years, large gaps still remain, particularly in north-western Europe. The dearth of ship remains is most acute in France, where for the first millennium scholars must depend on small-scale pictures, such as those on coins, for knowledge of the different kinds of vessels in existence. The British Isles have produced some archaeological evidence for the kinds of ships in use during the first millennium, but it is scanty and ill-distributed and cannot as yet provide a comprehensive overall picture of indigenous boat-building techniques.

Britain is situated in a remarkable position midway between north-eastern and south-western Europe (Fleure and Davies, 1971:fig. 2). Throughout her history she has been the recipient of foreign traders and settlers, arriving in (necessarily) sea-going craft of many different types. For this reason

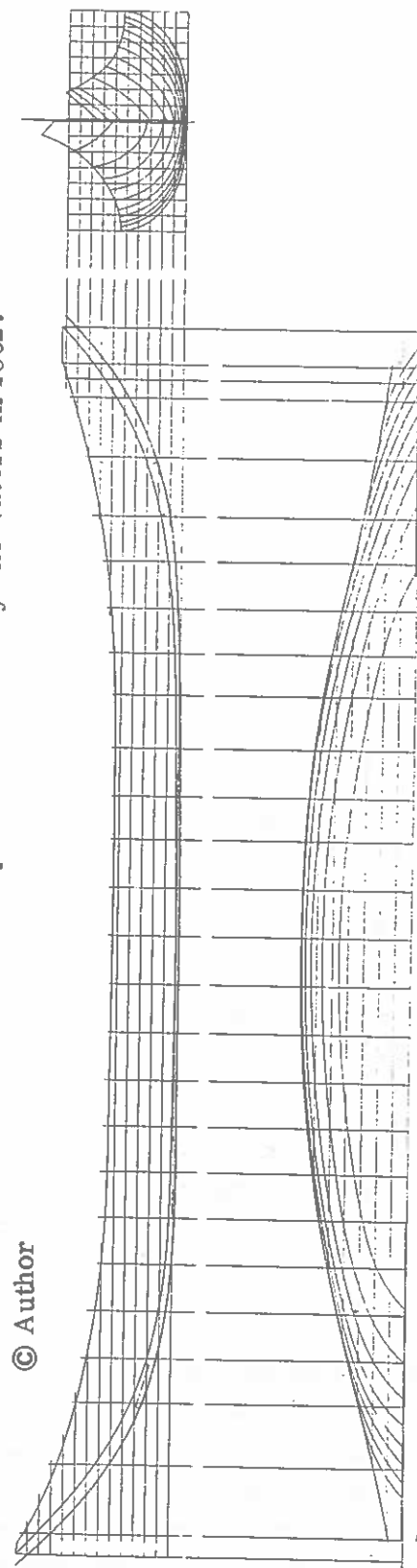


SNAPPE (SCOUTING-775)

WF 1715

Fig. 8.1 a. Outline of 6th-century ship, deliberately buried at Snape, Suffolk. Dotted outline shows section and gunwale reconstructed on the evidence of the rivet pattern recorded by excavators in 1862.

© Author



b. Lines of 7th-century ship from Sutton Hoo, Suffolk, taken from the rivet pattern in the soil by Lt. Cdr. J. K. D. Hutchison in 1939; the stern is slightly fuller than the bow. © Science Museum

there is no homogeneous ship-building tradition but many different ones. Some have continued with little change until the present day, while others have developed as a result of various consequences, such as availability of raw material, local conditions and differing needs. Not least, these different traditions have interacted.

#### EARLY CLINKER BOAT-BUILDING IN BRITAIN

No evidence at present exists for the arrival of the clinker boat-building tradition in this country before the 5th-century invasions of peoples from the Schleswig-Holstein area. These immigrants were probably using warships in the form of large undecked clinker-built rowing boats, if it is safe to generalize from the well preserved example, 23.7 m long, found together with weapons of the 4th to 5th century in a bog at Nydam and from another vessel of c. 350 (Engelhardt, 1865). Parts of ships of later date found in the Jutland peninsula are sufficiently different in constructional details from finds in other parts of Scandinavia for an independent S. Scandinavian boat-building tradition to have been postulated (Ellmers, 1972b:14). It is, therefore, worth considering whether the few clues at present available make it possible, first, to detect any similarities between this S. Scandinavian ship-building tradition (which has elsewhere been called 'Saxon') and the earliest clinker boat remains in this country, and, second, to fit the Graveney ship's structure into this sketchy picture.

Fewer tangible remains of craft belonging to the period A.D. 500-1000 have been found in the British Isles than in almost any other N. European country. The only excavated vessels certainly or probably known to date from this period were, with the exception of that found at Graveney, all found in Suffolk.

##### 1. SNAPE

A deliberately buried ship, c. 14.6 m long, was excavated in 1862. The hull survived only as an impression in the soil marked by decomposed wood and rows of iron strake-fastenings. Plans were made of these and the original accounts have been the subject of a careful re-examination by Bruce-Mitford (Bruce-Mitford, 1974:114-40). No satisfactory interpretation of the remains of the hull has been published, although it is clear from the position of the rivets that the sheer strake was not recorded—as indeed happened more recently in the excavation of the ship at Ladby, Denmark (Crumlin-Pedersen, 1970:9). This omission permits a modification of the sheer-line to be put forward (Fig. 8.1a). The contemporary plan shows an uneven number of rivet alignments, but as the excavator, Septimus Davidson, expressed some doubt as to whether there were four or five rows of rivets in the bottom of the vessel, it is more probable that there were originally sixteen alignments rather than the eighteen suggested by Bruce-Mitford (Bruce-Mitford, 1974:20).

The date of the grave-goods is still a matter of dispute, but the ship was probably constructed in the second half of the 6th century.

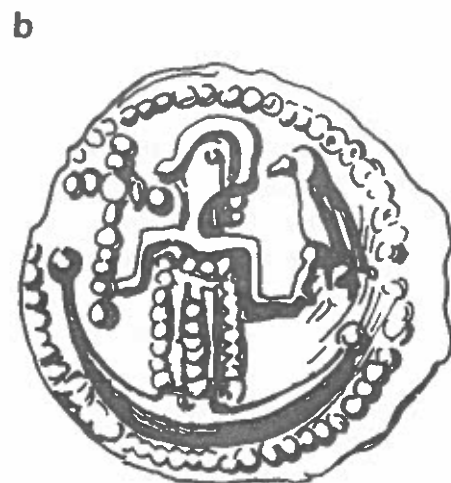
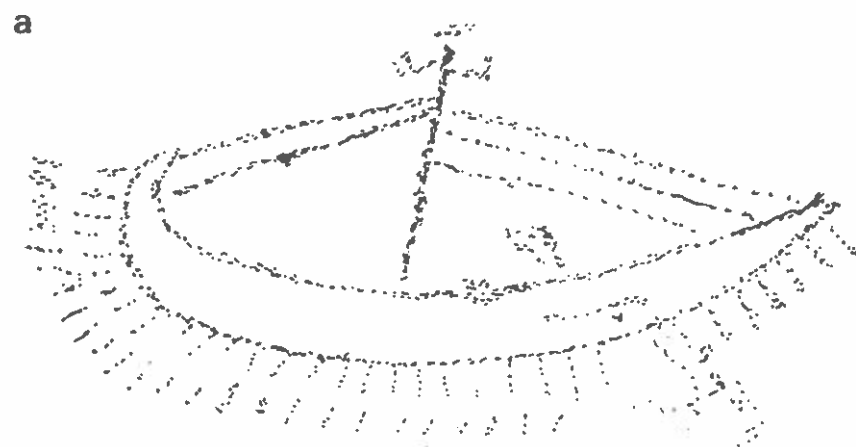


Fig. 8.2 a. Ship with a mast and an asymmetrical hull engraved on a 7th-century Merovingian strap-end from N. France  
© Author  
b. 7th-century Anglo-Saxon sceatta showing a man on board an asymmetrical ship; probably minted in London  
After Ellmers, 1972a

## 2. SUTTON HOO

In 1938 a deliberately buried boat with a recorded length of 7 m was uncovered beneath Mound 2. Iron strake-fastenings alone survived and the hull impression in the loose sandy soil had been badly damaged by grave-robbers. In 1964 the present writer identified the iron bands supposedly fitting a transom stern (Maynard, 1942) as the hoops of an iron-bound wooden bucket (Bruce-Mitford, 1964:27-31) and it seems that the excavator mistook the confines of the robbers' pit for that of the boat-trench.<sup>1</sup> The original hull may in fact have been as much as 10.5 m long, and there is a possibility that a third of it still lies *in situ* and undisturbed. It was dated to the early 7th century on the basis of a silver-gilt drinking-horn mount. My detailed study of the fragments showed that it was made from a die identical with one used to decorate drinking-horns in Mound 1 (Bruce Mitford, 1964:fig. 6).

## 3. SUTTON HOO

In 1939 Basil Brown carefully uncovered the superb impression of an early 7th-century oared ship, 27 m long, beneath Mound 1. With the exception of a provisional and unsatisfactory plan and lines (Fig. 8.1b) the records of the ship made by Cdr Hutchison of the Science Museum were tragically destroyed on his death. The ship was succinctly described by Phillips (Phillips, 1940a; 1940b:183-92) and, because of the damage the impression sustained during the war, re-excavation in 1965-7 was unable to add very much to this and to the details visible in the 1939 excavation photographs (Evans, 1972; Fenwick in Bruce-Mitford, 1975:296-300; Evans and Bruce-Mitford in Bruce-Mitford, 1975:345-435).

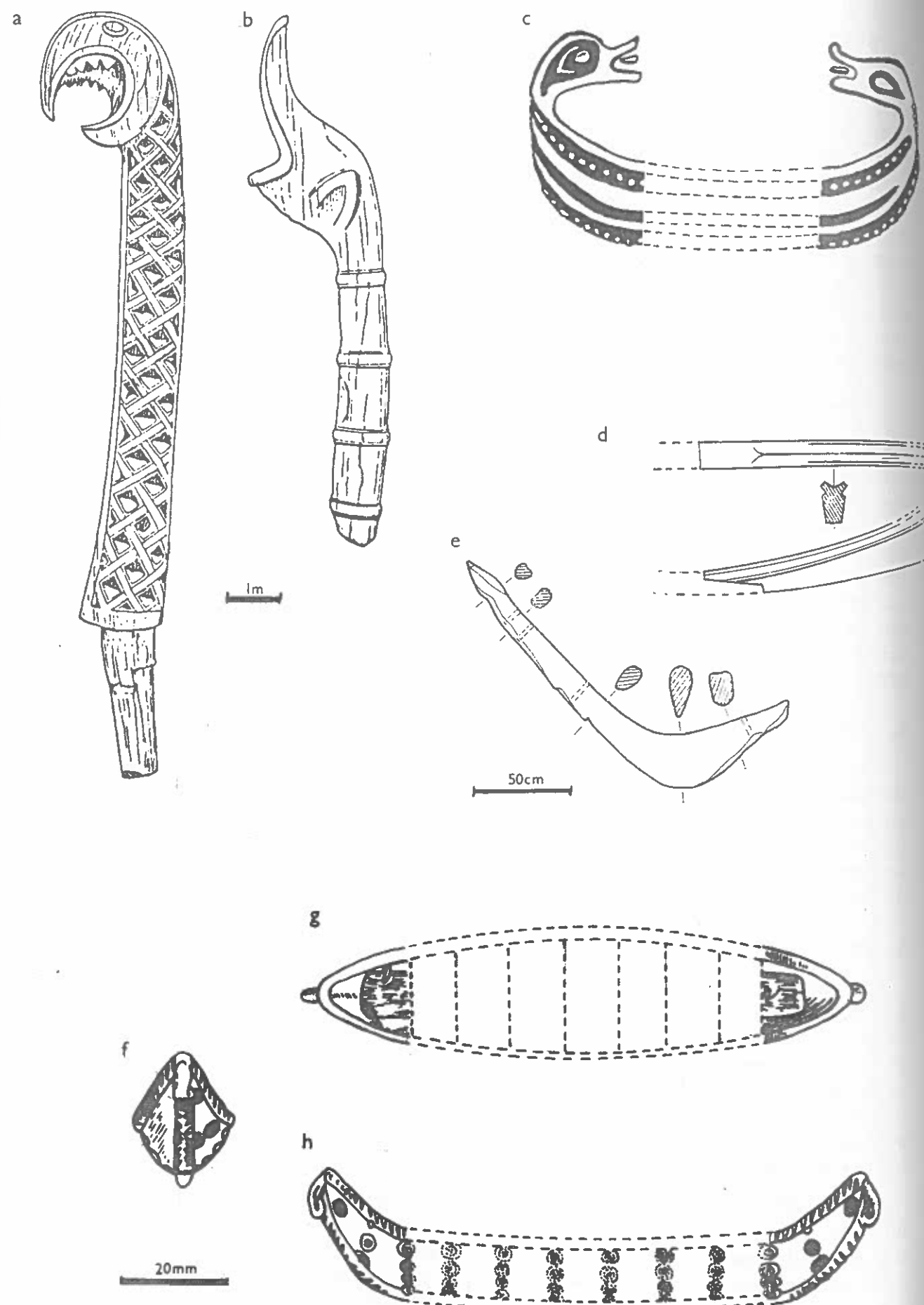
## 4. ASHBY DELL

In 1830 a ship was found in the NE. corner of Suffolk. It may belong to this period and is of interest in that it was perhaps constructed from local woods and was sewn (or wood-fastened) throughout. Unfortunately the original records were destroyed and information derives solely from a newspaper account by Kenneth Luck (Green, 1963:60ff.; Evans and Bruce-Mitford in Bruce-Mitford, 1975:426-7).

## 5. OTHER FINDS

In addition to these discoveries parts of clinker-built boats as much as 9 m long have been found at Caister-on-Sea, Norfolk, used as 'pseudo ship-burials' (Meaney, 1964:171). Several of these could be 7th-century. Boat-graves have been found in Scotland and the Isle of Man (listed in Müller-Wille, 1970), and two stepped stems, 1.85 and 1.93 m long, derive from a bog on the Island of Eigg. These are, however, Viking, as are the boat fragments and boat-models recently discovered in Dublin (Ó'Riordáin, 1973:17-18; 1975), and do not concern us here.

Two other supposed clinker-built boats can also be dismissed, but for a different reason. The Rother barge, 19.4 m long, found in Kent in 1820, was carefully recorded. The manuscripts (National Maritime Museum, RCE/1.53/017) are a model of early nautical archaeological recording. The ship



- Fig. 8.3 a-b. Carved wooden posts of the Migration period dredged from the R. Scheldt at Appels and Moerzeke-Mariekerke, Belgium, showing a ship embellishment in vogue before the Viking period. Drawn by M. O. Miller  
© British Museum
- c. Carolingian river-boat with an animal-headed stem carved on a gaming piece from Mainz; compressed to make a circular design. Original lost, drawing from cast  
© Author
- d-e. 7th-century ship from Gredstedbro, Denmark; d, reconstruction of the stem with a horizontal scarf secured with iron rivets; e, incomplete frame fitting the shell closely and secured by trenails, a feature not apparently found elsewhere in Scandinavia at this period  
After Crumlin-Pedersen, 1968
- f-h. Bronze model of a ship on a sword pommel of c. A.D. 700 from a grave, Sibertswold, Kent; the ship was shortened to fit the space; the rows of circles may represent trenails with projecting heads on the frame-stations.  
Drawing: Author, based on Vierck, 1970

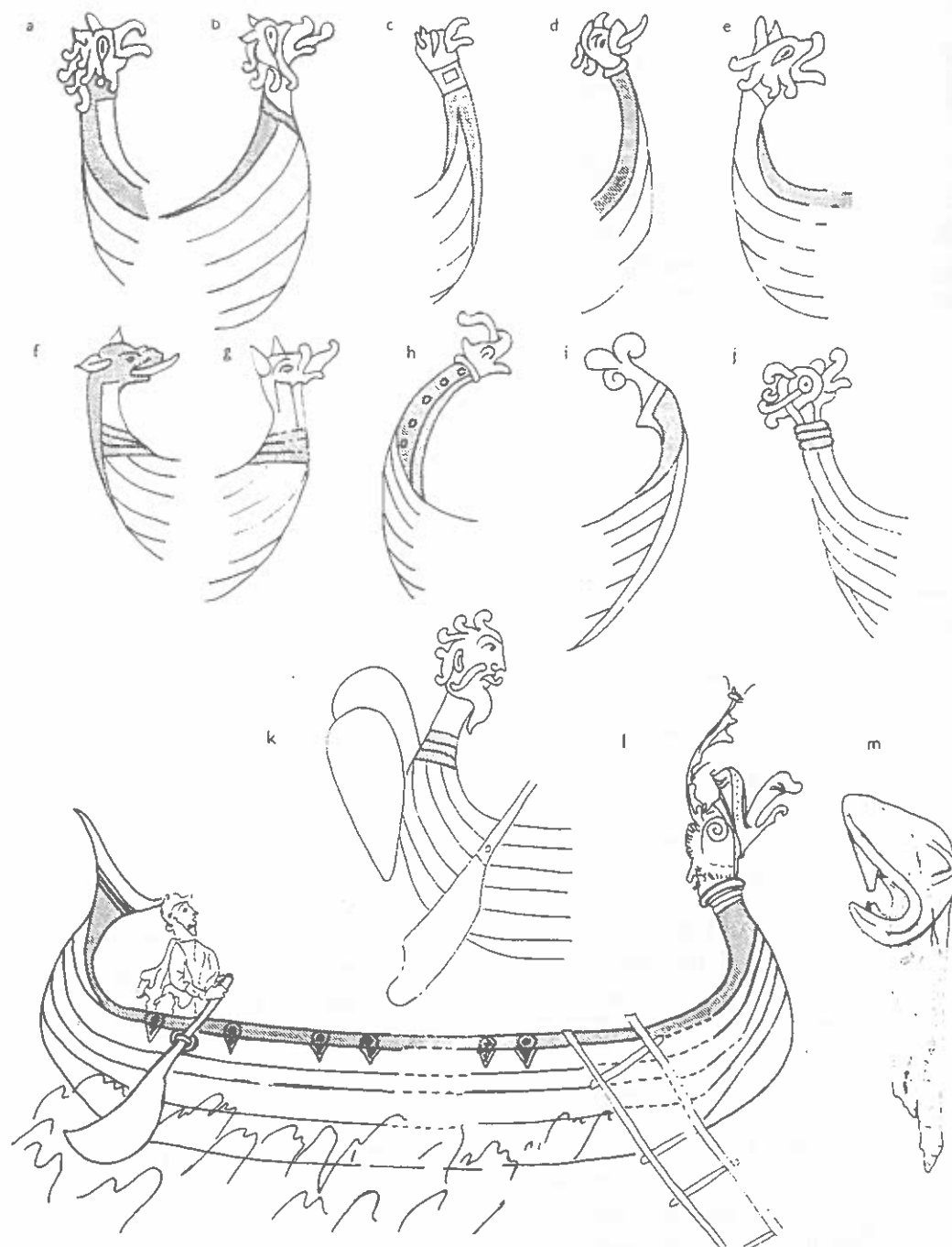


Fig. 8.4 ANGLO-SAXON AND NORMAN SOLUTIONS TO PROBLEM OF TERMINATING STRAKES

- a-g. 11th-century Norman solutions on Bayeux Tapestry  
© Author
- h-l. Anglo-Saxon solutions; h-k, on Bayeux Tapestry;  
l, the ark, a beamy ship in Caedmon Genesis, c. 1000  
Drawing: Author (after Bodleian Library, MS, Junius 11, f.66)
- m. For comparison with a-l, actual zoomorphic wooden post from the R. Scheldt at Zele, Belgium, of 8th century or later; the 'ear' is perhaps part of eye; the rest of the design was originally painted. 1 m high. (Drawn by M. O. Miller  
© British Museum)

and the objects found with her have not survived, but a study of her inventory shows that she should not be dated earlier than c. 1500 (Appendix, pp. 258-60). The vessel from Walthamstow, Essex, 13.7 m long, has been a candidate for ship-burial (Miller-Wille, 1970: no. 421). Study of the archive material, together with a carbon-14 date for the planking, has shown that this too is not earlier than the 16th century (Fenwick, 1978b).

## 6. PICTORIAL EVIDENCE

The pictorial evidence is slight and consists of small-scale representations which appear on 7th-century Anglo-Saxon *sceattas* (Fig. 8.2b), the pommel of a sword from Sibertswold, Kent, of c. 700 (Fig. 8.3f-h), and illustrations in Anglo-Saxon manuscripts (Fig. 8.4), and a graffito on a pot from Caistor-by-Norwich.

From this review it can be seen that the carefully-excavated and superbly-photographed impression of the ship in Mound I at Sutton Hoo must be our main object for comparison in this country.

## DESCRIPTION OF THE HULL

The structure has already been described in its essentials (Evans and Fenwick, 1971; Fenwick, 1972a, 1972b). The date of construction has now been narrowed to  $927 \pm 2$  (p. 123). The following description should be used in conjunction with the plan (Fig. 1.2.9) and is intended to supplement Cdr McKee's account and drawings of the individual components (chap. 3.2).

### KEEL (Figs. 8.5-6)

The keel is called a plank-keel to express its comparative width and absence of a substantial projection beneath (Figs. 8.5b, 6b). It was shaped from half a tree-trunk and survives to a length of 5.5 m. At its widest point it measures 0.44 m and is c. 0.08 m deep; its lower profile, 0.17 m wide, thus barely projected below the garboards.

As it lay in the ground in 1970 the upper surface of the keel was horizontal and lacked any curvature or rocker.<sup>2</sup> The strakes on each side of the keel had clearly sagged; this was particularly noticeable on the port amidships, as the waterlines on the hull during excavation show (Fig. 1.2.2). The tendency for a hull to settle and flatten was noted during the Sutton Hoo re-excavations (Bruce-Mitford, 1975:347) and was very apparent in the excavation of a late medieval barge at Blackfriars, London, in 1970 (Marsden, 1972:pl. 4). Reasons for supposing that the Graveney plank-keel originally had an upward curve or rocker at each end are: 1, in its absence the hull looked distinctly 'unfair' in the ground; 2, it was shown to be necessary in order to fit model copies of the hull components together; 3, vertical holes in the keel at what seemed to be the midships position, near the sternpost scarf and, it was assumed, originally near the stem scarf also, showed how the keel might have been pegged to a hard-back, or former, while the curvature was applied. These holes, 25 mm in diameter, were clearly no longer functional, for they had been made good with oak dowels and neatly smoothed off.

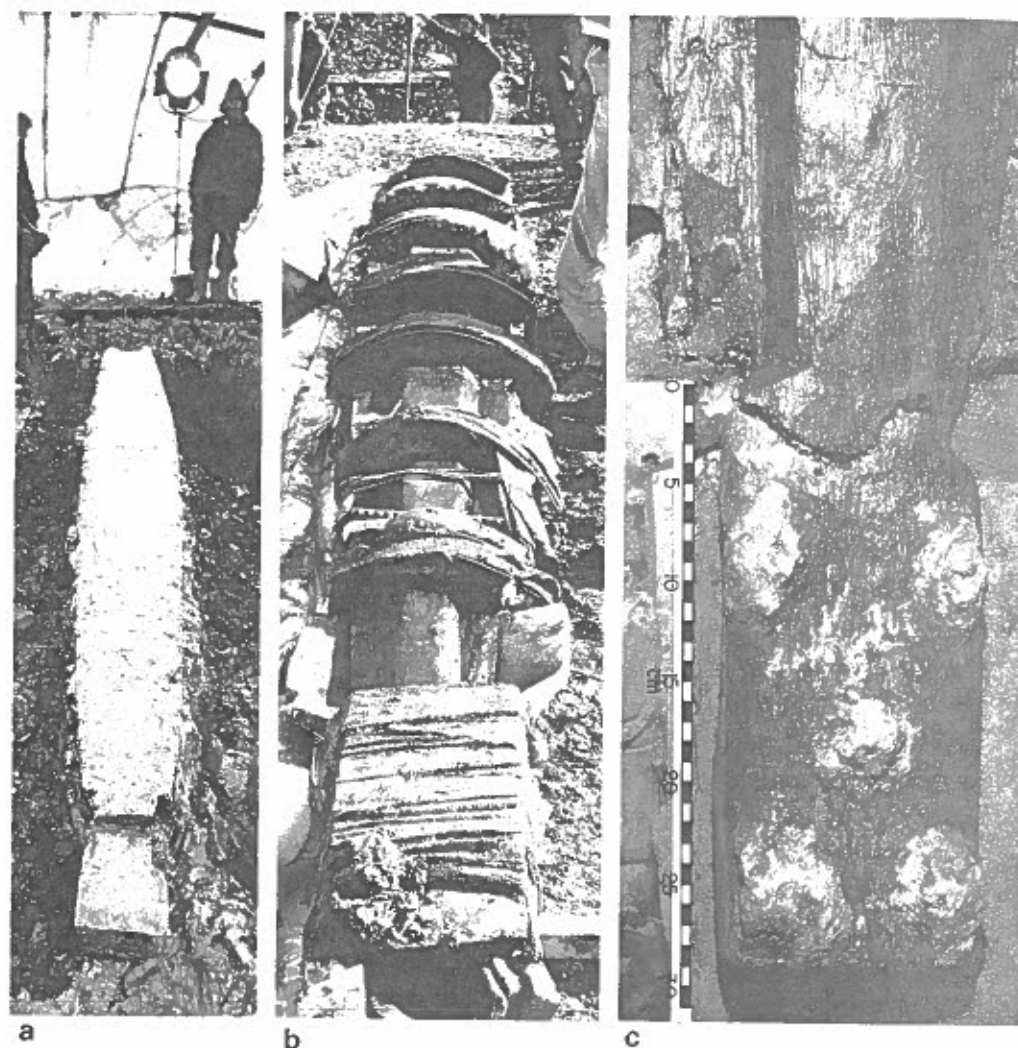


Fig. 8.5

# KEEL

- a. In situ with the rabbet for the sternpost in foreground
- b. Inverted, showing the lower profile between bandage supports (c is concealed beneath the splint in foreground)
- c. Aft extremity showing expansion of the lower profile at the scarf with the sternpost. The heads of five rivets give it a zoomorphic appearance. Scale in cm

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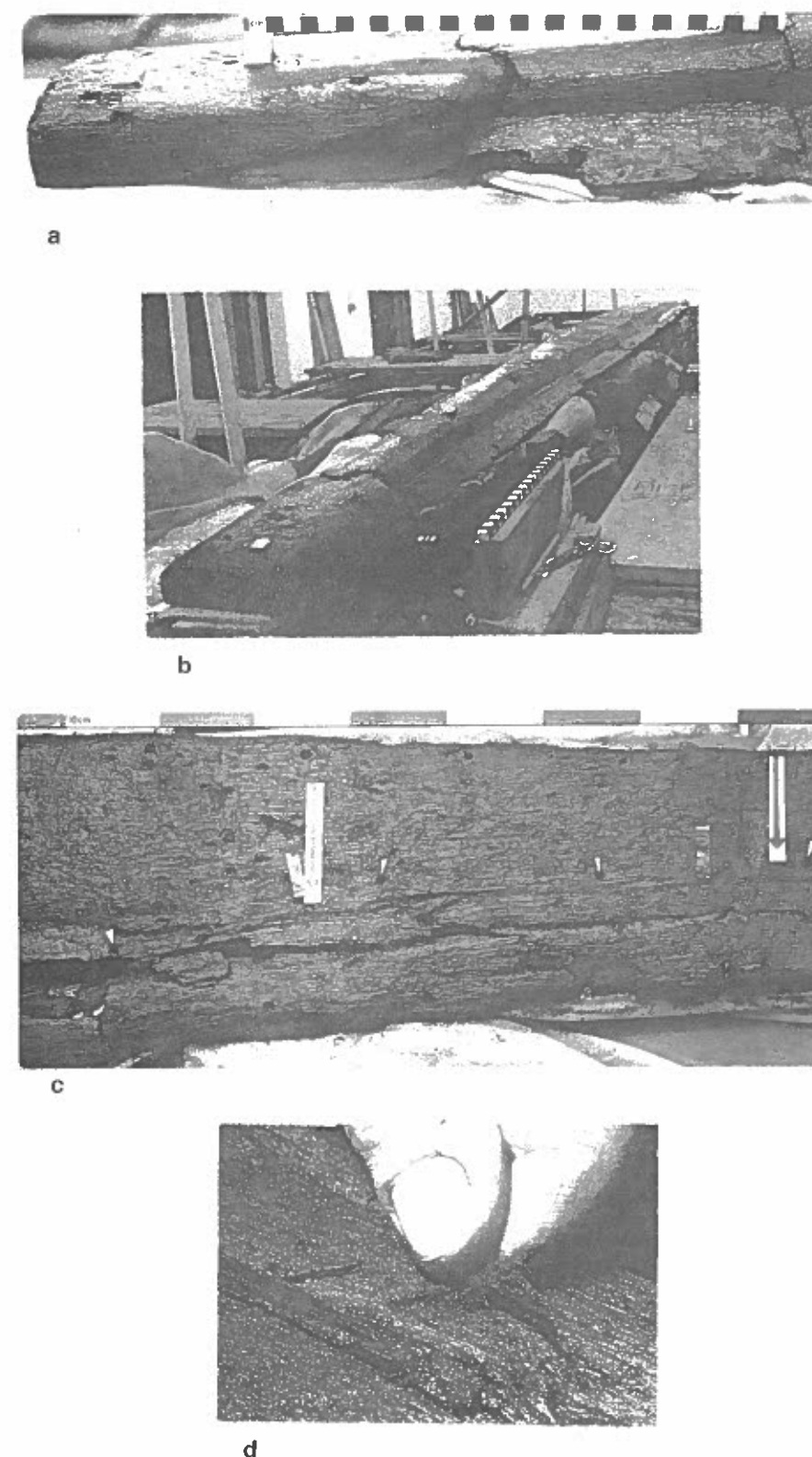


Fig. 8.6

# DISMANTLED KEEL AFTER CLEANING

- a. Damaged scarf with sternpost after the removal of clay encrustations; side view of the inverted keel showing the rabbet traversing the scarf
- b. Inverted keel showing the smooth flat lower profile amidships; the scarf with the sternpost in foreground Scale in cm
- c. Upper surface near frames R1 and 2 (black arrows), showing a fracture repaired in antiquity with a twisted strand of wool (d) and four rivets (white arrows)

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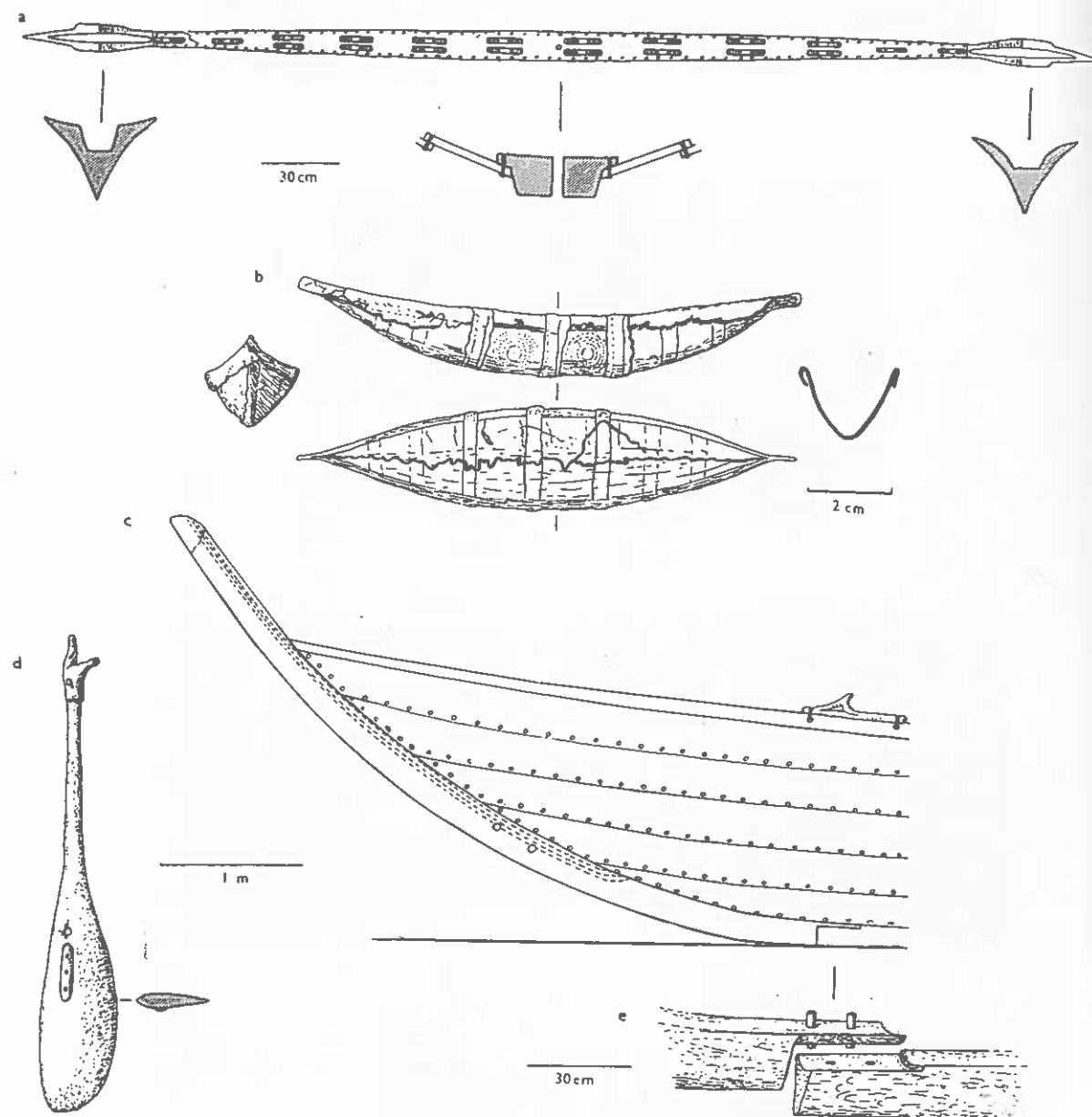


**Fig. 8.7** a. Drawing of the expanded keel of the fir ship from Nydam, Schleswig-Holstein, found in 1863, showing the vertical hole amidships; the ship has not survived  
After Engelhardt, 1865

b. Model ship of gold foil with bronze bindings from Nors, Jutland, one of 100 models from a votive hoard, perhaps of Migration period, all with raking stems and unpronounced sheer like Nydam oak ship  
After Müller, 1886:238

c-e. Oak ship from Nydam; c, raking stem with continuous rabbet, horizontal scarf (e=detail) and transverse holes low down; d, steering oar  
After Engelhardt, 1865

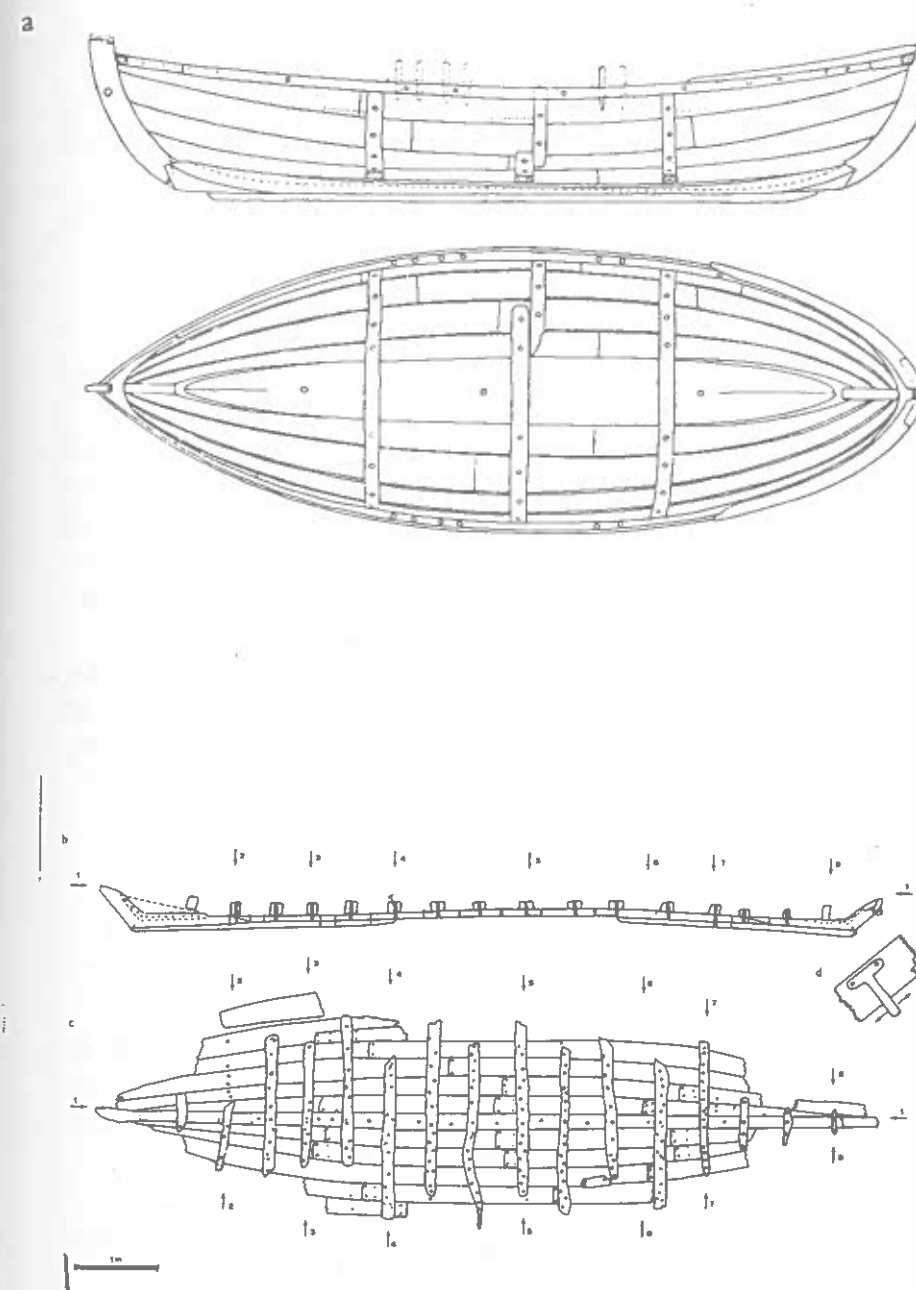


**Fig. 8.8** a. False-keel, 3,2 m long, secured by three trenails to the keel of the late medieval fishing boat (Kalmar III) found in the harbour of Kalmar, Sweden; the false-keel extends beyond the scarfs at stem and stern  
Author's reconstruction after Åkerlund, 1951

b-d. Late 12th-century wreck Q75 from IJsselmeerpolder, Zuider Zee, earliest known vessel with fittings for a stern rudder (d=detail); b, section showing two parts of the false-keel secured by vertical fastenings to the keel; c, plan showing the heavy frames of rectangular section winding across the hull  
© van der Heide

Such holes are not unknown. One was noted on the fir ship found at Nydam (Fig. 8.7a) between the third and fourth frames forward of amidships, on wreck 6 from Skuldelev, Denmark (Olsen and Crumlin-Pedersen, 1967:147), and several are visible on the expanded keel-plank of the boat from Årby in the Statens Historiska Museum, Stockholm. The occurrence of plugged holes in the bottom of dug-outs, for instance in the 14th-century boat from Kentmere, Cumbria,<sup>3</sup> does suggest an alternative function—that of thickness gauges to control the shaping of the all-important element of the hull. It is not improbable that the holes in the Graveney keel may have served both as thickness gauges in the first stage of shaping, and to hold pegs while curvature was applied in the second stage.

A third possibility is suggested by the three holes in comparable positions on the keel-plank of Kalmar III in Sweden (Fig. 8.8a). These were for the attachment of a false-keel to this flat-bottomed clinker-built boat which belongs perhaps to the 14th century (Åkerlund, 1951). The, apparently, two sections of false-keel on wreck Q.75 from IJsselmeerpolder, Netherlands, which is of 'mixed carvel and clinker' construction and belongs to the 12th century, were attached by single fastenings in corresponding positions on the keel (van der Heide, 1978). The extremities were fastened only by small spikes to heel and gripe (Fig. 8.8b-d). This wreck seems to have similarities with the Graveney ship, in that it is a small heavily framed cargo vessel, flat-floored and with a raking, heeled sternpost secured to the keel by a weak scarf. In both designs there seems to be a need for a longitudinal reinforcement in the form of a keelson or false-keel. Certainly on the analogy of Q.75 it is possible that the notably smooth lower profile of the Graveney plank-keel once had a false-keel secured by three trenails to the keel and by small spikes to the stem and sternpost, since spike-holes were extremely difficult to detect in the waterlogged oak. If so, the position and condition of the two holes in the keel would point to this fitting having been an original feature of the design.

In the vicinity of the sternpost scarf the plank-keel tapers to a breadth of 0.17 m (Fig. 8.5a). Looked at from above, therefore, it has a very marked expansion amidships. Comparison with other vessels shows that the closest known parallels are to be found in a group of loosely dated medieval ships from Poland and two 4th to 5th-century examples from Denmark. The Slavonic finds, particularly those from Bagart, Frombork and Szezecin, show a comparably expanded plank-keel. However, the keels of all these ships, unlike the Graveney one, positively project below the adjacent strakes (Ellmers, 1972a:nos. 75, 85, 94). Of the Danish finds the fir ship from Nydam of c. A.D. 350 (Fig. 8.7a) has a plank-keel about 0.43 m wide amidships, tapering to about 0.16 m; the oak ship of c. 400 (Fig. 8.7c-e) is equally wide amidships, but the proportions of both keels are different from those of the Graveney keel since they are considerably longer. On the other hand, the keel-planks of both the fragmentary Gredstedbro and the Sutton Hoo ships are narrow and shallow. The former has been estimated to have been about 0.22 m wide amidships and 0.10 to 0.11 m deep, while the latter is without any expansion, reaching a maximum observable width of 0.27 m and depth of c. 0.10 m, although it is twice as long overall (Crumlin-Pedersen, 1968; Evans and Bruce-Mitford in Bruce-Mitford, 1975:426, fig. 290; Fenwick in *ibid.*:300).

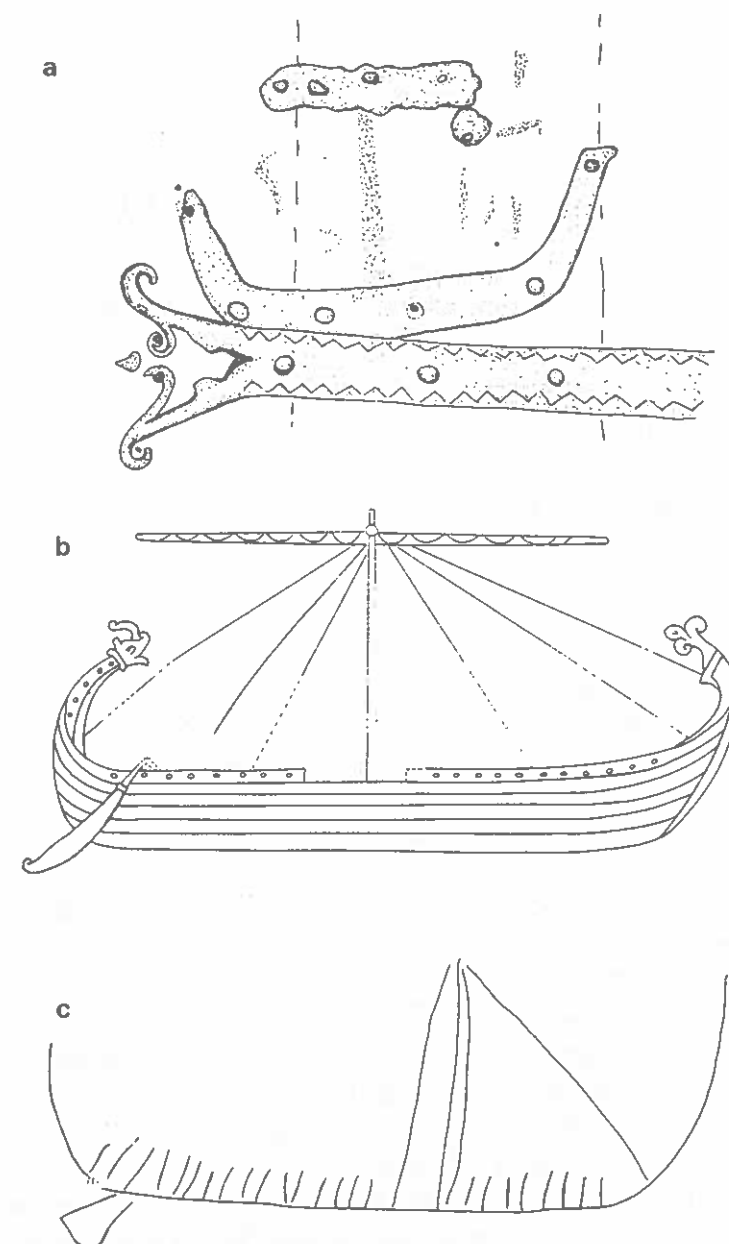


Fig. 8.9 a. Iron appliqué of ship on early church door, Staplehurst, Kent, with slightly angular stems suggesting an incipient heel; the lower part is partly obscured by the iron strap; raised areas on the woodwork indicate missing iron portions. 0.355 m long  
© Author

b. Ship on Bayeux Tapestry with a slight heel near the steering oar. 0.55 m long  
Drawing: Author

c. Piece of slate incised with a ship, from Viking house, Jarlshof, Shetland; the stern is slightly differentiated aft of the large steering oar, while the mast is set forward of amidships. 0.165 m long  
© Author

## BOW

The presumed bow and a substantial portion of the foremost end of the keel had been destroyed before discovery;<sup>4</sup> it is therefore not possible to say whether the two stems and stem scarfs were identical. The surviving stem was fashioned from half a tree-trunk and suggests that a pair may have been shaped from the same slightly curving tree-trunk. This does not preclude a modification in the shaping of, for instance, the cutwater or gripe. The Anglo-Saxon ship in the Caedmon manuscript appears to have a distinct gripe (Fig. 8.4).

A differentiated bow and stern design is of much greater antiquity than was once realized (Ellmers, 1969:8), perhaps having its origin in dug-outs of Fox's Group II (Fox, 1926:fig. 3). Recent discoveries on the former bank of the Rhine in the Netherlands include Gallo-Roman river barges with transom sterns (de Weerd and Haalebos, 1973; de Weerd, 1977). In England the transom stern of the Sutton Hoo boat should, as has already been suggested (p. 197), be discounted, but the original lines taken by Cdr Hutchison (Fig. 8.1b) of the ship in Mound 1 show a slightly fuller stern and it is possible that the missing upper parts of the stem and stern were differently worked. The Snape plan shows a more pronounced difference. Indeed it is tempting to surmise that the upper parts of the stems were missed or missing in 1862 and that the fuller end originally terminated at a higher level (Fig. 8.1a). This kind of hull appears on some 7th-century Anglo-Saxon *sceattas*, probably minted in London. From the direction in which the figure on board is looking the stern seems to have been the higher end (Fig. 8.2b). An even more pronounced differentiation appears on a Merovingian strap-end of the 7th century (Fig. 8.2a) (Bruce-Mitford, 1975:fig. 321, c, d). This find from northern France depicts a masted ship with what appears to be a quarter rudder; if this is so, it has a stern as raking as the Graveney sternpost, and an upcurved bow.<sup>5</sup> On the Bayeux Tapestry some of the stems and sterns of both English and Norman ships are differentiated, in particular nos. 4, 6, 12, 24 and 27 (Fig. 8.9b). The Tapestry is now generally agreed to be of southern English origin, if not Kentish (p. 185). A greater degree of differentiation can be seen on two Kentish representations—an iron appliqué on a Norman door at Staplehurst and a graffito on a Norman column at Deal (Figs. 8.9a, 10a).<sup>6</sup> The stern of a ship incised on a piece of slate found in a Viking house at Jarlshof, Shetland, is slightly differentiated (Fig. 8.9c).

For these reasons it would be rash in the present state of knowledge to assume that the missing bow of the Graveney ship matched the surviving stern exactly.

## STERNPOST (Figs. 8.11, 13, 16, 27)

The surviving stem was identified as the sternpost of the vessel on two grounds:

1. The majority of the plank scarfs faced in this direction (p. 97).
2. An isolated trenail hole pierced the port garboard aft of frame R1; this was assumed to be the bung-hole and, therefore, aft.<sup>7</sup>

The portion remaining measured 3.30 m. The lower part was intact, but from

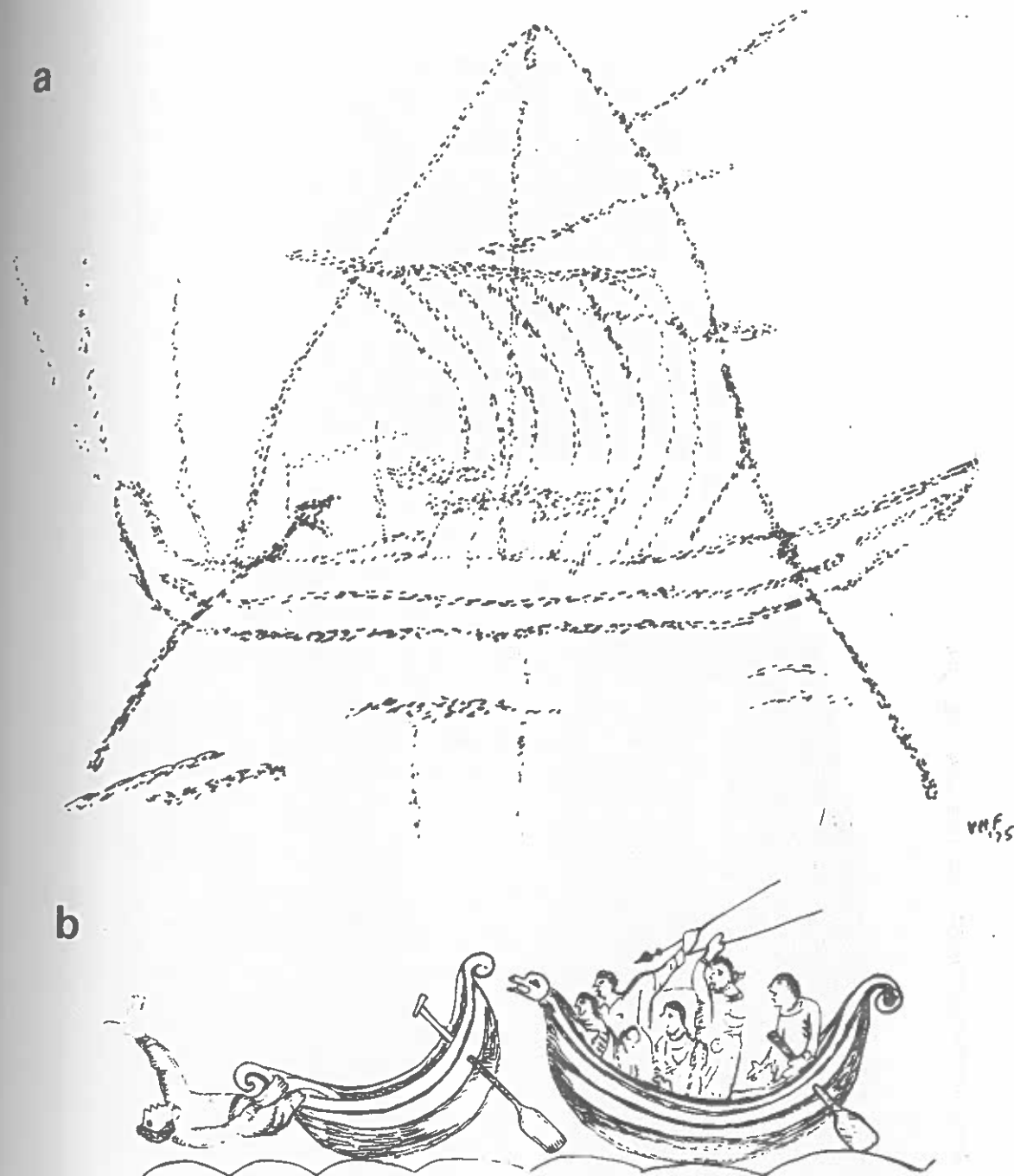
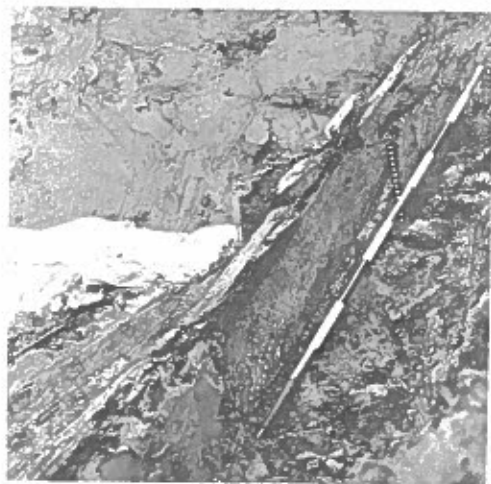
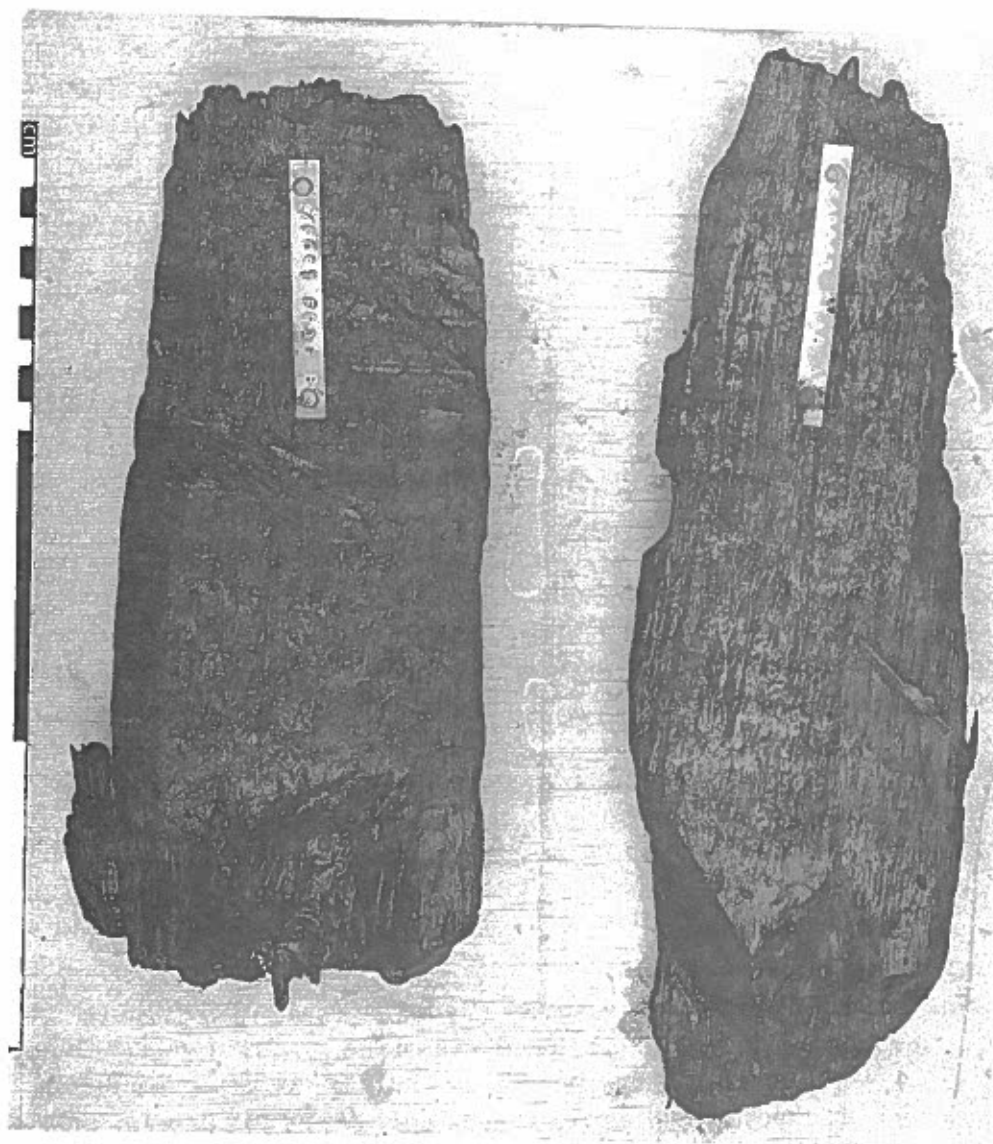


Fig. 8.10 a. Undated graffito of a ship on early Norman column, Upper Deal Church, Kent; the stem is very raking; the ship seems to be fitted with a *bugruder* as well as a steering oar. Rubbing made in 1931 by Francis Turner

b. 12th-century manuscript (Eadwine Psalter) written in Canterbury and a copy of an earlier psalter from Utrecht; river-boats with asymmetrical hulls have steering oars worked through ports  
Drawing: Author, after Trinity College, Cambridge, MS. R. 17.1

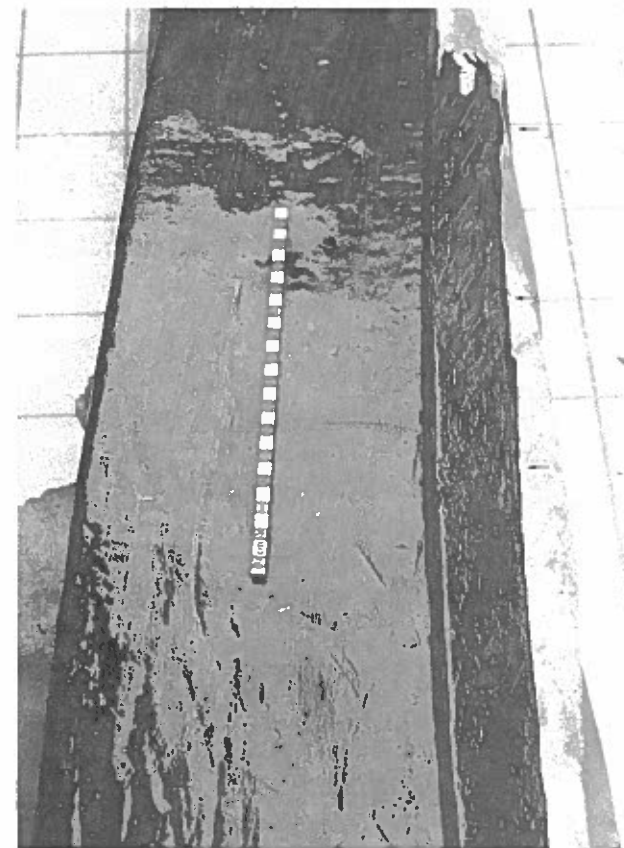


a



b

c



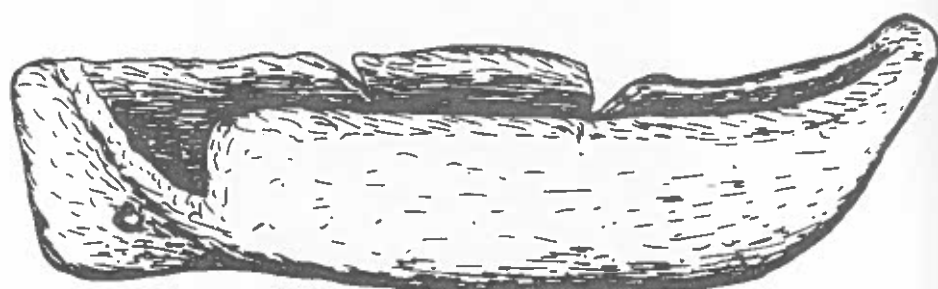
d

Fig. 8.11

#### STERNPOST

- a. In situ, showing the absence of grooves on the inboard face above the second strake; the two upper fragments, b-c, are out of place; vertical scale in cm below a hole in the sternpost, to which the 'painter' is attached  
© Author
- b-c. Fragments A and B, Gr88 and 89, from upper aft extremity. There is a fracture between the rabbets on each side on the plane on which the medullary rays lie; on the lower end of B, iron residues in a roughly cut cavity (bottom l.) may represent through-fastenings, but otherwise the plain upper surfaces of A and B suggest that the higher strakes were spiked and not riveted to the sternpost  
© National Maritime Museum
- d. Starboard side dampened to show tool marks and wear (note the diagonal tooling of the bearding to which a luting of wool partly adheres); blind fastenings (arrows) for the hood-end of strake 3 were not detected during tracing; ripples perpendicular to the rabbet line (top r. and lower l.) are possibly the result of finishing with a scraping-plane.  
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a



b



Fig. 8.12 a. 10th-century pottery model of boat from Lake Paterswolde, Netherlands; it is remarkable for its mast-step set well forward and its heeled sternpost with a perforation below the waterline. Original in Ryks Museum, Leyden, 0.14 m long  
Drawing: Author, after Verwey, 1934

b. Ship with massive stern rudder fitted to strongly curving hull; carved on a black steatite font in Zedelgem, Bruges, Belgium; second half of 12th century  
Drawing: Author

a point 2.5 m from the keel scarf it was badly damaged and decayed, while the rabbet into which the plank-ends had once fitted showed a sudden droop (Fig. 8.11a; Fig. 3.2.2). There was no sign of a scarf at the broken upper end.

Three horizontal holes, approximately 25 mm in diameter, pierced the sternpost between 0.87 and 1.17 m above its lower edge. The middle hole was very ragged and broken away but still connected to it were the remains of a rope of vegetable fibre, Gr164.

Inevitably called a painter, this rope seems to have been attached to the hull during the later stages of its career. It was made of three strands with an S, right-hand, twist and had once apparently been knotted to the sternpost (Fig. 1.1.3). The rope was carefully excavated but before the ship could be rescued it was damaged (Frontispiece) and its already fragile condition worsened. It lay above the general level of the remains of the hull and dried out very rapidly beneath the polythene cover. As a result, although the fragments were lifted in a block to be conserved, little coherent structure remained. A sample with enough structure for identification was obtained with some difficulty and it is possible that it derives from an intrusive stick, since the wood was identified as alder (p. 153).<sup>8</sup>

The rope curved out from the starboard side of the sternpost in a wide sweep and disappeared into the side of the ditch, 0.50 m away, giving the impression that the vessel was tied up. This, however, proved to be illusory; when the cutting was extended, only the unravelled tips of the rope were found. The rope was 2.5 m long and was floating, or lying, on the surface of the mud on a level with the broken upper extremity of the planking when the vessel silted over. It is of course possible that the rope had previously been attached to either Post 1 or 2 (Fig. 7.4).

As it seems likely that the rope had only passed through the central hole at a late stage in the life of the boat, the problem of the original purpose of the three holes remains. Comparison with the short list of vessels in which either stem has survived does not shed much light. The two holes through the stems of the oak ship from Nydam (Fig. 8.7c) have not been satisfactorily explained, but they are thought to have been connected with the attachment of a quarter rudder—in a vessel which, theoretically, could be rowed in either direction, since the tholes were merely lashed on the gunwales and might be reversed (Åkerlund, 1963).

Although the sternpost rudder is not known until the mid 12th century, it is first depicted on stone reliefs carved in Belgium (Fig. 8.12b), on which strongly curving sternposts are shown (Zarnecki, 1953). They seem to be singularly ill-designed for this fitting. It is possible, therefore, that the invention of the sternpost rudder sprang from the practice of lashing a quarter rudder to the sternpost of this type of hull, when the need arose, for instance, to increase the waterline length.

This explanation of the holes on the Graveney sternpost cannot be discounted, but they are more likely to be connected with the landing-place considered above (pp. 181, 183). If, as is there suggested, the ship was habitually beached (and this is consistent with the absence of *teredo navalis* or *limnoria* in the planking),<sup>9</sup> holes low on the stern would be ideally placed for hauling her out

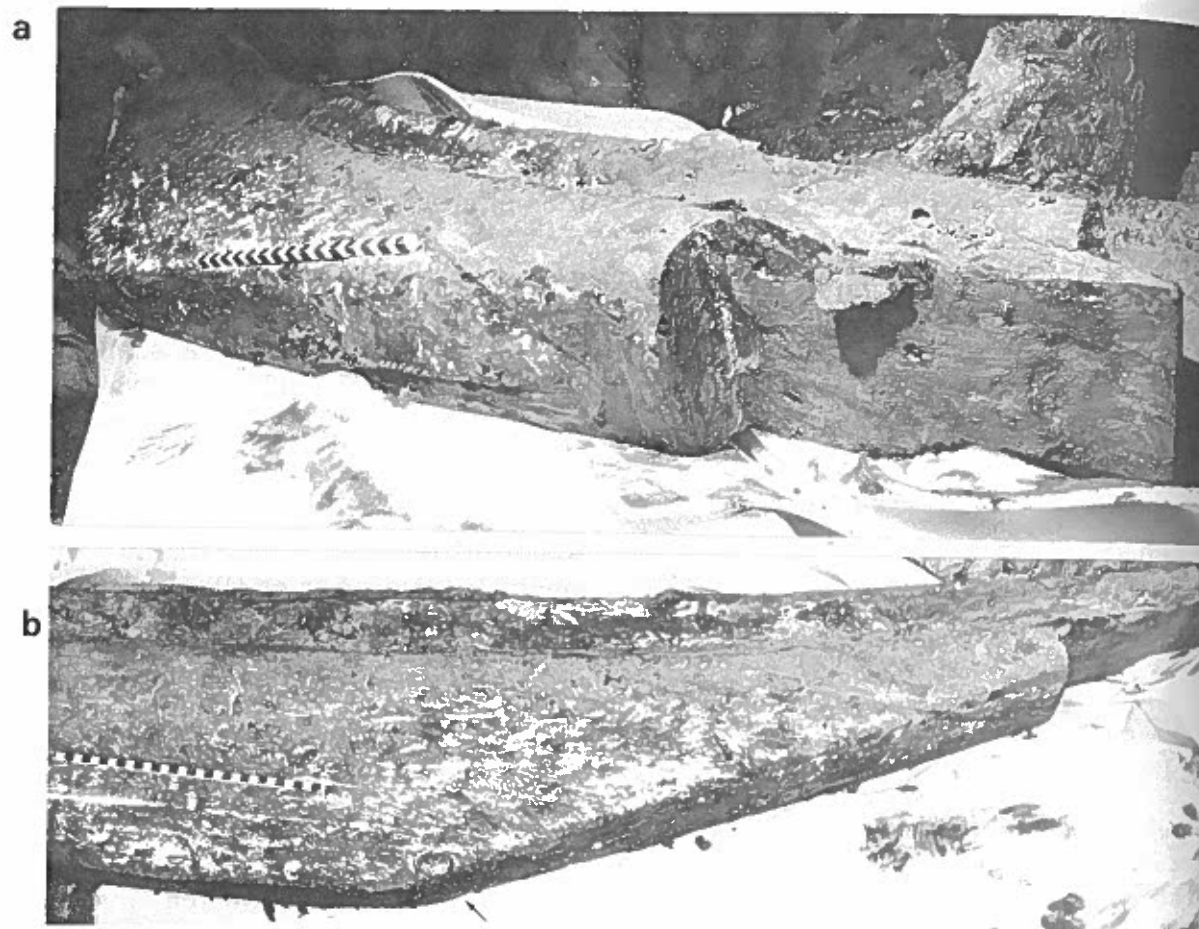


Fig. 8.13 BOTTOM OF STERNPOST IMMEDIATELY AFTER EXCAVATION

- a. Scarf with keel in foreground on r., with a felt of wool still in position; the lower profile tapers rapidly to the heel (l. of cm scale)
  - b. Starboard side showing a white deposit which covered parts of the hull; the head of an iron rivet at extremity of the heel is indicated by arrow. Scale in cm
- © National Maritime Museum

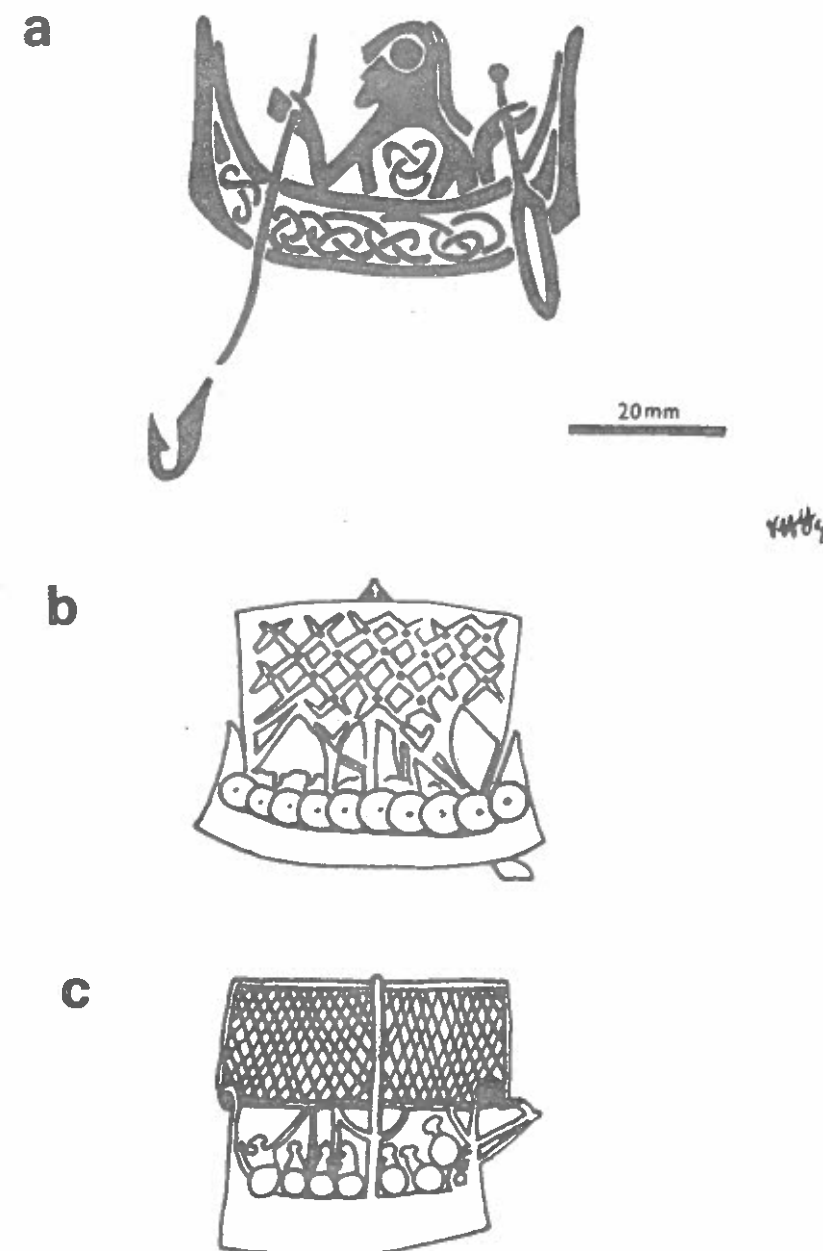


Fig. 8.14 EARLY CLINKER-BUILT VESSELS FROM SCANDINAVIA WITH ANGULAR STEMS

- a. Design on a bronze ornament from Solberga, Sweden of the pre-Viking Valsgarde period showing a man fishing in a boat with sharply angled stems  
© Author
- b. Picture cut on a gravestone from Gotland, Sweden, Halla Broa IV, c. 700; one of the earliest representations of sail in Scandinavia  
© Author
- c. Large ship filled with warriors on an early Viking gravestone from Hunninge, Gotland. Ship 0.72 m long  
© Author

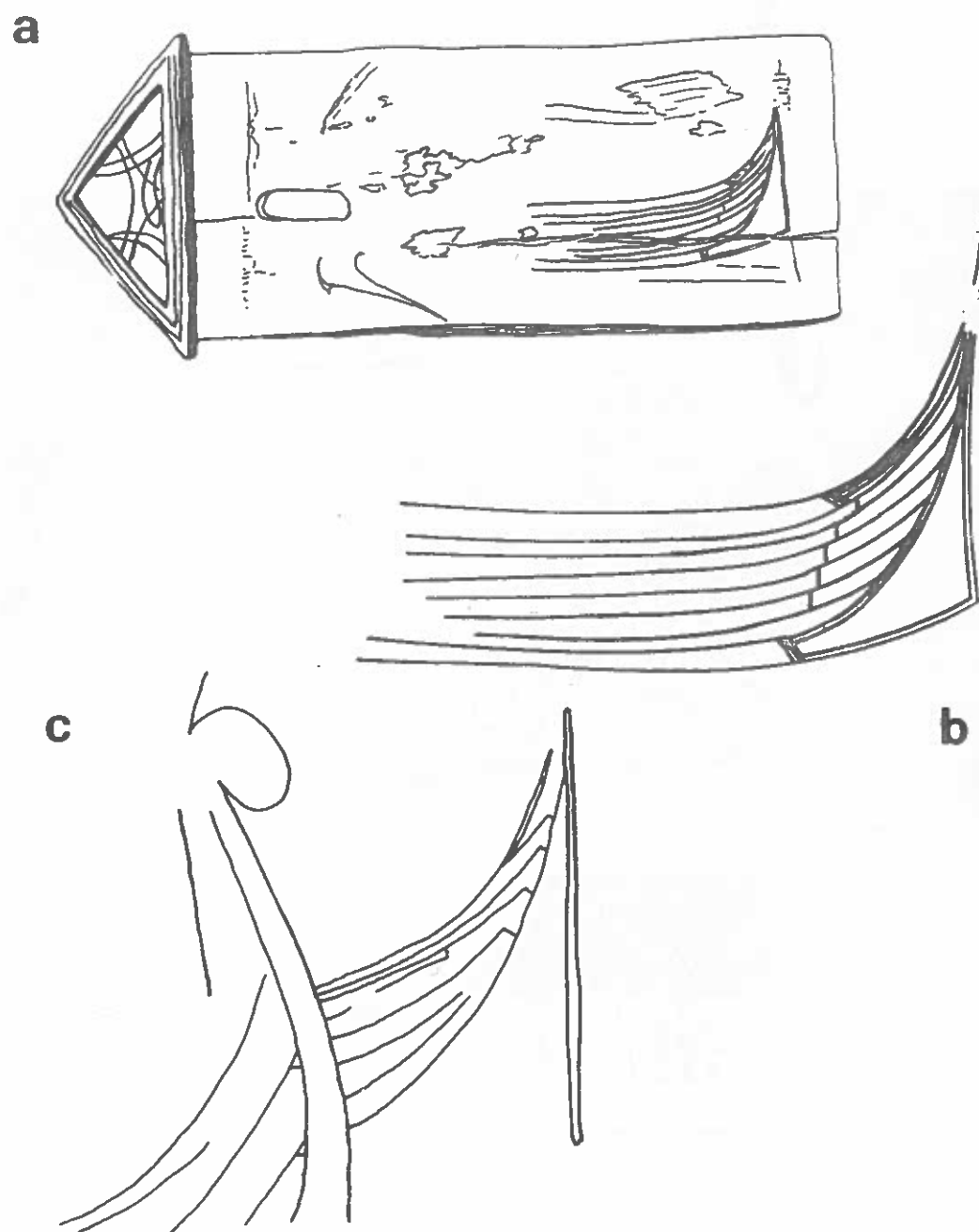


Fig. 8.15 a. Stempost engraved on a bone or horn lid of c. 800 found in the Oseberg ship. 0.193 m long  
After Brøgger, Falk and Shetelig, 1917

b. Design of a, with the damage removed  
Drawing: Author

c. Stems of ships scratched on a wooden sledge from the Oseberg ship; on l., a curving finial like that on the Oseberg ship with the ends of the strakes nibbed; on r., an angular stem like b, but combined with angular hooked hood-ends and complex runs of the lands  
After Brøgger, Falk and Shetelig, 1917

of the water. A similar consideration, of course, applies to the oak ship from Nydam (Fig. 8.7c) and to ships V, XVIII, XXIV and XXV from Kalmar, in which both single and paired holes occur above heel and forefoot (Åkerlund, 1951:pls. 14, 25, c-d, 27, a). The two 10th-century models from Lake Paterswolde, the Netherlands, have single holes low down on their sternposts (Fig. 8.12a) (Verwey, 1934), but these, like Graveney, it must be admitted, are ill-suited to beaching stern first.

Another transverse hole in the sternpost compounds the problem; this is smaller (9 mm in diameter) and occurs at the tip of the heel. When it was lifted, an iron rivet head was in position on the starboard side (Fig. 13b), but it did not survive the journey back to the Museum. As the head appeared to fit tightly, it is unlikely to have been used to attach anything on the starboard side. Like the four extra rivets on the keel (p. 221), it seems to have been used to repair an incipient crack in this vulnerable part of the hull.

Two pairs of grooves in the inboard face of the sternpost enable the hood-ends of the garboard strakes to be through-fastened to the sternpost. The damaged remains of a square(?) depression with fragments of corroded iron in it (Gr 88 and 89) imply that the aftermost fastening of the third strake was also through-fastened, with two blind fastenings forward of this. Strake 4 seems to have been similarly secured. The rough workmanship and unevenness of the grooves (Fig. 8.16) are an indication that they may be secondary features, cut to repair with rivets some sprung hood-ends which were originally nailed.

The profile of the sternpost is so far unparalleled at this period, although, as we have seen (p. 208), slight heels seem to be portrayed on some of the ships on the Bayeux Tapestry (Fig. 8.9b). Pronounced heels are found on representations of ships of this period and earlier (Figs. 8.14-15), but not on such raking sternposts. The function of the heel seems to have been to increase the lateral plane and reduce drift on a keel-less design.

The scarf between keel and sternpost was very carefully worked, and was the most excitingly conceived part of the ship. It was secured by a quincunx (five of diamonds pattern) of rivets, originally 0.09 m long; combined with the neck-like transition between the keel and sternpost, they give a strongly zoomorphic aspect to the inverted keel (Fig. 8.5c). The scarf was a simple half-and-half type without a stopwater. The faying surfaces were covered with a luting of vegetable tar and a felt of sheep's wool (pp. 151, 153; Fig. 8.13a). The horizontal axis of the scarf was clearly dictated by the design of the hull, which provided for a wood thickness here of only 0.99 m (Fig. 8.5a). This was not enough for the vertical scarf commonly used elsewhere, e.g. in the Skuldelev ships (Olsen and Crumlin-Pedersen, 1967:165). The Slavonic finds already mentioned (p. 206), with slightly projecting keel-planks, have sufficient depth of wood for a vertical scarf with feather edges. Of other vessels with horizontal scarfs, that of the Nydam oak ship was 0.27 m long and secured with two trenails (Fig. 8.7d-e); that on the Grødstedbro ship measured 0.22 m and was fastened with iron rivets (Fig. 8.3d); about the arrangement on the Sutton Hoo ship there is much uncertainty (Evans and Bruce-Mitford in Bruce-Mitford, 1975:352), but the scantling will again have dictated a horizontal scarf.

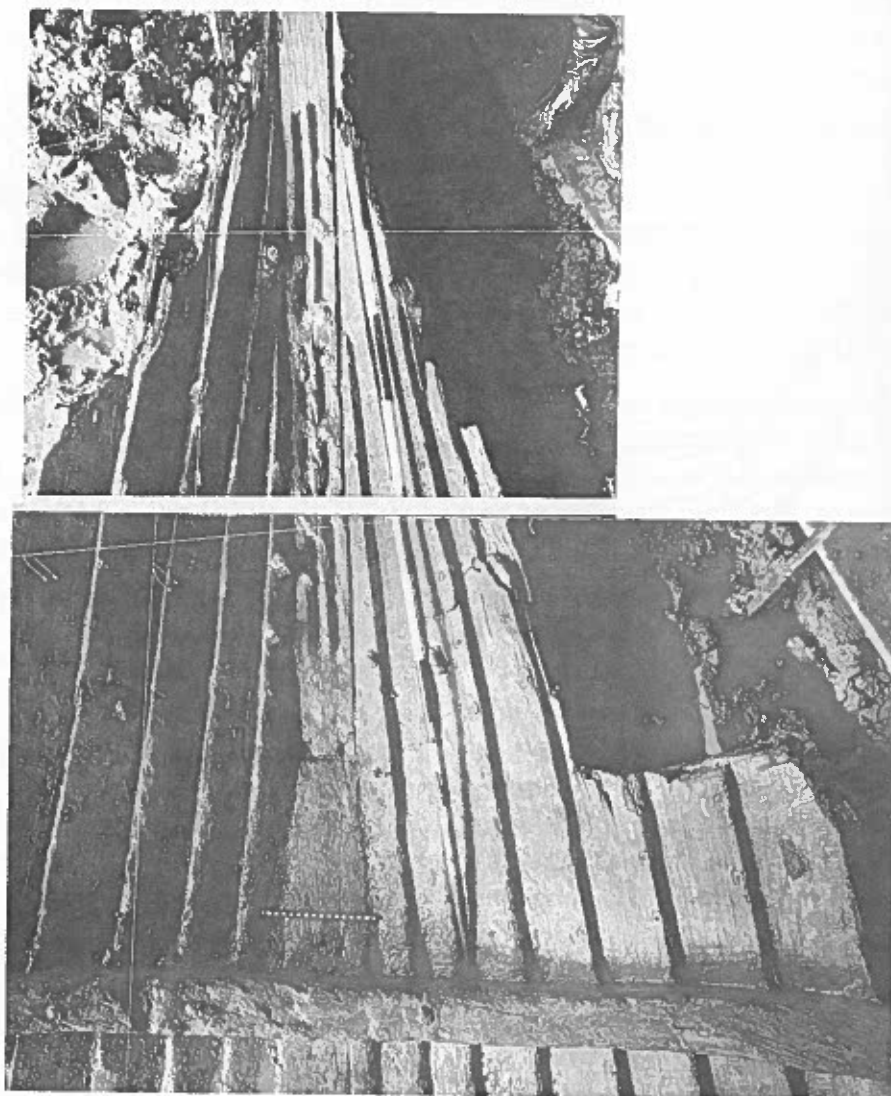


Fig. 8.16

STERN IN SITU FROM ABOVE

Running beneath frame R1 at the bottom, a fracture extends as far as the scarf with the sternpost, where there is a gap of more than 10 mm; the port garboard is fractured across a bung-hole(?); two pairs of roughly cut grooves are visible on the sternpost; the aft extremities of strakes 5-7 may have been deliberately cut. Scale in cm

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Fig. 8.17 Details of construction, such as wooden pegs inserted in the strake-fastening holes before iron rivets driven in, were revealed by careful cleaning.  
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Fig. 8.18 Form of a wooden peg (shaded) preserved by the corrosion products of an iron rivet shank (centre); part of an oak strake adheres on l. side. Gr279. Scale 1:1. Drawn by C. W. Gregson  
© National Maritime Museum

Despite the use of five iron rivets the scarf was a potentially weak spot and, when found, the keel had broken at the beginning of the scarf. As a result, the sternpost had dropped a little, so that a gap of more than 10 mm appeared inboard (Fig. 8.16). Deprived of its longitudinal stiffening, the whole stern section lay twisted out of alignment with the rest of the hull. An additional source of weakness was visible on site in the form of a longitudinal crack in the keel. This extended forward of the scarf and ran beneath frames R1 and 2. Four oblique holes had been bored in the keel to cross the crack (Fig. 8.6c), a twisted strand of wool (Fig. 8.6d) had been forced into it and iron rivets put in the holes to draw it together. One of the repair roves lay beneath frame R1, which thus must have been removed for this operation.

In order to make comparisons with the Sutton Hoo ship in this respect, it is necessary to imagine that the Graveney ship had been buried in sand. If so, the wood would have disintegrated and the repair would have been represented only by these four vertical rivets on the line of the keel. It is possible therefore that the three vertical rivets on the line of the slender little plank-keel at Sutton Hoo may represent a similar repair technique; they occur in an area where the hull was palpably repaired (Evans and Bruce-Mitford in Bruce-Mitford, 1975:figs. 301-2). These three rivets have hitherto been interpreted as scarf rivets, although they lie in what seems to be an unlikely position (Evans in Bruce-Mitford, 1975:392-8). If they were in fact rivets for repair, then tre-nailed scarfs, undetectable in the Sutton Hoo soil, could be assumed on the analogy of the Nydam oak ship (Fig. 8.7e).

#### STRAKES

Once the keel and stems were scarfed to form the backbone of the Graveney hull, carefully worked planks were fastened to it, using wooden pegs placed in prepared holes about 8 mm in diameter and at an average interval of 0.15 m (see histogram, Fig. 3.2.28). Sometimes mistakes were made (Figs. 21d-e, 22c-d).

#### Method of fastening

The wooden pegs, of which only the most fragmentary traces survived (Figs. 8.17-18, 21b), were obscured by the corrosion products of iron nails which had been hammered through them (much as a screw is driven through a 'rawl-plug', which it splits and compresses in the process). Such wood as remained could not be identified (p. 145). The iron nails had low domed heads about 25 mm in diameter and shanks which were sometimes of squarish section, but more usually many-faceted with one flat side, measuring approximately 4 mm across. The nails were driven in from outside the hull, and roves, snipped from iron sheet c. 2 mm thick, were fitted over the points, which were neatly clenched (Figs. 8.21a-c).

The land-nails on the Skuldelev hulls were driven through prepared holes, but had shanks of circular section (Olsen and Crumlin-Pedersen, 1967:102, fn. 2). The rivet shanks in both vessels from Sutton Hoo and in that from Snape had corroded into a circular outline with, in some cases, a squarish internal cavity. It is not possible to determine whether grain in the iron corrosion products parallel with the shank represents differential corrosion along the 'grain' of the wrought iron, or corrosion along the wood grain of a peg, the central cavity representing the original form of the iron.<sup>10</sup>

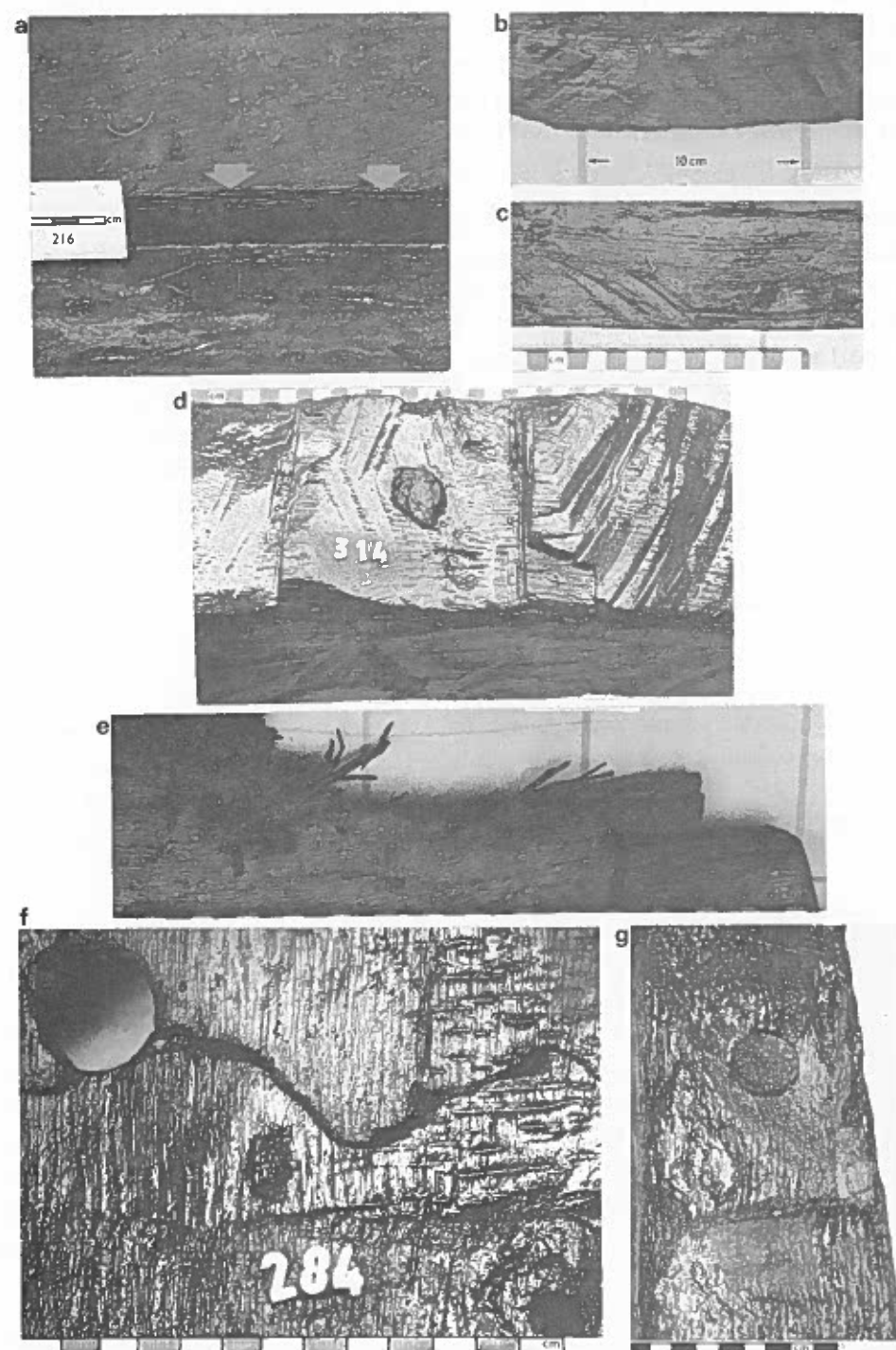


Fig. 8.19

#### TOOL MARKS

- a. Small grooves parallel with the rabbet-line on the sternpost perhaps made by a caulking iron. Gr216
- b-c. Diagonal tooling is preserved where strakes overlapped; an extra fastening used on c. Gr213
- d. An axe was used to shape the lower face of the frames to fit the shell; frame R1 alone was properly joggled
- e. Axe cuts along the extremities of the planking indicate a most determined attempt to cut up the ship sometime in the past

#### MEDULLARY RAYS

- f. Apparent tooling on the upper edges of the planking beneath the frames are actually the impression of medullary rays, g, of frames
- g. Harder medullary rays having resisted pressure more than the surrounding cells stand proud of the surface of the frame. Gr228

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The roves were not the neat lozenges which have been found in some ships of this period (e.g. Oseberg; Sutton Hoo 1 and 2; Snape), nor were all their points and axes aligned (as occurred in the Sutton Hoo ship). Rather they were irregular quadrilaterals with sides in the order of 28 by 22 mm (Fig. 8.21c).

The method of 'rawlplugging' the strake nails has not been noted in any other find. This does not mean that it does not occur elsewhere; as already described (Fenwick, 1972c:11), it was only discovered as the result of the most careful scrutiny of the iron corrosion products during cleaning (Fig. 8.17). However, in other finds where it was used on a larger scale (to secure frames to the shell), the technique has been noted. It occurs in the framing of cargo ships of the classical period found in the Mediterranean (Casson, 1971:207), in which the fastenings are for the most part of bronze. A somewhat similar technique was observed in the sailing barge of the 2nd century A.D., found in Blackfriars, London, in 1962, of apparently 'native' construction (Marsden, 1967:47). Here the spikes were of iron and the trenails appeared to pass through the frames but not the planking.<sup>11</sup> Strands of moss round the square iron fastenings of the Gallo-Roman barge from Bevaix, Switzerland (Arnold, 1974:135), were an apparently Celtic device for packing a square fastening in a round hole.

The Graveney technique of riveting the shell was so unusual in a clinker context that it was considered whether the hull had been either a), nail-sick and refastened; or b), originally wood-fastened. Wedged wooden fastenings of juniper, fir and pine have been found in roughly contemporary Slavonic craft from Rügen to Gdansk (Herfert, 1968; Lienau, 1934:33; Slaski, 1971:17; Slaski, 1974). Planks of a very small boat fastened in this way lay between a Roman and a medieval waterfront excavated at New Fresh Wharf, London, in 1973 (Marsden, 1974), so that the 'Baltic' technique of plank fastening may not have been unknown in the British Isles at this time. Wooden fastenings were also found in the 8th-century ship from Utrecht (Timmermann, 1956) and were used to fasten the upper (pine) planking of the 13th-century wreck, Kalmar I. A few were found on Kalmar XXII, a boat possibly of the Viking period, which was partly iron-fastened (Åkerlund, 1951:152, 155).

Militating against wooden fastenings was the fact that all the plank fastenings, without exception, were of iron; against nail-sickness was the fact that all the rivets were in round prepared holes and no square holes for through-fastenings were detected. It was therefore concluded that the shell had been originally and intentionally fastened in this way. Where blind nails were used on the sternpost the holes were very hard to detect. They were not noticed when the shape of the sternpost was traced during recording (Fig. 3.2.2) but are visible on some of the photographs (Fig. 8.11d).

Scribing (Fig. 8.22c-d)

As an aid to construction a line was scribed along the middle of the lap on the inboard face of the planks. It was thus invisible and protected once the plank was fastened. It also tended to be removed by the cutting of the 'luting cove' (see below). Thus the places where the scribing is still visible seem to be where the shipwright was a little short of wood to make a good fit. In one instance, at strake 6 in the vicinity of frame R1 (Gr74), he appears to



Fig. 8.20

#### TRENAILS

- a-b. Neatly shaped flattened head made watertight with a grommet of wool and a coating of vegetable tar. Gr339 (TN 2/7P)
  - c. Eased from hole to show a circle of bruised wood, roughly shaped and battered conical head. Gr241 (TN 9/8P)
  - d. Oak wedge, 65 mm long, driven in to split a willow trenail and secure it. Gr231
- © National Maritime Museum

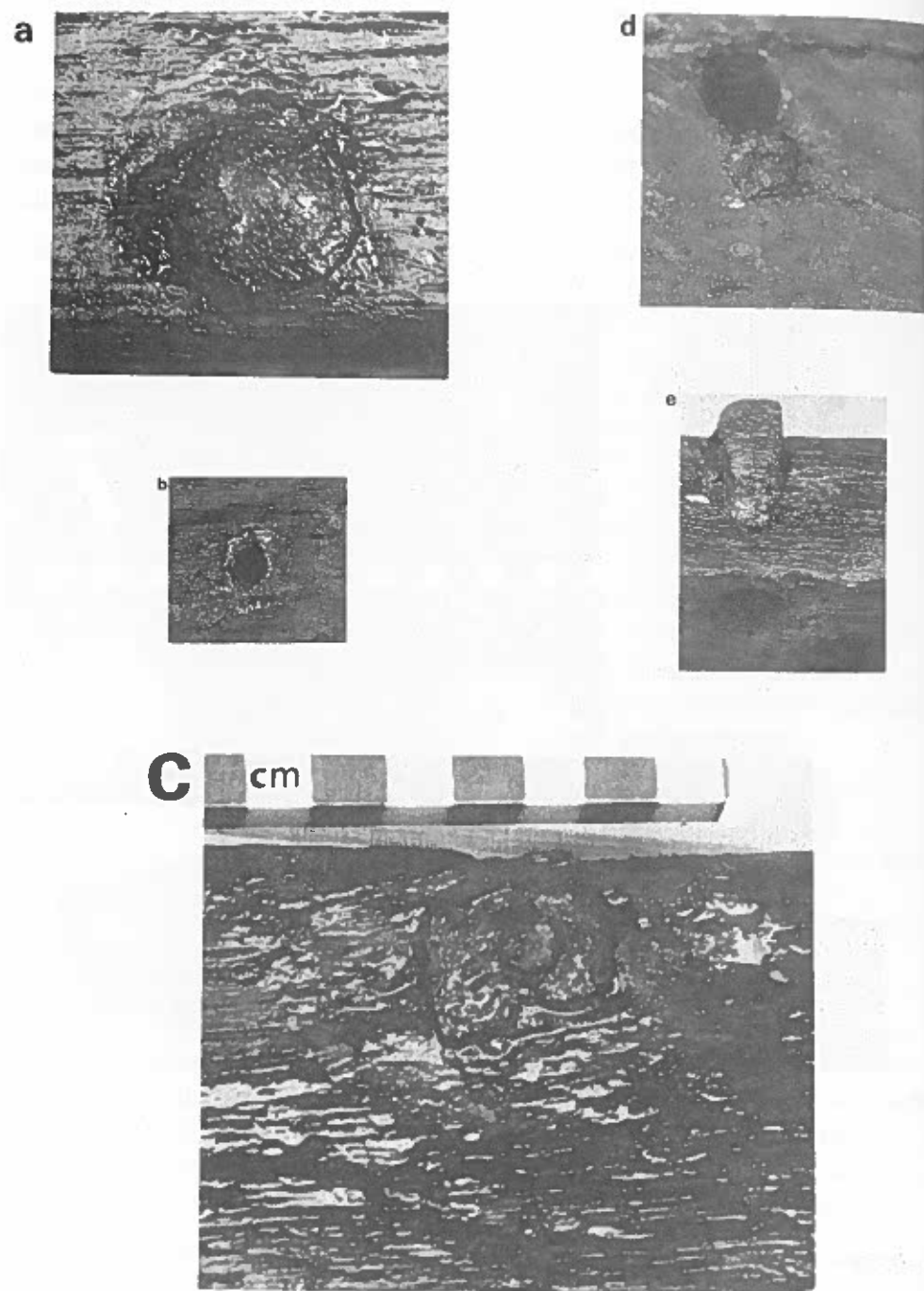


Fig. 8.21

#### RIVETS (actual size)

- a. Rare example of an iron rivet head beneath clay concretions. Gr284
- b. 'Ghost' of rivet shanks only survived; the central squarish hollow marks original shank and round it the iron-impregnated remains of a wooden peg which filled a pre-bored hole. Gr254
- c. Surviving rove showing a neatly clenched end of a nail. Gr274

#### MISTAKES

- d. When a fastening was wrongly positioned, the hole was filled with an oak peg and rebored. Gr235
- e. Unwanted hole on the edge of a plank; the peg has been loosened to show faceted sides. Gr235

have had a little trouble, for there are two lines, one presumably a correction, beneath a large mass of luting wool which extends the whole width of the land.

#### Luting and luting coves (Fig. 8.23)

The planks vary in thickness in a way in which modern mill-sawn planks do not, and as a result modern clinker-built boats do not need to be luted, although later in life they may need to be caulked. The slight ripples and irregularities of the surface produced by splitting green oak and the variation in thickness made luting necessary. To keep it in place a shallow channel, cove or groove was cut on the lower inboard lap of each plank—the luting cove. It was filled with strands of sheep's wool and vegetable tar (pp. 151, 153-4) to act as waterproofing (not cattle hair as was originally stated: Evans and Fenwick, 1971:93).

The hair of cow or sheep is a luting material characteristic of Scandinavian ship-finds from an early period. The oak ship from Nydam was luted with wool and pitch. The presence of protein and fatty substances at Sutton Hoo is indicative of animal-hair luting, and Stockholm tar was identified in the burial chamber (Bruce-Mitford, 1975:373, 486, fig. 367). On the other hand the luting material found in Polish wrecks, with the exception of those from Bagart and Frombork (Ellmers, 1972a:nos. 75, 85), is moss. It is not known whether the Sutton Hoo planks had luting coves, but they were commonplace in Scandinavia; they occur on the five ships from Skuldelev, which are perhaps only sixty years younger than the Graveney ship (Olsen and Crumlin-Pedersen, 1967:162-4) and on the Slavonic wrecks mentioned above (p. 206).

#### Use of scarfs

In some early N. European clinker-built ships the strakes were each made from a single plank without any scarfs. One of the most remarkable is the oak ship from Nydam, which has planks up to 23 m long (Fig. 8.7c). In discoveries of later clinker-built ships strakes were each formed of several planks scarfed together so that a more curvaceous hull was feasible. Thus in the Oseberg ship, in which the finest workmanship and materials were used, the planks averaged 4 m in length, and in the Sutton Hoo ship they measured about 5.5 m. These are vessels of war and pleasure. The planks in the Graveney hull were up to 4.5 m long, showing that there was no shortage of good timber to build this modest ship. Her strakes are joined by short scarfs, 0.11 m long, secured by one and sometimes two rivets (Fig. 8.26b,d). Most of the scarfs are arranged so that their outer edges are pointed towards the (presumed) stern; this seems to have been then, and still is, a very widespread boat-building practice and is carefully depicted on Fig. 8.25/1c,3). It is done to prevent water being forced into the joins when the boat is under way. On the Graveney shell a few scarfs face the wrong way (p. 97). This may be connected with a particular method used in planking up; more probably it was prompted by the occasional necessity of eking out the available timber. These forward-facing scarfs are clearly not repairs, and it should be noted that they occasionally feature even in the best quality Viking ships, such as Oseberg (Sjøvold, 1969:22).

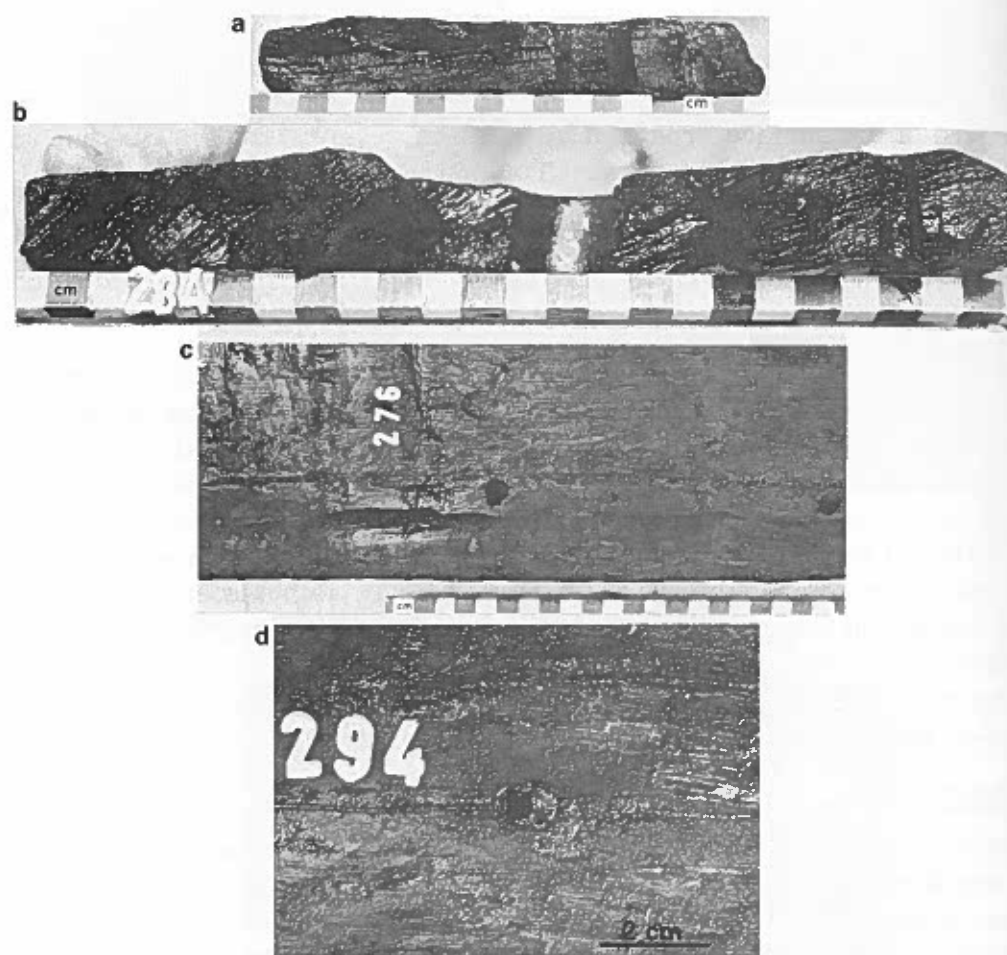


Fig. 8.22

#### TIMBER CONVERSION

- Planking trimmed from radially cleft oak trunks as the medullary rays show. Gr274
- Some planks were not radially cleft throughout their length, but run off the grain or considerably trimmed. Gr284

#### SHIPWRIGHT'S MARKS

- Neat score protected by a land intended either as a lap line or a nail line, apparently ignored. Gr276
- Similar to c on Gr294, but on the line of fastenings (note the plugged hole)

Subsequent cutting of the luting cove generally removed any scribing in this position

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#### Production and preparation of planks

The slightly wavy wedge-shaped planks were produced by splitting green oak along its medullary rays (chap. 7, note 8; Figs. 19f-g, 22a-b, 26). They were trimmed until they were of the required thickness. They taper slightly in section and vary in thickness. The adze as well as the axe seems to have been used for trimming (Fig. 8.19b-d; Figs. 7.7f-m, 7.8d-e). The planks were so fitted that the outer edge of the tree was uppermost and thus inboard. Since the ledges inside a clinker-built hull are trouble-spots as far as rot is concerned, and since sapwood is more prone to rot than heartwood, it seems clear that the builder aimed to exclude it.

However sapwood, sometimes called wane, is found on the upper extremities of a few planks where the shipwright was working the curve of his plank to the limits of his timber, and it is these few instances which have been most valuable for dating the vessel closely by dendrochronology (chap. 4.2). From Dr Fletcher's study of the samples it seems that all the planking was cleft from only two, or perhaps three, trees, each straight-grained and about 250 years old. The trunks employed were thus about 1 m in diameter, which is the size of the large oaks found in our forests.<sup>12</sup>

The upper and outer portion of each plank was trimmed, or hemmed, as required, to provide the subtle change of angle needed between each strake to create the curvature of the hull. Since the cleft planks, even after trimming, still tended to be slightly thicker at the upper end than at the lower, this trimming only served to reduce the difference in thickness (Fig. 8.22a). For this reason the length of the strake rivets was twice that of the plank-join rivets, a detail also observed at Sutton Hoo and on the basis of which similarly trimmed wedge-shaped planks may be assumed.

The method was not universally practised at this period and is the kind of concealed constructional technique which is more likely to be transmitted in a ship-building tradition than copied in the way that more obvious features are. The oak planks of the Skuldelev ships were radially cleft but were trimmed to produce planks of lentoid section (Olsen and Crumlin-Pedersen, 1967: *passim* and fig. 62). Smolarek (1969:fig. 64, a, d) has noted distinct bevels on the planks of the Gdansk vessels, but rather surprisingly the bevel is shown on the lower outboard edge of the plank, and the grain suggests that the planking is not radially orientated.

A more obvious difference which sets the planks of the Graveney ship apart from those of other ship-finds is the absence of any decorative mouldings along the edges.

#### Hood-ends

The last planks in each strake average only 1.5 m in length. The aft extremity of each (the hood-end) was trimmed off. A deep rabbet (Fig. 8.23d) was carefully worked on the inboard face to accommodate the aftermost end of the strake below, so that a continuous run of uniform thickness could be offered up to the sternpost rabbet. The last fastening of each strake was shared by the strake above, into which it was rabbeted. A subtle curve was given to the lower outboard edge of each plank with a hood-end. This only becomes

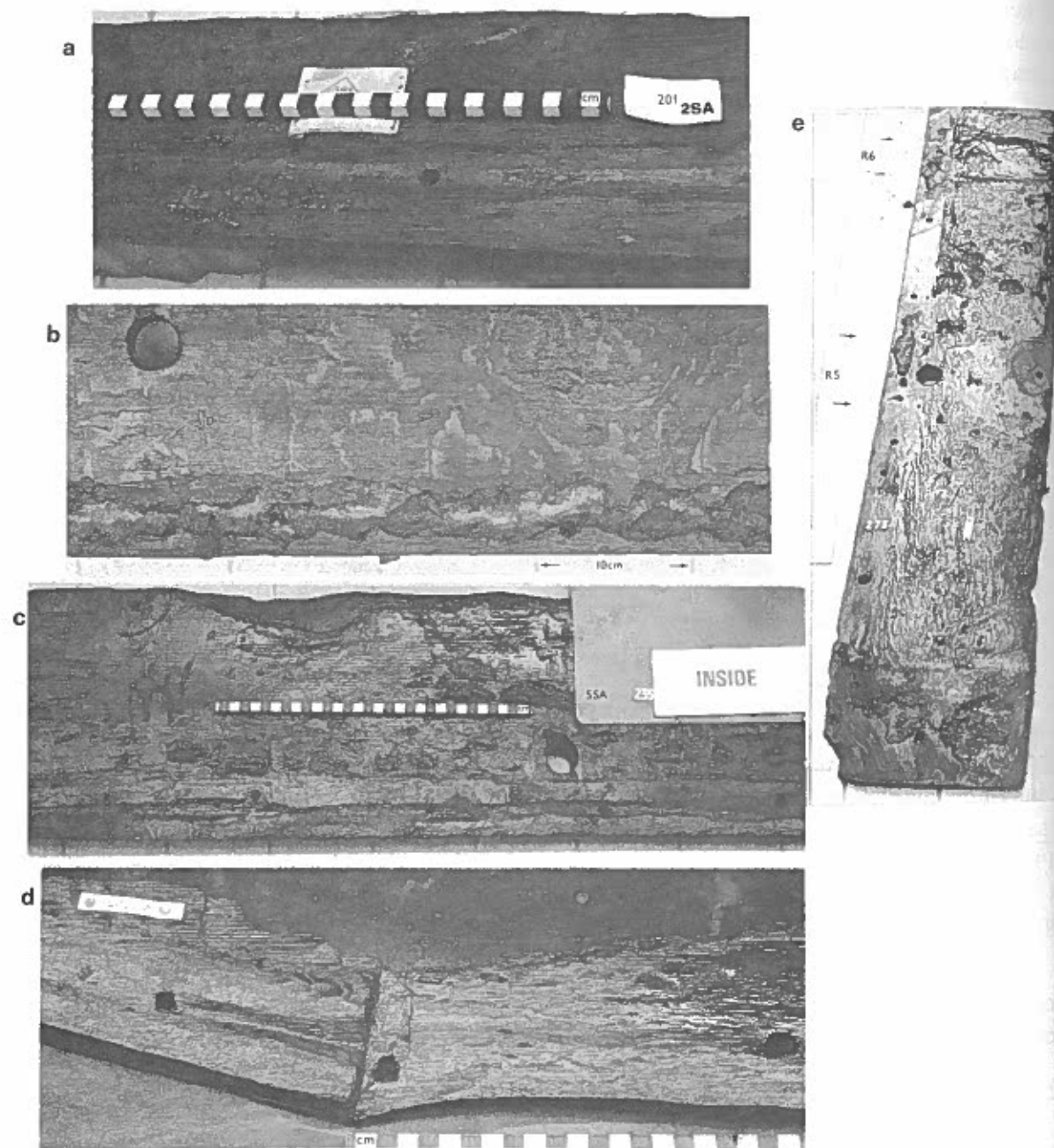


Fig. 8.23

#### DETAILS OF PLANKING

- a. Clearly defined groove or luting cove along the lower inboard edge of the strakes in the centre of the landing with the strake below. Gr201
- b. Twisted strands of sheep's wool and wood tar laid in a luting cove of radially cut planks—identified by the 'silver grain' of the medullary rays
- c. The level of craftsmanship varies. Strake 5 starboard with an uneven luting cove and fastenings not all aligned; the marks on l. of scale and the score, top l., are recent damage. Gr235
- d. Junction of the third strake with the sternpost on l. of the rabbit worked to accommodate the hood-end of the second strake; the luting cove was deepened and widened (note the delicate curve of the lower edge of the plank)
- e. Wet plank and oblique light showing the surface details of strake 2 starboard; the heavy luting on the plank scarf (foreground) and on the landing which had little or no luting cove; the severe bruising was caused by the working of frames R5 and 6. Note the uneven plank fastenings. (The circular pits between frames R5 and 6 were caused by the circulating pump which was used during the first stage of the rescue.) 10 cm grid

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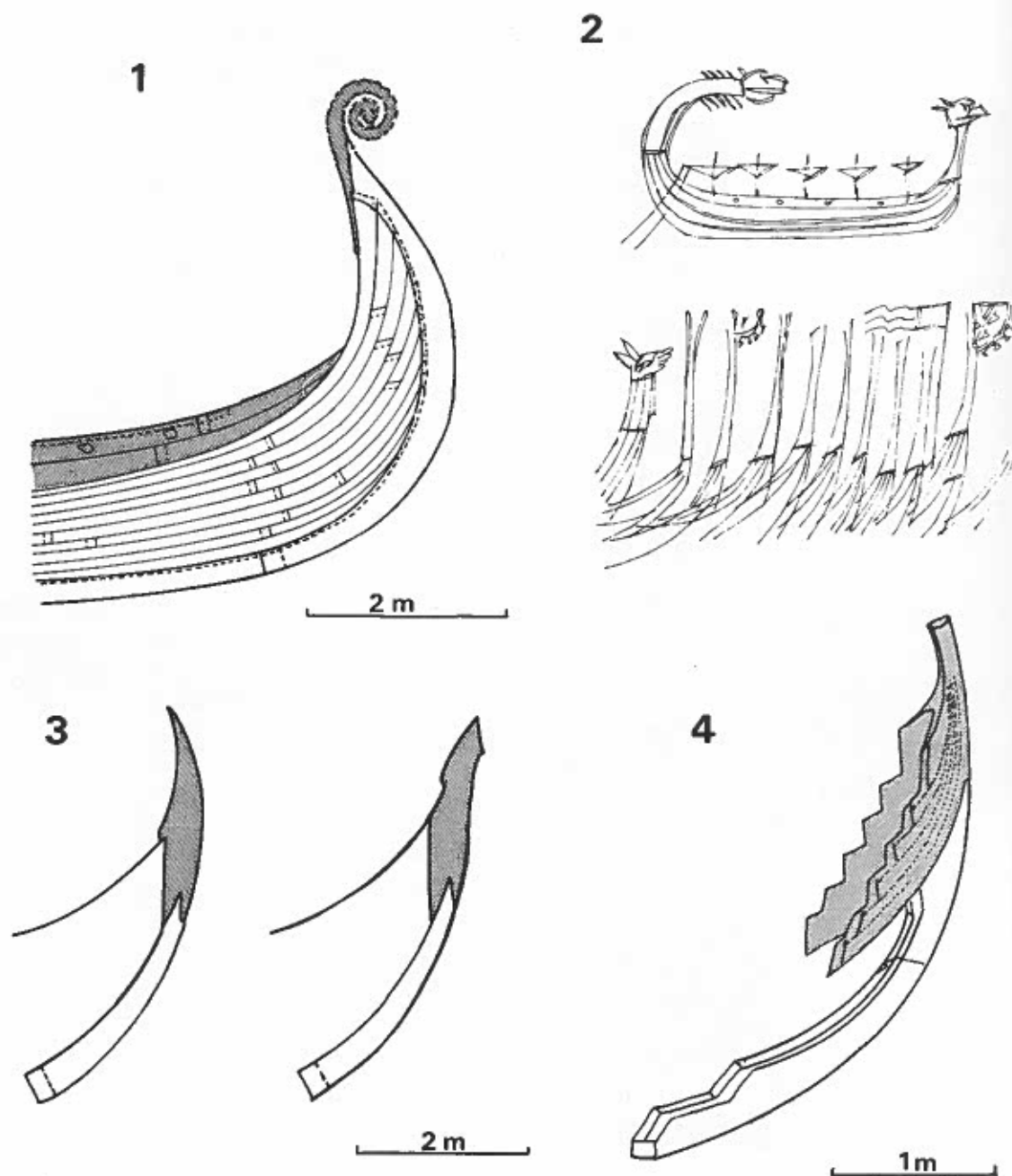


Fig. 8.24 SCANDINAVIAN SOLUTIONS TO PROBLEM OF TERMINATING UPPER STRAKES

1. Oseberg, Norway, *c.* 800. Not all the strakes run into the stem rabbet, the line of which was modified to accommodate the hood-end of the sheer strake. Both devices occur on the 'Norman' ship on the Bayeux Tapestry (Fig. 8.4e); the latter on the 12th-century English ship on Fig. 8.25/1c After Sjøvold, 1969
2. Bergen, Norway. 13th-century engraved runic stave showing the strakes scarfed into horizontal rabbets on the stemposts Drawing: Author
3. Gokstad, Norway, *c.* 850. Upper parts of the stems have disintegrated; alternative reconstructions a and b were proposed by Christensen, 1972; in both, the upper part of the rabbet is nearly vertical and straight
4. Skuldelev, Denmark, *c.* 960. Reconstruction of the stern of Wreck 1 by Olsen and Crumlin-Pedersen, 1967, the rabbet being a series of steps and curves



1a



1b



1c



2



3



4

Fig. 8.25 HOOKED HOOD-ENDS IN ENGLISH MANUSCRIPTS AND ON SEAL

1. Illustrations from *Life of St. Alban*, made before 1240, probably at St. Albans, Herts.  
Trinity College, Dublin, MS. E. I. 40
  - a. Germanus and Lupus embarking for Britain (f.53a). Stern of the ship with progressively more hooked strake endings, that of the sheer strake looking like a large axe; note the gang-plank, the shape of the quarter rudder with a 'staple' fastening and the pair of slotted oar-ports aft of the hold, in which horses are being tethered.
  - b. They land in Britain (f.53b). Tender with hooked strake endings like the ship; the sheer strake is not in a smooth curve to meet the rabbet, but clearly terminates aft of it. Note the technique of landing horses.
  - c. Offa landing in England on return from Rome (f.62a). Detailed drawing of the stern of the ship showing the runs of the strakes and the pairs of rivets for the plank scarfs, indicating that the ship is beaching stern first; the hood-ends are hooked, but the gunwale and sheer strake do not finish in the sternpost rabbet; the latter is scarfed transversely across the sternpost like the Oseberg ship (Fig. 24/1). Note the form of the anchor and the absence of a jetty.
2. Late 12th-century English bestiary (Syndics of University Library, Cambridge, MS.II.IV.26)  
Ship moored in mid ocean alongside a monstrous fish mistaken for an island; the hooked strake endings are well-defined at the bow but not at the stern, which has a more pronounced rake; animal-headed posts face fore and aft.
3. Late 12th-century English bestiary, possibly produced in Canterbury (Trustees of British Library, Harley MS.4751, f.69)  
Subject and composition similar to 2 above, but the details vary; the square sail is patterned with crosses, not reefed, although the mast is unstepped; the aft facing plank scarfs were fastened with pairs of rivets and the curved hooked hood-ends were also fastened with rivets; the hooks of the upper strakes were apparently worked from very short planks; unlike 2, the stems project beyond the rabbets, where all the strakes, including the sheer, terminate; a single port was probably added to the fifth strake forward; the sternpost is undecorated.
4. 2nd seal of Winchelsea, Sussex, early 14th-century. Note the carefully executed details; in addition to the anchor-cable, windlass, tiller-bar and quarter-rudder fixing, the ends of three through-beams and vertical rows of knobs on the shell are shown. Compare these with the trenail heads on the frame-stations of the reconstructed shell of the Graveney ship (Fig. 10.1.2).

pronounced by the time the third strake is reached (Fig. 8.27a). It perhaps echoes the fine swirl of the planking of the 9th-century Oseberg ship, for instance (Fig. 8.27b). This kind of hooked hood-end has not been found so far elsewhere on the Continent; alternative 'stepped' and 'winged' solutions were devised to resolve the problems created by increased sheer and more numerous strakes. The hood-end is, however, clearly illustrated in a series of medieval English manuscripts (Fig. 8.25/1-3). On the evidence of these and of the Oseberg ship it is fairly certain that the missing hood-ends of the Graveney ship were made progressively more hooked.

The hood-ends of the Sutton Hoo ship were probably hooked also. The un-interrupted rows of rivets high in the bow appear on a photograph (Bruce-Mitford, 1975; fig. 270). They were subsequently plotted on a drawing (Fig. 8.28b) (*ibid.*:fig. 274); the lines connecting the rivets are a drawing convention and do not represent the upper inboard edges of the strakes (which, of course, must have occurred above the rows of rivets). Small shelves along the lines of the rivets were the result of the technique of excavation; it is these which are visible on most of the photographs and not the upper edges of the strakes. For this reason a different interpretation from Angela Evans's asymmetrical strake termination is possible (Evans in *ibid.*:359-60). An alternative solution (Fig. 8.28a) shows that, as on the Graveney ship, the planking can be symmetrical even when the strake fastenings are staggered along the line of the stem. Another similarity between the planking of the Sutton Hoo ship and the Graveney hull is that the garboard strakes are narrower amidships than the other strakes.

Certainly the bearding lines in both the Sutton Hoo and Graveney stems are of the same kind, being of the simple rabbet type. That is to say, there was a continuous groove along each side of the sternpost, into which the ends of the strakes fitted, instead of, for instance, the intermittent notches which occur on some Slavonic stems, or the stepped stems with carved imitation hood-ends, which are found on the Skuldelev ships (Fig. 8.24/4). Olsen and Crumlin-Pedersen considered the simple rabbet type to be obsolete by c. 950, in view of the absence of representative archaeological material when they wrote (Olsen and Crumlin-Pedersen, 1967:166). However it would clearly be a mistake to call the design of the Graveney stem old-fashioned or less efficient, since it is the simple rabbet type which has outlived the stepped alternatives and which is found today on craft both large and small.

#### FRAMES

Parts of nine frames were found in position (or could be put back in position), together with another which had been dislodged by the mechanical excavator (Fig. 1.1.2). None of them was complete, but it was clear from their rebates that they had been constructed in two unequal parts, the scarfs being arranged on alternate sides of the hull. None of the side frames, or futtocks, survived.<sup>13</sup> With the exception of R2 (where a spike may have been used) the rebates are in trenail positions. The frames were heavy in comparison with those on other vessels of this period, and the frames and the spaces between them also fail to fit into the tentative chronological sequence put forward by Olsen and Crumlin-Pedersen (1967:167). The frames are on average 0.5 m apart from centre to centre, giving a space smaller than the Scandinavian

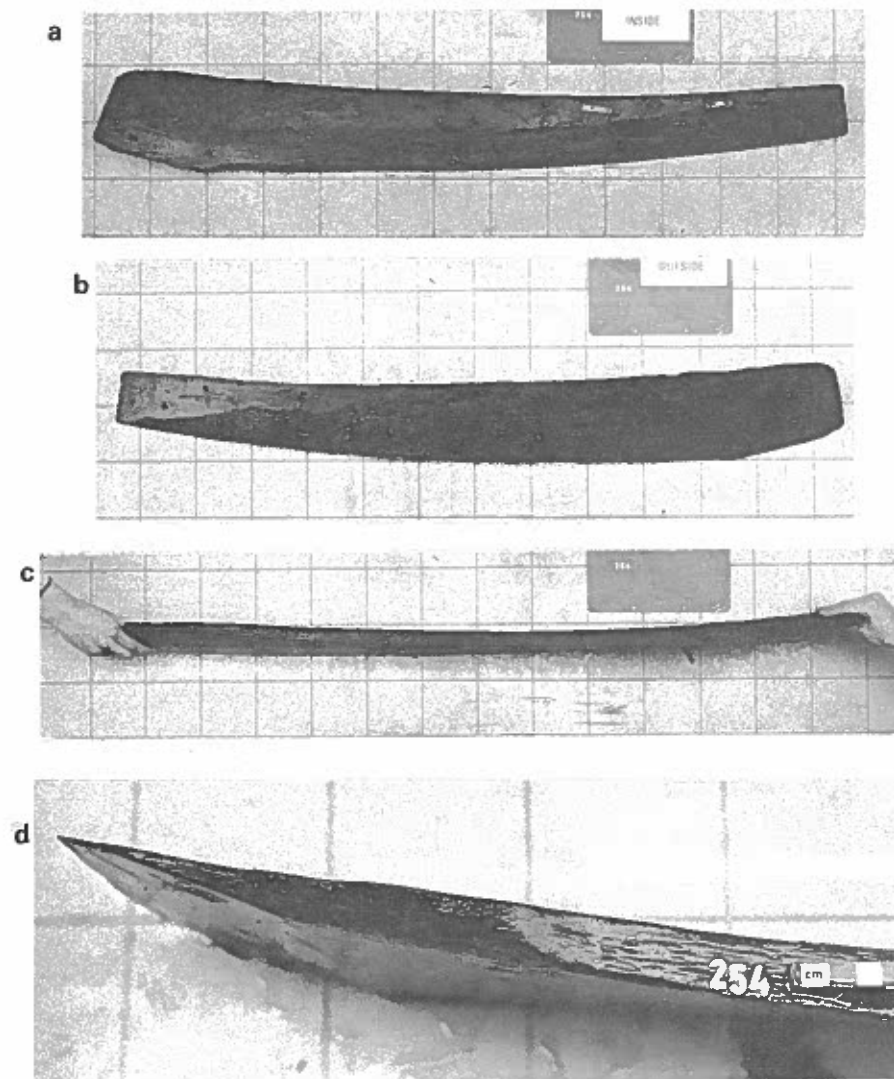


Fig. 8.26 RECORD PHOTOGRAPHS OF GARBOARD HOOD-END PLANK ON 10 CM GRID

- a. Inboard, showing the 'silver grain' and the curve worked on the lower edge of the plank at its junction with the sternpost
  - b. Outboard, showing a large faying surface worked on the aft extremity which is nibbled; the last fastening was secured both to the strake above and the sternpost.
  - c. Profile, showing the twist worked on it
  - d. Profile detail, showing the sharp feather edge of scarf PJ25 and the bevel developing on the edge of the plank
- © National Maritime Museum

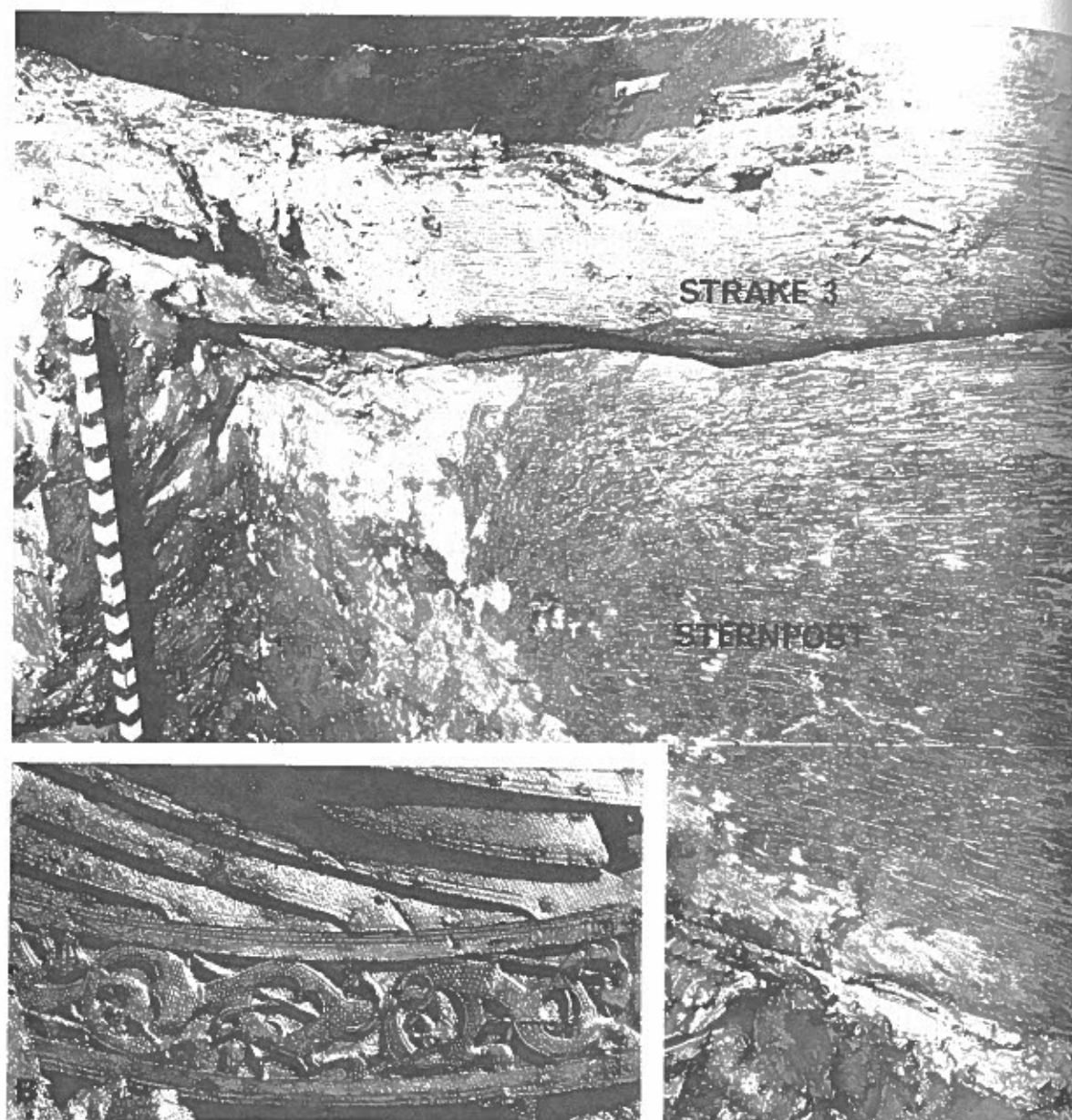


Fig. 8.27 a. External view of the stern of the Graveney ship *in situ*. Scale in cm. (© National Maritime Museum). Compare the curvature of the lower edge of the strake with b.

b. Corresponding hood-end of the Oseberg ship (© Universitetets Oldsaksamling, Oslo)

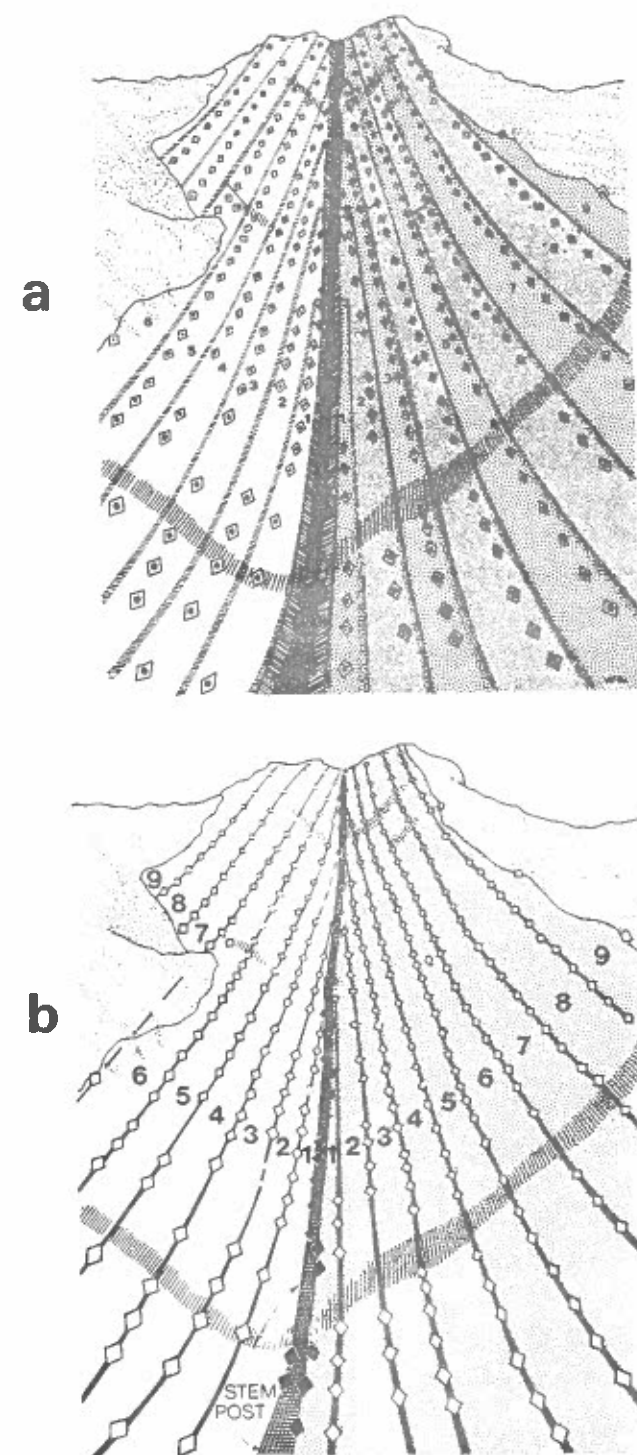


Fig. 8.28 a. The rivet pattern in the bow of the Sutton Hoo ship in terms of clinker construction. Interpretation, based on b, suggests that the hood-ends were worked like those of the Graveney ship (V. H. Fenwick. b. Traced from a photograph taken in 1939. Drawn by E. Eden. © British Museum)

cargo space of 0.7 m (Faeroyvik, 1948:42). They were fashioned from young slow-grown forest trunks (p. 115), and the correct curvature was evidently a main consideration in their selection, for they wind across the hull (Fig. 8.29). Winding heavy frames are found on the 12th-century Q.75 wreck from the Netherlands, which was of mixed carvel and clinker construction (Fig. 8.8b-d) (van der Heide, 1978:fig. 1; Fenwick, 1978a), but are not a feature of the early purely clinker hulls so far found.

Only frame R1 was carefully shaped, or joggled, to fit the shell (Fig. 8.19d; Fig. 3.2.18). It is certain that this frame was removed at some stage in order to repair the keel (p. 221). Frame R2 is slightly joggled; it is probable that this frame too was removed, since the wool-caulked crack runs beneath it (Fig. 8.6c). The joggling was probably worked at the time of this repair in order to reinforce a weakened area. The absence of limber holes supports the view that the joggled frames are secondary; only if all the frames were originallyunjoggled would there have been a free passage for bilge water. It is a mystery why no limber holes were cut in frames R1 and 2 when they were refitted; the thurrock (bilge) would indeed have 'stynketh right fowle', to use a medieval phrase. The Kvalsund ship has joggled fore and aft frames which seem to be part of the original design, but these are in the nature of bulkheads at the extremities (Shetelig and Johannessen, 1929).

#### Method of fastening

A fairly consistent pattern of trenails is used to secure the frames to the clinker shell. According to this, the frames are fastened to alternate strakes, but not to the keel or garboards. The avoidance of garboards is again at variance with widespread practice (reflected e.g. in Skuldelev 1, 5 and 6, Eltang, Galtabäck, Kalmar IV, Falsterbo trader, Ralswick, Szczecin, and Charbrow I and III, Fig. 8.30 (Ellmers, 1972a). It is thus unfortunate that the pattern of trenails used at Gredstedbro and Sutton Hoo cannot be determined. The massiveness of the Graveney frames seems to have made it difficult to bore holes for the trenails, with the result that departures from the pattern do occur, mainly on the starboard side. Frame R9 is not fastened to the shell below the fourth and fifth strakes respectively, and trenail holes in the fourth and fifth strakes respectively aft of R1 may show that there was a similarly fastened frame there. The single frame retrieved from the Gredstedbro ship (Fig. 8.3e) is trenailed in this lop-sided manner and is also not fastened to the lowest strakes.

There is consistent evidence for a (missing) stringer fitting in rabbets on every frame, to which it was trenailed through strake 8. This strake was slightly thicker than the others. A tendency for the hull to flatten out has already been noted (p. 201), and some allowance should be made for loss of deadrise, or curvature, in the frames.<sup>14</sup> This has been very conservatively estimated in the reconstruction and the sides of the hull may have flared less (p. 275). This factor should be borne in mind together with the likelihood that the stringer supported cross-beams and a deck, or partial deck, at the level of strake 9. If the ship had provision for oars, a further three or four strakes and corresponding framing were needed above this for rowlocks, or oar-ports. The difficulty of determining the extent of the upper works when no fragments survive is illustrated by Johannessen and Åkerlund's

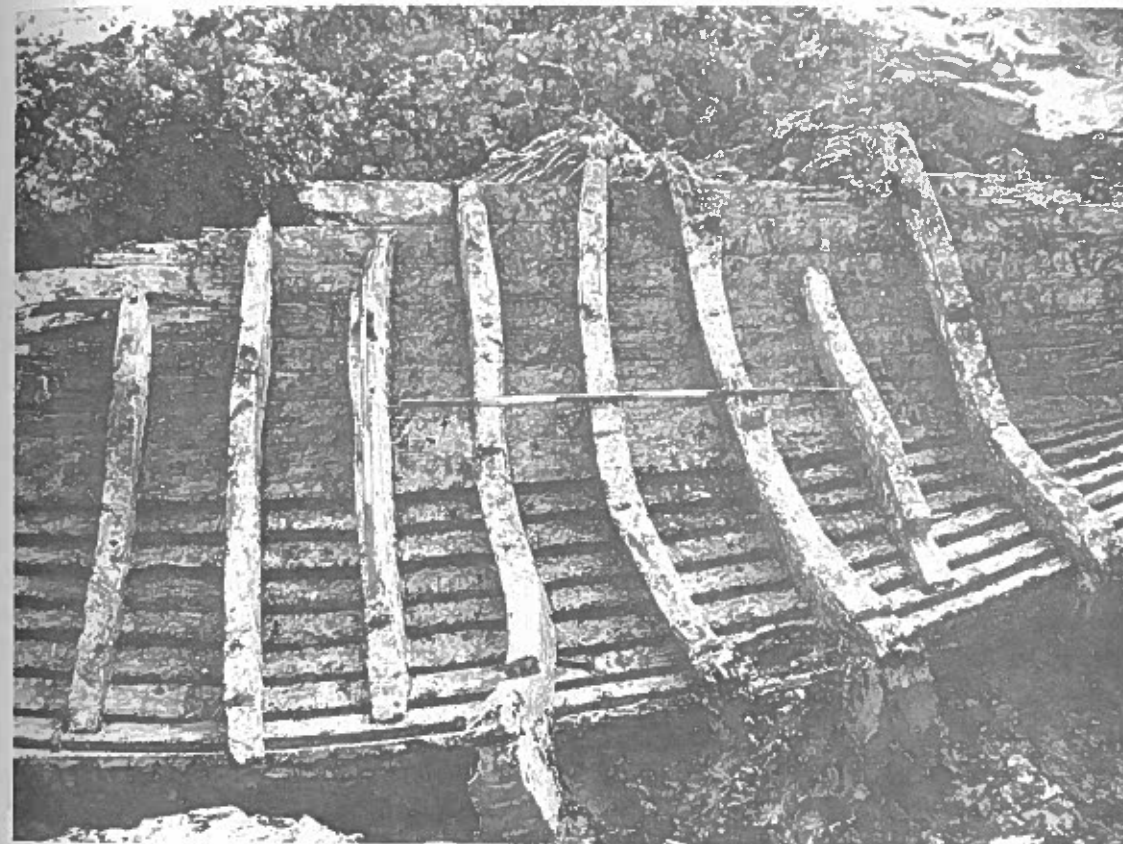


Fig. 8.29

#### SHIP IN SITU

View from the port side on October 4th, 1970, showing a white deposit covering the hull (before being washed and sprayed with water); the heavy frames wind across the hull; beyond the starboard, are the brushwood platform and the remains of the timber standing (top r.) Scale in ft.

© Cecil Hogarth

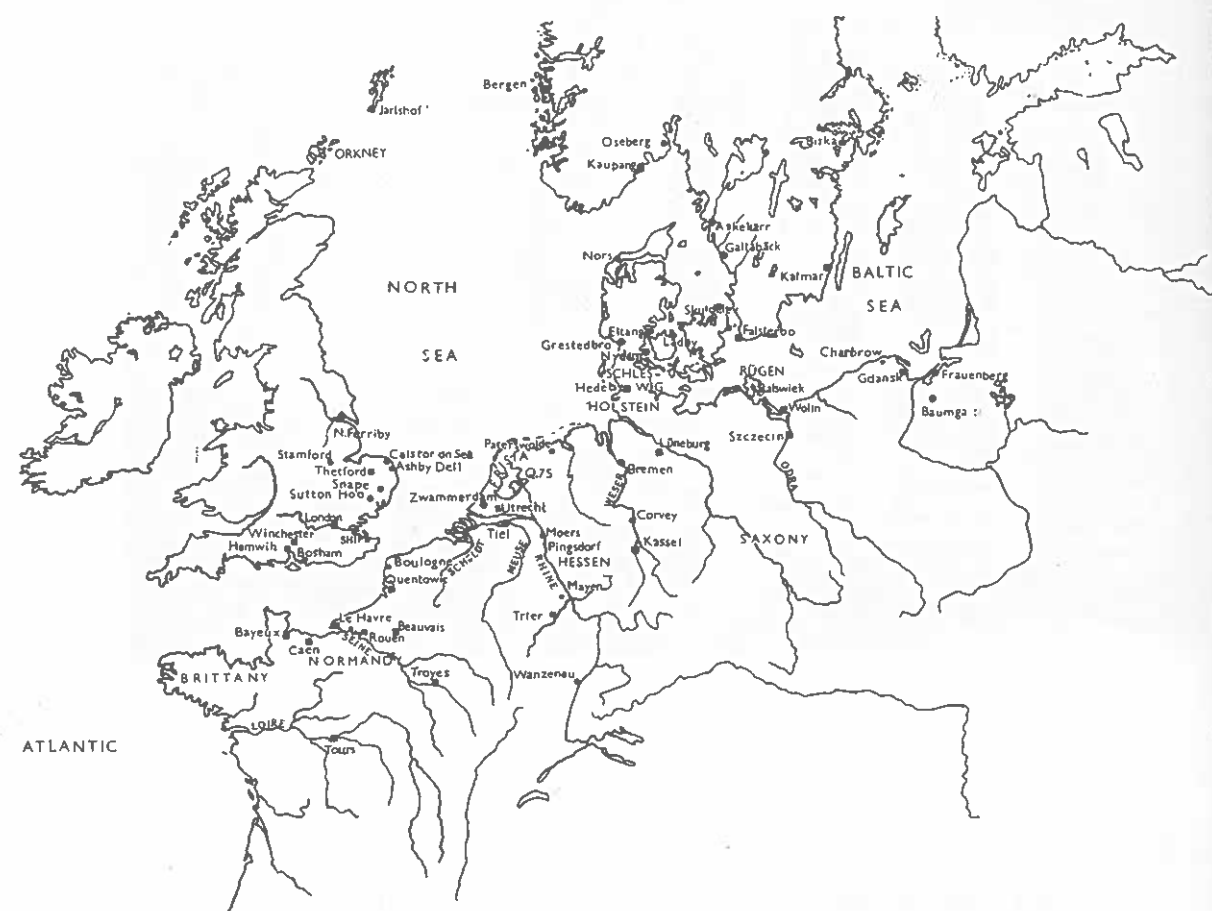


Fig. 8.30 MAP SHOWING SITES MENTIONED IN TEXT  
© V. H. Fenwick

very different reconstructions of the 12th-century merchantman from Galtabäck, a comparable portion of which was found (Ellmers, 1972a:figs. 19-21).

#### Trenails

**Trenails.** The trenails used to fasten the frames to the shell were carefully shaped from willow stems, which had a diameter about four times that of the finished trenails. Not all the trenails were identically tooled (Figs. 8.20a-c, 31). The shanks were trimmed in a series of facets, which average 5 mm wide, but some are as much as 10 mm, while a large number are only 3 mm. The heads are expanded and many are also carefully faceted. They projected about 12 to 25 mm above the surface of the planking and so must have made the positions of the frames very obvious when viewed from alongside (Fig. 8.31; Fig. 10.1.1), particularly as there is evidence that their heads were tarred.<sup>15</sup> Lines of knobs apparently on frame-stations occur in some early representations of ships, e.g. on the sword pommel from Sibertswold (Fig. 8.3f-h), the second seal of Winchelsea (Fig. 8.25/4), a late 12th-century bestiary (Fig. 8.25/3), and the second seal of Faversham (Fig. 8.32c); they perhaps depict this type of trenail. Skuldelev 2 and the Polish finds had trenails of this type (Olsen and Crumlin-Pedersen, 1967:115; Smolarek, 1969:fig. 67). The technique of manufacture is discussed on p. 185. Willow was the preferred wood, no doubt because of that quality of resilience which makes it ideal for cricket bats.

The inboard head of the trenail was trimmed flush with the frame and secured with a long oak wedge (Fig. 8.20b). Some of the wedges were formed from a radial chip; in others the grain ran obliquely across the axis of the wedge. A grommet of wool had been twisted round the neck of a few trenails (Fig. 8.20a-b), perhaps during the course of repair.

The trenailing of frames is one of the most obvious characteristics of the S. Scandinavian or Saxon school of ship-building (Fenwick, 1978a) and occurs on the 7th-century warships from Sutton Hoo and Gredstedbro and on all the ships found at Skuldelev. It is tempting to see a representation of trenails in the concentric circles on the sword pommel from Sibertswold (Fig. 3f-h). However, by the Viking period, it is unlikely that this technique was confined to Slavonic and S. Scandinavian craft; it may have been used widely, at least for merchantmen.

In two places the pattern of trenails is broken by fastenings through the garboards. Both these exceptions are connected with rebates, which had been roughly cut in the upper surfaces of the three frames amidships. These frames had clearly been damaged in the past (Fig. 8.34a); there is a spiked split on frame R7 (Fig. 8.33a), and the rebates are each filled with a saddle of very poor workmanship. One saddle, Gr205, is old and worn on its (protected) under side (Fig. 8.33c), while even the bark still adheres to Gr230 (Fig. 8.33b). They were most ineptly trenailed in position. It is quite clear that these three saddles are secondary.

#### Purpose of rebates amidships

Objections to the theory advanced in 1971 and 1972 (that the ship was converted from sail and the rebates housing its mast-step made good; Evans and Fenwick, 1971:93; Fenwick, 1972b:12) centred on the problem of the uneven disposition of these features on each side of the keel, together with a lack of

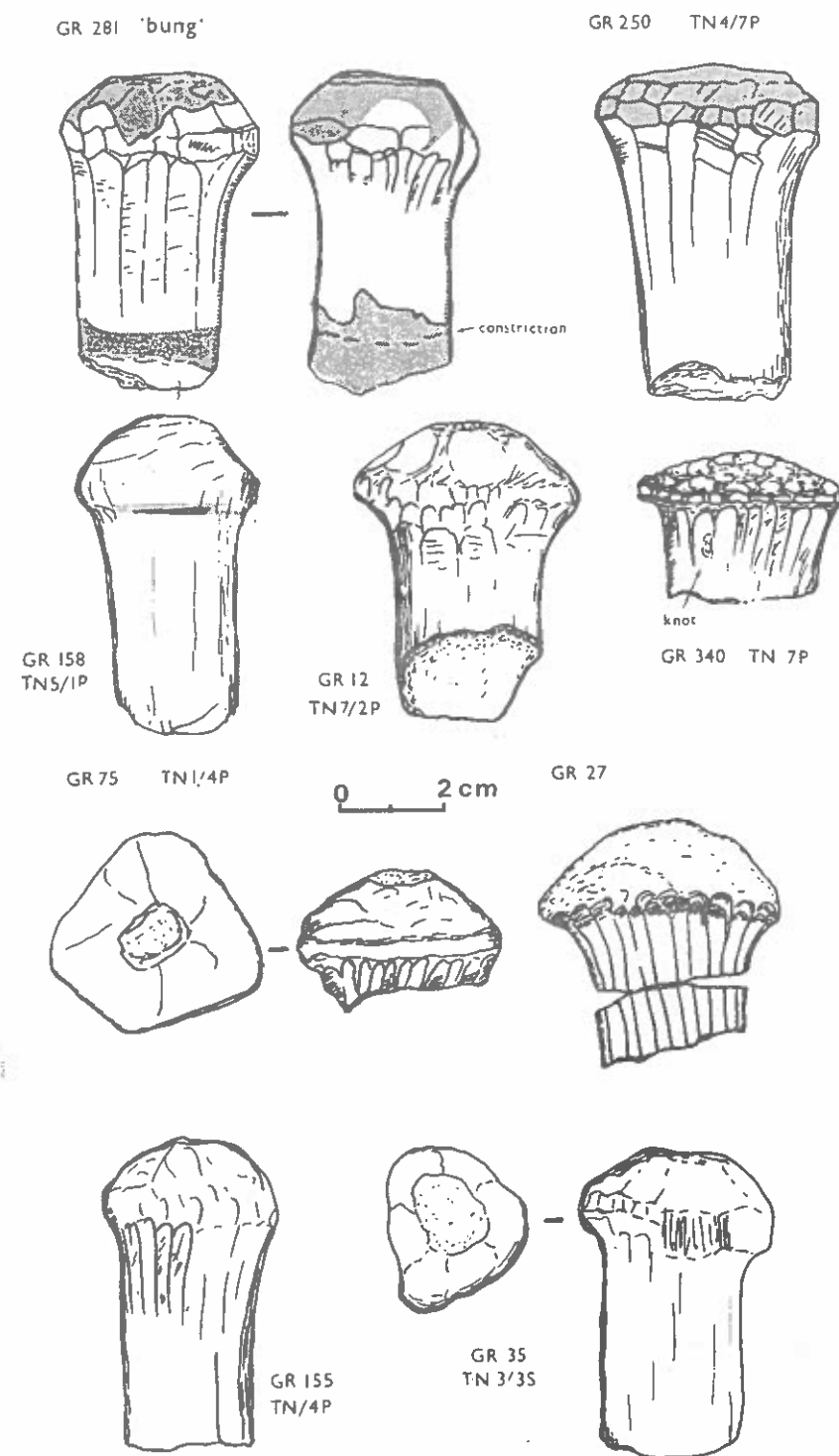


Fig. 8.31

### TRENAILS

Severed heads of trenails projecting on the outside of the ship; shading represents tarring visible on the specimens which were not impregnated with PEG. Scale 1:2 (TN4/7P = fourth trenail on seventh strake port etc.)

© National Maritime Museum

Fig. 8.32

### NORTH KENTISH SHIPS ON SEALS

- 1st seal of Fordwich, probably early 12th-century, showing the 'town bote', a clinker-built sailing barge, necessarily of shallow draught to negotiate the R. Stour. Diam. 50 mm  
© Trustees of British Library, cast LXV, 67
- 1st seal of Faversham of c. 1200, showing a locally built cargo-boat with a tall mast and heavily raking stems reminiscent of the Graveney ship. Diam. 65 mm  
Trustees of British Library, cast LXV, 55
- 2nd seal of Faversham showing a 13th to 14th-century war-ship from the Faversham yard. Note the raking stems which sweep clear of the rabbets and the heads of the trenails in alternating pattern as on the Graveney ship  
© National Maritime Museum, cast K.17



confidence in the sailing qualities of the hull. Dr Corlett's analysis (chap. 10.2) will resolve doubts about the latter, while other finds of lop-sided mast-support systems, for instance, Blackfriars I and the late medieval wreck I ENZ III from the Zuider Zee, mean that this reason alone is not sufficient to discount a mast-step in the Graveney ship.<sup>16</sup>

It may, however, be unnecessary to postulate any asymmetrical mast-support. In view of the physical condition of the three frames in the vicinity of the rebates (Fig. 8.34a), one may argue that a symmetrical mast-step once fitted here, but was removed after the hull had been seriously damaged. The repairer removed the badly damaged surrounding wood, spiked the top of frame R7, and restored the upper profiles of the frames with saddles. The addition of two central trenails (the hole on frame R5 was empty when found) was hardly necessary to hold the little saddles in place; it is therefore likely that the repairer was trying to bore through the saddles into two holes which already existed on those frames. This he signally failed to do, as the double trenail holes in the top of the frames testify.

A more important objection to the mast-step theory is that the comparative material from northern Europe does not provide examples either of frames which are rebated for a mast-step, or of mast-steps trenailed directly to frames. However since there are other unparalleled features in the Graveney hull, it would be unwise at present to discount such a design in the absence of comparative material from a large area of northern Europe, particularly as there is no evidence on this point from Gredstedbro and Sutton Hoo. Certainly some Mediterranean mortise-and-tenon hulls had rebated floor timbers, e.g. Chrétienne A at Anthéor (Dumas, 1964:124, fig. 4) and Chrétienne C (Joncheray, 1974), while mast-steps actually integral with the frames are found in Gallo-Roman craft, e.g. Zwammerdam IV (de Weerd, 1977; Fenwick, 1978a) and Blackfriars I (Marsden, 1967). It is in NW. Europe that the clinker boat-building tradition is most likely to have been modified as a result of contact with Mediterranean and Celtic influences.

There seem to be two obvious reasons why a design using rebated frames might have been chosen. The first, suggested by Dr Ellmers, is that supporting knees wedged in them would have prevented any lateral movement of the mast-step. Such 'keelson knees' were used on Skuldelev 3 (Olsen and Crumlin-Pedersen, 1967:129), but they were spiked to the tops of the frames and not inset. The second reason is that a mast-step, moulded to provide enough wood above the massive frames and yet make contact with the keel, would have to be very bulky indeed, unless the frames were rebated to accommodate it. This seems to be the reason for the rebated frames on the late medieval wreck, Kalmar V (Fig. 8.34b), which accommodated a keelson.

The mast-step solution has been developed by Cdr McKee in his drawings for the replica and extended to rest on frames R4 and 8 (p. 300; Fig. 9.1.11). It is possible that slight marks on these two frames amidships are the result of pressure from a mast-support system. Whatever the solution to the puzzle of the rebates, it seems abundantly clear that the function of the makeshift saddles can only have been to make good the midships frames and provide a smooth upper profile on which to dispose cargo.

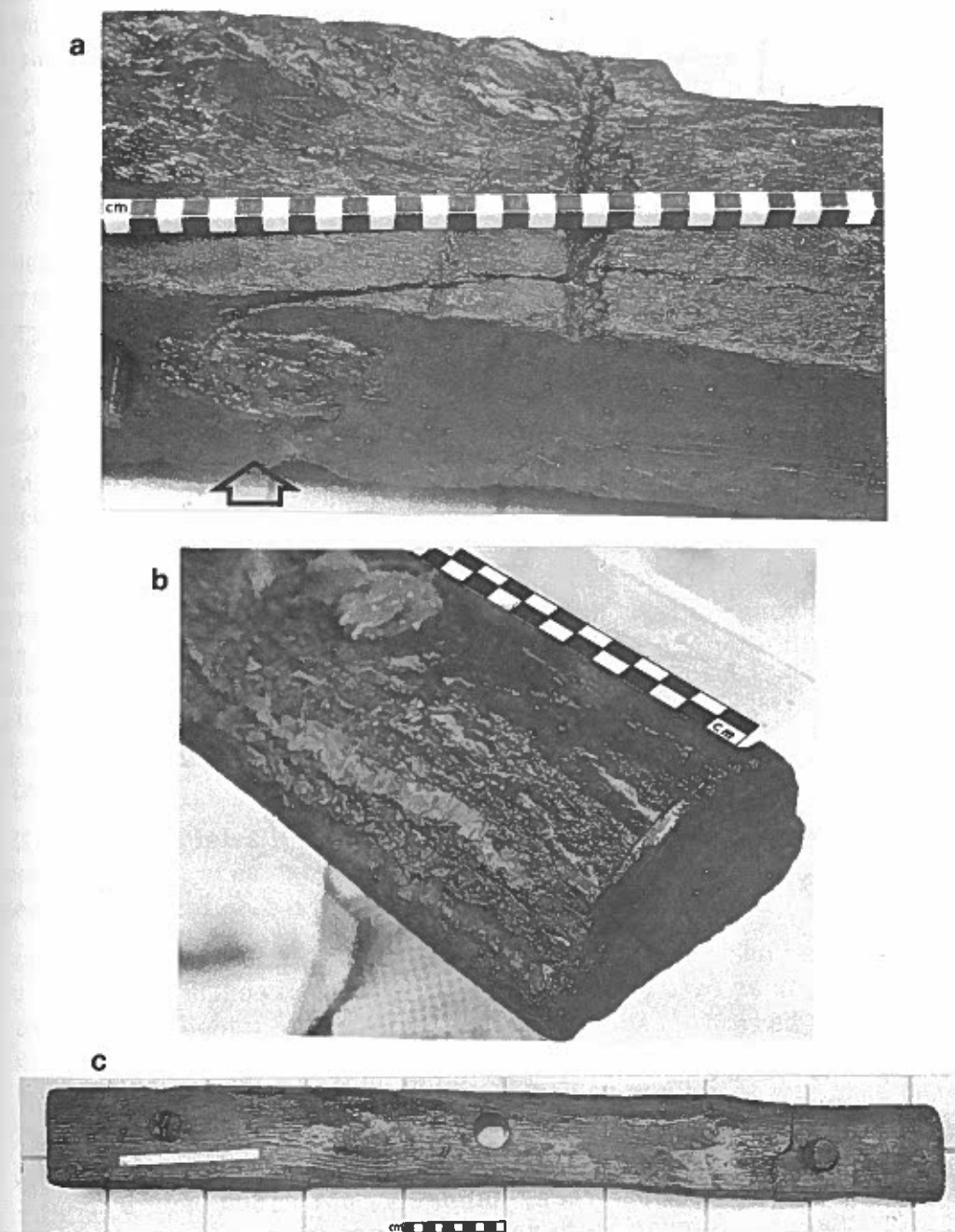


Fig. 8.33

#### REPAIRS TO MIDSHIP FRAMES

- a. Frame R7 lying on its side showing a large crack sealed by an iron nail (arrowed) (the gouge beneath the scale is modern)
  - b. Saddle filling the seating on frame R7 of very poor workmanship with the bark left on. Gr230
  - c. Saddle on frame R5 made from an old piece of wood; the (protected) under surface is very worn. Gr205
- © National Maritime Museum

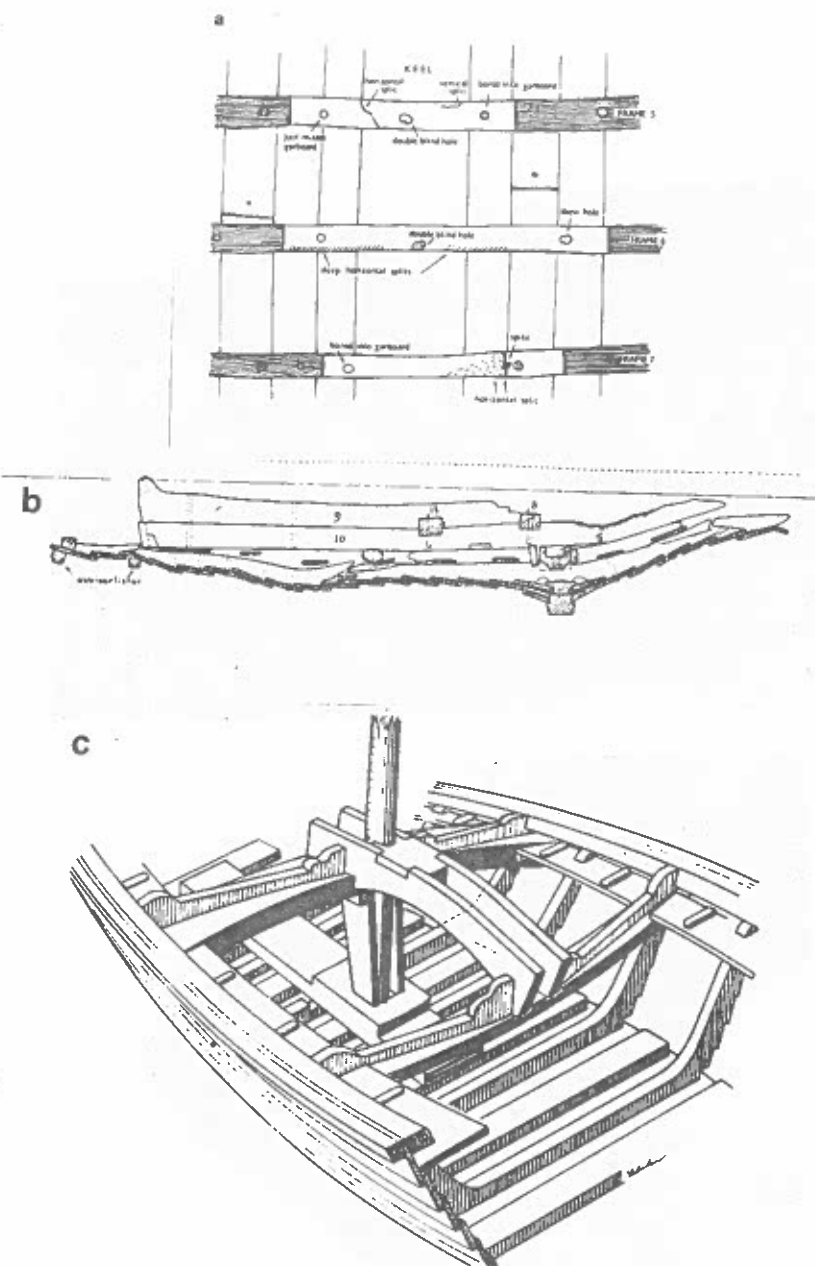


Fig. 8.34 a. Sketch to elucidate damage to the midships frames below the saddles of the Graveney ship  
© Author

b. Cross-section of wreck, Kalmar V, of c. 1500 from Kalmar, Sweden, with rebated frames to accommodate a keelson; above it are the collapsed remains of the sailing thwart and through beam.  
After Åkerlund, 1951

c. Model, dated 1710, of a Lüneburg salt-carrier showing the slab keelson to support the retractable mast, with rebated frames to accommodate a keelson. It was designed to operate in similar conditions to the Graveney ship, but is of 'mixed car carvel and clinker' construction like Q75 (Fig. 8.8b-d) and the Bremen cog.  
After Salemke, 1971

## CONCLUSION

The foregoing analysis of the surviving elements of the ship from Graveney has shown that, although the place of its construction cannot be pin-pointed at present, the balance of internal evidence supports a home W. of the Baltic and S. of Norway and Sweden. Both dendrochronological and typological considerations seem to eliminate Germany or central Europe and a place of origin W. of the Rhine should be sought. The Frisian region can be discounted in view of the evidence for boat-building traditions of quite a different type, summarized by Crumlin-Pedersen (1972; 196-7), although there are features in the hull which may reflect Frisian influence. In northern France there is no evidence at present for a clinker boat-building tradition before the Viking settlement of Normandy. However, in view of the Frankish origin of many of the 5th-century invaders of parts of Kent, Sussex, the Isle of Wight, Surrey and the upper Thames (Evison, 1965), it is likely that there was considerable interaction at this time between the boat-builders of southern England and those of northern France living between the R. Meuse and the R. Seine.

In Britain on the other hand there is the clearest evidence for a clinker boat-building tradition established centuries before the Viking invasions. During these centuries this, originally S. Scandinavian, tradition may be expected to have been influenced by local conditions and indigenous boat-building. In particular the Celtic tradition may have contributed a legacy of heavier framed merchantmen (evinced by Blackfriars I). Equally Celtic is the combination of a keel-less bottom and a sail; this was observed by Caesar in Venetic Brittany (*de bello Gallico*:III,14). As we have seen, features of the Graveney hull imply that it was the product of a boat-building tradition modified in this way.

If the British Isles provide the most likely country of origin for the Graveney ship, the area can be further reduced to southern and eastern England. A specifically local origin is based:

1. on probability. She was berthed and not wrecked. She was repaired in a way which makes it unlikely that she had been used as anything more than a local lighter in the latter part of her life. Worked fragments of the woods used in her construction, oak and willow, were found in the mud around her and wool of the same type as her luting was used to repair her (pp. 145, 153-4).
2. on suitability. Her hull was clearly designed to carry a heavy cargo with minimum draught and thus to operate in muddy creeks such as that in which she was found. Her flattish shape offered little resistance to the strong currents of the Thames estuary and the N. Kent coast and would have been an advantage when she tacked across fast-running water.<sup>17</sup>
3. on hull form. The few earlier finds from SE. England, as we have seen, share details of construction with the Graveney ship and have the marked raking stems which are characteristic of her hull. The only comparable raking stems from elsewhere are much earlier and support the idea that this design may have originated in Jutland (Figs. 8.3d, 7b-c).
4. on the technique of working the hood-ends. The hood-ends have a stylistic affinity with the Oseberg ship (Fig. 8.27), but, as long as there are so

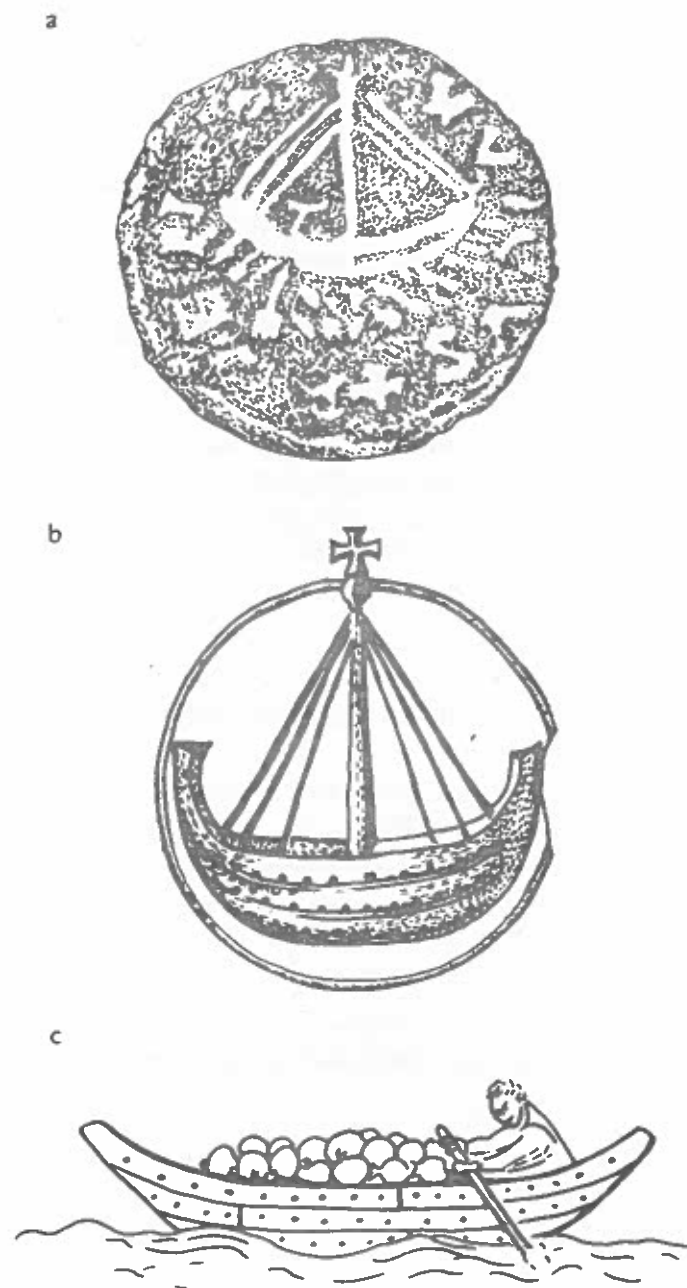


Fig. 8.35

# CARGO-BOATS IN NORTHERN FRANCE

- a. Trade-ship on coin of Quentowic minted between 814 and 840  
After Bruce-Mitford, 1975
- b. Beamy cargo-boat of c. 1200 chosen as the emblem of the guild of 'Marchands de L'Eau', Paris; the massive mast is secured by many stays, by which it would have sailed up the R. Seine  
© Author
- c. Lighter with raking stems and a cargo of melons on the R. Seine in the 14th century  
Drawing: Author, after Vie de St. Denis, MS.fr.2092, f.18v

few and such ill-distributed ship-finds for this period the geographical significance of this fact cannot be assessed. It is possible that this technique of finishing hood-ends originated in southern Norway; equally it may have evolved in Anglo-Saxon England. If once widely practised in Norway, it seems to have given way to alternative methods of employing stepped stems or an angular rabbet line (Fig. 8.24/1-3). On the other hand the invention, wherever it was made, continued to be practised in England, certainly until the 13th century. The southern English manuscript evidence for hooked hood-ends (Fig. 8.25/1-3) is perhaps the strongest argument in favour of an English rather than a continental home for the Graveney ship.

If the balance of evidence at present favours a place of origin in southern or eastern England in the first half of the 10th century, the remains of the Graveney structure seem, generally speaking, to fit into a boat-building tradition represented on the seals of Winchelsea, Faversham (Figs. 8.25/4, 32b-c) and Dover, while the way her planks are worked is detailed on a number of southern English manuscripts. More nearly contemporary are the ships depicted on the Caedmon manuscript and the Bayeux Tapestry (Fig. 8.4a-e), and these sources, together with the 'town botes' on the first seals of neighbouring Faversham and Fordwich (Fig. 8.32a-b) provide a basis for the following assumptions about the missing part of her hull and the method of propulsion:

1. The ship probably had a simple mast-step with provision for lowering it forward (Fig. 8.25/3), as is shown on the Bayeux Tapestry, ship 31. It may have extended over several frames, or have been inset in the three midships frames, perhaps resembling the simple rectangular plank of the 18th-century model of a little salt-trader which worked up the R. Illmenau to Lüneberg (Fig. 8.34c). A single mast was probably set about 0.3 m forward of amidships. The absence of a projecting keel would not have precluded a tall mast; both the Illmenau salt-trader (Salemke, 1971:9), the Humber keel and the 'hoy' on the first seal of Faversham (Fig. 8.32b) have masts taller than the length of their keels.

2. The mast will have been well stayed, with more stays aft than forward. The single sail would have been a square sail and was possibly made of wool. This is the material which was freely available for luting and caulking the hull, and wool sails were used on boats in the Graveney locality as late as 1474 (Woodruff, 1895:33). There would have been a parrel and the sail would have been furled below the yard. A bonnet is extremely unlikely; there may have been reefs near the foot of the sail, but the yard was more probably lowered (Figs. 8.25/3, 35a-b; Fig. 7.3).

3. The gunwales may have had a break amidships in the hold area. The 'English' ships on the Bayeux Tapestry are consistently depicted in this way (e.g. Fig. 7.3). A continuous run of oar-ports is unlikely anyway; oars, or sweeps, were surely a means of propulsion always secondary to that of wind or current for a heavy cargo-boat. The ship on the first seal of Faversham (Fig. 8.32b) seems to have thole-pins along its gunwales, as well as a sail.

4. A fixed stern rudder cannot be excluded despite the rake of the stern-post. No example as early as this is known, but the Zedelgem font (Fig. 8.12b)

shows that rudders were fitted to curving Frisian hulls by at least the 12th century, while the gudgeon found on the IJsselmeerpolder Q.75 (Fig. 8.8b, d) is evidence for its use with hulls of 'cog type' at about this time. Experiments with steering oars lashed to the stern may have been taking place much earlier, perhaps in estuarine conditions where a stern sweep could be used to advantage.

More probably the rudder was fixed to the starboard quarter; this is the steering technique shown on the Bayeux Tapestry and on English seals and manuscripts for the next two centuries (Figs. 8.4k-l, 9b, 25/1a, 32b-c). The type chosen will probably have had a flattened lower profile, because shallow draught was clearly a main consideration in the hull design. A simple staple mechanism (such as is lovingly depicted on Fig. 8.25/1a) may have attached it to the planking; the framing was certainly stout enough for no extra internal reinforcement to have been needed. On the other hand a quarter rudder-port should not be ruled out. No examples have so far been found, but representations occur over a long period: the 7th-century strap-end (Fig. 8.2a); coins of Quentovic and Dorestad (Fig. 8.35a); and the copy of the Utrecht Psalter made in Canterbury in 1150 (Fig. 8.10b). Indeed, one seems to be shown on the first seal of Faversham (Fig. 8.32b); the proximity of this town to Graveney makes the evidence of its seals of particular importance when the ship is viewed as possibly the product of a local yard.

5. The original extent and termination of the stem and sternpost are the most vexing problems of all, for the reconstructed continuation of the missing planking depends on resolving the way in which the surviving stem could have continued upwards. It is difficult to believe that the faint echo of the hooked hood-end found in the garboard (Fig. 8.26), which is rather more developed by strake 3 (Fig. 8.27), should not have progressed up the sternpost. The design enables a shipwright to resolve the problem of attaching the ends of his planks to a slightly raking stem, and the manuscripts (Fig. 8.25/1-3) show a variety of ways in which this could be achieved.

It is certain that a stem raking as strongly as that of the Graveney ship would have rendered this solution even more attractive for the lower strakes. Higher up, however, the rake would rapidly have made for extremely large hooked hood-ends—difficult to work and wasteful of timber. Representations suggest ways in which the upper portions of the stems and the sheer strake were modified to avoid these difficulties; e.g. the 'English' ship, no. 6 (Fig. 8.4h-i), on the Bayeux Tapestry seems to have had the extension of its stem scarfed inboard of the bearding line, and Christensen's solutions to the problem of the stems of the Gokstad ship use this principle (Fig. 8.24/3). Another and apparently very popular solution was to terminate the upper strakes horizontally, scarfing them into a strong stempost with mouldings. (Fig. 8.4f-g, j-k). Yet another solution seems to have involved a modification in the run of the sheer strakes ('Norman' ship, no. 30, on Bayeux Tapestry; ark on Caedmon manuscript: Fig. 8.4d, 1; Oseberg graffito: Fig. 8.15c).

It would be attractive to superimpose decorative terminals on the Graveney stems. Actual examples of carved wooden posts of the Migration period have been found in Belgium (Fig. 8.3a-b), while the Utrecht Psalter (of which Fig. 8.10b is a copy), a gaming piece from Mainz (Fig. 8.3c) and a carved wooden post



Fig. 8.36

#### GREAT BENFLEET, ESSEX

An informal approach to boarding and landing and the intimate relationship between the settlement and the stream are well shown. The scene it depicts has changed very little in a thousand years.

Drawing: C. W. Wyllie (from Benham, 1973, published by Harrap)

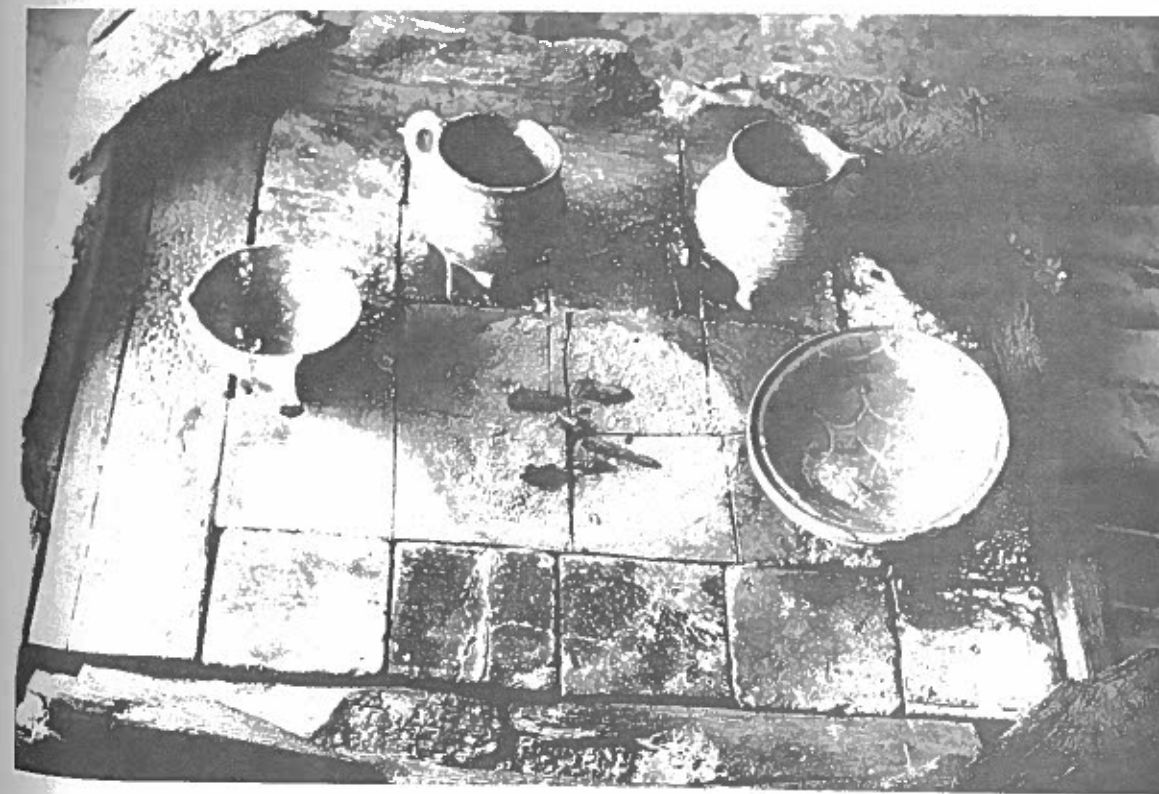


Fig. 8.37 Pottery and hearth of old tiles encased in wood; from a 16th-century Dutch fishing vessel wrecked in the Zuider Zee  
© Rijksdienst voor de IJsselmeerpolders

from Zele (Fig. 8.4m) suggest that Rhenish river-craft may have been embellished in this way in the 9th century. On the other hand the scanty evidence for shipping on the Seine (Fig. 8.35b-c) suggests that here was a ship-building tradition in which they were not used. This seems to be true, too, of N. Kent (Fig. 8.32a-c). No mouldings or decoration were found on any of the wood-work recovered from the Graveney ship; this fact, combined with her apparently humble role, makes carved stemheads inappropriate. Her stemposts perhaps resembled those depicted on cross-Channel craft in the early 13th century (Fig. 8.25/1-3). Both the ships and the boat have planking which is worked like that from Graveney and, from what is known of the length of time in which a boat-type may remain unchanged, it is likely that the type of vessel depicted had been for centuries the general purpose ferry used to transport kings and bishops, horses and baggage across the English Channel and, with its shallow draught, to bring them close inshore.

The overall length of about 14 m of the Graveney ship puts her into the category of average size sailed merchant vessels in the period before 1250.

TABLE OF ROUGHLY-CONTEMPORARY SAILED NON-WARSHIPS<sup>18</sup>

| Cat. No. | Name        | Length (in metres) | Ratio of length to breadth | Draught (in metres) | Capacity (in tons) | Date        |
|----------|-------------|--------------------|----------------------------|---------------------|--------------------|-------------|
| 9        | Graveney    | 14                 | 4.6                        | 0.65                | +7                 | c 930       |
| 102      | Åskeklarr   | 16?                | 4.3                        | ?                   | ?                  | c 840       |
| 75a      | Bagart      | 11.9               | 4.6                        | 0.5                 | 3½?                | 10 cent.?   |
| 80a      | Charbrow I  | 13.2               | 4                          | ?                   | 6?                 | 11-12 cent. |
| 136      | Eltang      | 17.5               | 4.4                        | ?                   | 19?                | 12 cent.?   |
| 106g     | Falsterbo   | 13.5               | 3                          | ?                   | 40?                | 12 cent.?   |
| 109a     | Galtabäck   | 14                 | 3.5                        | ?                   | 15?                | c 1080      |
| 114      | Kalmar I    | 11.2               | 2.4                        | ?                   | 20?                | 13 cent.    |
| 89       | Czarnowsko  | 13.8               | 4.1                        | 0.5                 | 5                  | 12 cent.?   |
| 72a      | Ralswiek    | 13-14              | 3.9-4.1                    | ?                   | ?                  | 10 cent.    |
| 142a     | Skuldelev I | 16.5               | 3.5                        | 1.5                 | 30?                | c 990       |
| 142c     | Skuldelev 3 | 13.3               | 4.2                        | 1                   | 9?                 | c 990       |

The Graveney vessel was a sea-going trading ship—a scip rather than a båt to her contemporaries.<sup>19</sup> If she seems small, it must be remembered that, before the coming of the railways and the internal combustion engine, bulky goods were carried by creaking wagon or barge. Sailing barges which could work up every little creek in Essex or Suffolk (Fig. 8.36) also took freights up the Rhine (so regularly at one time that their captains had their own room in the office at Düsseldorf; Benham, 1973:64), and all the year round ketch-rigged sailing barges carried heavy cargoes of stone and tiles, bricks and flint across the Channel with very little freeboard.<sup>20</sup> 'Every farm within reach of the water used her; growing London swallowed up every freight she could carry, and called for more; she served the old world because there was no other means of communication or conveyance to compete with her.' (Benham, 1973:56.)

If the role of the coaster in the 19th century tends to be overlooked, it is easily ignored altogether in the earlier period. Medieval trade depended on ships, not the grand armed ships depicted on English coins and seals, but work-a-day coasters too ordinary to be painted or written about. In large numbers they plied from port to port and could put in at places where there were no harbour installations. As Laird Clowes (1932:49) observed: 'Such vessels must have been of the greatest importance in the life of the people, and unless we can obtain some idea of their structure we must miss an important side of medieval life.'

## NOTES

1. 'At the east end of the ship was an iron band marking the extremity of the vessel'; Brown in Bruce-Mitford, 1974:151.
2. It is possible that a certain amount of flattening of the keel took place during excavation, since the excavators principally stood on this member.
3. Two plugged holes, 19 mm in diameter, are visible in the dug-out base, approximately 114 mm aft of frame R4 and 0.35 m aft of frame R7. They are not shown by Wilson, 1966:fig. 30. The forefoot of the vessel has a transverse hole, presumably for pulling her out of the water, and this is perhaps what the holes in the Graveney sternpost were used for (p. 269).
4. The drainage channels on the Seasalter Level gradually silt up and require clearing from time to time. It was perhaps in the course of a fairly recent recut, the upcast of which was visible in the freshly cut section, that the forepart of the vessel was destroyed.
5. The larger number of stays at the raking end again suggest that this is the stern. However it is just possible that a 'bugruder' worked through an oar-port is represented and not a quarter rudder. Both are shown on beamy asymmetrical hulls in the Utrecht Psalter (Fig. 8.10b). Undoubted bows which are higher than the stern are represented on Fig. 8.41, 9c).
6. Norman door at Staplehurst: a detailed study with arguments for an earlier date is in preparation by Dr H. Vierck and the author. Deal graffiti: among H. H. Brindley's papers in the National Maritime Museum are drawings, made in 1931, and notes on some ship graffiti on two of the early Norman pillars in Upper Deal Church published in 1934 (Brindley). In addition there are tracings of the ships by Francis Turner. The ships depicted have steering oars and single square sails; the clearest is reproduced as Fig. 8.10a.
7. Although bung-holes are generally assumed to occur aft—under the helmsman's eye—the practice is not consistent and of course depends on whether the vessel is habitually beached bow or stern first. Out of four Skuldelev wrecks, for instance, two had the bung-hole in the starboard garboard forward, one in the port garboard forward and one in the port garboard aft (Olsen and Crumlin-Pedersen, 1967).

8. Remains of what may be an intrusive stick are visible in Fig. 1.1.3. Alder is an unsuitable wood for rope; Hvass, 1960, does not mention its use in this way. (I am indebted to Mrs Gay Wilson for this reference.)
9. Teredo was found in the boat of the Roman period from Blackfriars, thought to be a locally built coastal vessel (Marsden, 1967:38). It was rife in the Mediterranean in classical times, but opinions differ as to its prevalence in northern Europe before there was regular traffic to tropical waters. The evidence for a warmer climate in Roman Britain should, however, be noted (Frere, 1967:293). The nail-studded shells of medieval wrecks from the Zuider Zee show that, before the advent of copper-bottoming (attributed to Piet Heyn: Harland, 1967), it was evidently a menace. No doubt a bigger and more voracious variety was brought home from the tropics. It cannot survive in waters with a low salinity, such as the Baltic or the Humber estuary.
10. An intact wooden shell acts as an underground water-catchment area until the wood decomposes. As a result the corrosion of ironwork in a deliberately buried hull may resemble that found in a wreck site under water. In the decomposition process grains of sand and pebble are cemented together to form concretions, while inside a shell of iron oxide there is a cavity in which powdery fragments of iron oxide remain (Katsev and van Doorninck, 1966). This phenomenon occurred at Snape (Bruce-Mitford, 1974:pl. 24, a-b, k-m), Sutton Hoo, Mound 2 (Bruce-Mitford, 1964:fig. 10, f, which shows a bucket foot incorrectly reconstructed as hollow on the evidence of radiographs), and Mound 1 (Bruce-Mitford, 1975:figs. 277-8).
11. The Blackfriars I frame-fastening technique, as shown by Marsden, 1967:fig. 12, would have involved boring and plugging a frame, and then locating the plugged holes with long iron spikes driven first through the planking.
12. Larger diameters do occur, but a tree of 1.22 to 1.83 m diameter (given as an average tree in McGrail, 1974:51) will probably be hollow, having dropped one or more of its heavy branches during the course of its life, whereupon rot usually sets in and renders it useless for conversion. (I am indebted to Dr Fletcher for this information.)
13. The dislodged fragments, Gr62 and 303, seem to represent the damaged horns of floor timbers. When conservation is completed, it will be possible to examine them in conjunction with the frames. No futtock fragments remained in position because the hull was apparently deliberately dismantled to the level of its floors. Gr313 is possibly a futtock fragment.
14. There was a loss of deadrise in the considerably more massive and better preserved frames of the Bremen cog (Ellmers, 1975:338). This was discovered during rebuilding.
15. Alcohol-ether-rosin treatment of one trenail has revealed what was invisible after PEG treatment, i.e. that its head was tarred. See also Fig. 8.31.
16. 1 ENZ III is unpublished; plans in *Nederlandisch Historisch Scheepvaart Museum*, ref. no. Arch. Afd. C4.0176. Mast-steps integral with frames are found for example in Blackfriars I (Marsden, 1967); Bruges (Marsden, 1976); Zwammerdam 4 (de Weerd, 1977); Bevaix (Arnold, 1974).
17. The advantage of the keel-less design was noted by Brown, 1904:148-9: 'In fact the boats of the lagoon had to be so built that they should be capable of sailing in deep water and of being rowed or punted in the shallows; and a large rudder, which could be shipped and unshipped at pleasure enabled them to do this. But the second reason has been less generally observed. It is well known that, in the open sea, with large spaces for tacking, where the wind is the chief factor in the motive power, and currents count for little, a boat with a keel will make less leeway than a flat-bottomed boat. But the case is different at the ports of the Venetian lagoon, where the outgoing or incoming tides run with the speed and volume of large rivers. There the current counts for as much as the wind; and the keel of a boat that is tacking presents such a surface to the opposing water that the power of the sails is minimised, and the boat loses seriously upon each tack. For purposes of entering the lagoons from the sea against wind and water, a flat-bottomed boat, which offers no resistance to the current below and feels the full value of the wind above, has every advantage over boats that are built with a keel.' I am indebted to Lt Cdr Alec Tilley for this reference.
18. Based on that of Ellmers (1972a: 257), where further references to these ships can be found.
19. Contemporary view: e.g. Garmonsway, 1967:XCI, 114. Sea-going: a contemporary navigational aid found, coincidentally, in Canterbury Cathedral is described by Binns, 1971. It is a portable sundial.
20. The 'Shamrock', a flat-bottomed sailing barge, 18 m long, carried a cargo of 60 tons of stone to Cornwall with a freeboard of 0.6 m. She was towed by horse through the last of the ebb tide when necessary. I am indebted to Alan Viner for this information.

## APPENDIX

### THE BARGE FROM THE R. ROTHER, KENT

The original documents and measured sketches of the barge, found in 1820, are a model of early nautical archaeological recording (National Maritime Museum, RCE/1.53/017). Unfortunately, at the time, the associated objects were not susceptible of close dating and, despite all the clues carefully noted by William Rice, the clinker-built vessel could only be interpreted as Viking. She was inevitably connected in the minds of the public with the Danish fleet defeated by Alfred in 893, and as such she was raised and transported to the S. side of Waterloo Bridge, where she was publicly exhibited for some time. She was eventually destroyed and the associated objects disappeared.

She was found in the level of East Matham in Kent, near Matham Wharf (N.G.R. TQ 278868), under the bank of a stream or sewer running into the present R. Rother. She lay beneath 20 ft (6.1 m) of sand, and it is fairly evident that the vessel must have sunk before 1623 when the stream was diverted to Wintersham Level. The hull was 63 ft 8 in. (19.4 m) long with a beam of 15 ft (4.57 m) and was entirely of oak. She had a rounded stem and stern and nearly vertical stem and sternposts, with a hinged sternpost rudder. She was clinker-built and luted with moss. Her floors were flat and her frames were fastened with trenails wedged at both ends. She had a mast-step about one third of her length from her bow, and evidence of a bowsprit was noted. Rice commented: 'The form of this ship is somewhat similar to the present Dutch Galliot, the aperture for the mast is just before the main beam.' Her trading and unwarlike character was evinced by the ceiling of oak planks, 2 in. (5 cm) thick, found intact.

Below this ceiling when cleaning out the internal spaces of the hold, various objects were discovered, and more were recovered from the cabin and galley. Although these objects were not drawn, the verbal descriptions provide means of arriving at a closer dating for this wreck than hitherto.

#### From the hold:

'An earthen jar or pot, very thin, of a dark (nearly black) color with three short feet triangularly placed.

Another earthen pot, of a rather lighter color, but with two handles and longer feet similarly placed.

A pint pot of earthenware, rudely fashioned and similar in shape to those depicted by Teniers.

A hollow ball of yellow metal, to which part of a blade about an inch wide and much corroded is attached; a crescent and a hollow tube, each of a similar metal; these from their perforations and apparent conjunction, formed

the handle and hilt of the sword; there are some dots and strokes marked on each side of the crescent, but too imperfect to be decyphered.

A large steel, sufficient to embrace the hand, and a piece of flint lying beside it, black and much worn with use, but still retaining the property of emitting sparks.

Two rusty locks, one with an iron ring as if it had belonged to a chest or a locker; the other with an iron handle in the wood as if for a latch.

A brick of light red color, measuring in length 6 inches and a half, in breadth 3 inches and a quarter.

Parts of the stays of the mast with iron hoops attached to the rope, which is an inch in diameter.'

#### From the cabin and galley:

'The gloom of a cooking-stove with the charred wood ashes still adhering to it.

A tile, checkered green and red, glazed.

Another tile, about seven inches square, glazed, with a five-pointed star in a circle.

Part of another of larger square, nearly similarly marked and glazed.

An hour glass about 5 inches in height, on the one half of which was delicately delineated the figure of a ship in full sail, which on the glass being dried, peeled off and was obliterated.

A pair of leather soles, very round (or cow-mouthed) in shape, with the upper leathers to cover half the foot only, and fastened with thongs, the hinder part unconnected with the front and surrounding the heel, with a strap on each side as if to buckle in front of the instep.

A paper pen case & ink pot, round, curiously marked.

A circular board with several perforations, supposed to have been used in ascertaining the ship's course.

A sounding lead about 8 inches long very heavy and of octagonal shape, excavated at the bottom to admit the soil, the metal not in the least corroded.

A piece of board, on which is traced with a sharp instrument, what, by some is supposed to have been a rough chart of the ship's progress, but by others, (and perhaps more reasonably) a number or date.

A circular plate about 4 inches in diameter, of a metal similar to pewter, with the following stamp, P. I. in a circle on the upper part. This was fastened on the side of the ship towards the stern.'

The inventory is clearly late medieval. Galleys are found in medieval wrecks, for instance that of the 13th to 14th century in Kolding Fjord (Crumlin-Pedersen, 1972:187), and galleys have been found as an almost standard feature on the late medieval traders excavated in the NE. polder of the Zuider Zee (van der Heide, 1975). (Fig. 8.37). Hour glasses seem to have come

use in Holland in the 14th century. Mrs Elizabeth Eames of the British Museum kindly comments on the tile descriptions as follows:

'Plain chequers were used in the 13th and 14th centuries. I am not certain of any in the later 15th and early 16th centuries, but there may have been some. The tiles are usually chequered brown and yellow. Brown and green would be more difficult to achieve, but it is probable that the red was body colour from which the dark olive green, which was most likely to be combined with green, had worn off. This would take place if the design was depressed below the surface and the cavities had a thin slip in the bottom. This technique does not appear until the 14th century.

'The motif in a circle is a 13th-century form which persisted through the 14th, although usually elaborated...Stars are not common and are six-pointed. Seven inches square is large. Tiles were sometimes even larger, but on the whole the large ones tend to be early 13th and early 14th-century. The general run of our material is from four to six inches square....

'The tiles could quite easily be continental, but on the whole fashions in design and technique were much the same over the western European tile-producing area.'

The tiles seemed to suggest a 14th-century or later date for the vessel, bearing in mind the possibility that old tiles might well have been utilized for the galley hearth. The description of the shoe, an article with a much shorter life-span than tiles, was, it was hoped, capable of dating the wreck more closely. Miss June Swann of the Northampton Boot and Shoe Museum kindly contributes the following note:

'The Regency description of the pair of shoes suggests a Tudor date, 1510-40, with the use of the term "cow-mouthed" and this would fit in with the description of the "hinder part", being unconnected with the front. It suggests the low cut style with an ankle-strap, though the buckle is generally on the outside and not in front. This originated as a German style, but was worn in other parts of Europe including England and Holland. What is not clear in the description when talking of Tudor shoes is "the upper leathers...fastened with thongs". I have seen Tudor forepart uppers with leather laces, but they are usually high-cut and either a complete ankle shoe or a mule with no quarters ("hinder part").

The sounding lead shows that the vessel was sea-going and Rice perhaps correctly discerned Dutch build. The inventory does not preclude this view and, if the description of the shoe is accurate, a date no earlier than the beginning of the 16th century seems probable.

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## CHAPTER 9: RECONSTRUCTION

### PART I. RECONSTRUCTING THE HULL

by Eric McKee

When recording was finished, a complete reconstruction was attempted using a copy of the site plan (Fig. 1.2.9), a set of photographs, a set of prints of the 1:10 scale drawings (chap. 3.2), and the direct-measurement book.

#### MUTUAL LOCATION OF COMPONENTS

Although I had not seen the hull *in situ* there were various clues to show how the pieces had been put together (Fig. 9.1.1). The nails were so spaced that there was an exclusive solution for the location of strakes and planks relative to each other. In addition the following gave less accurate but quicker results:

- a, reference pins
- b, raking grooves
- c, original scribing
- d, tool marks on faying surfaces
- e, protected surfaces
- f, splits along lap lines.

Similarly, the best way of locating planks relative to ribs was indication of fastenings, generally holes for trenails, but also rusty prints that nails had made on under sides of ribs. Other clues were:

- g, joggles and pressure areas on ribs
- h, protected surfaces on inside of planks
- j, pressure areas and fractures on planks.

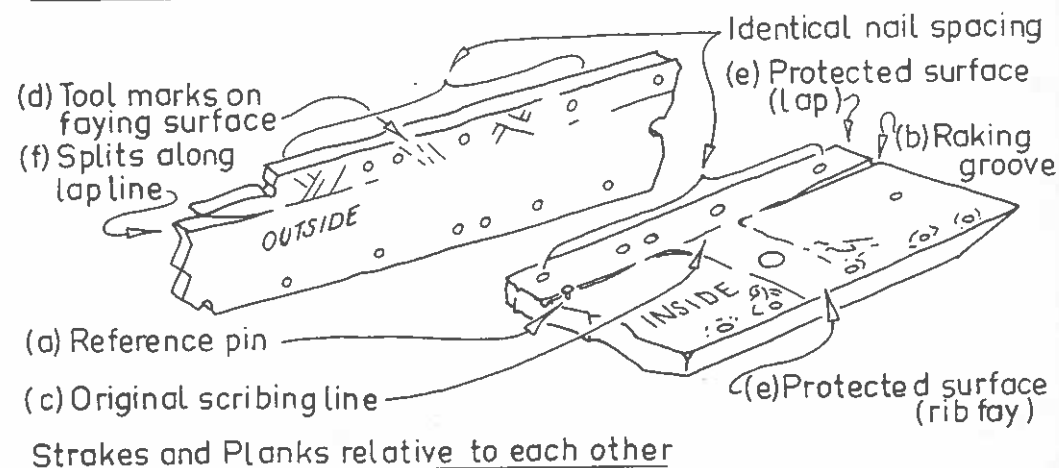
Again, the location of a rib in the length of the vessel could be established from the pattern of the trenails, pressure areas, protected areas and fractures.

All these features are evident on either the 1:10 scale drawings or on the photographs (sometimes on both), and are described in detail on in chapter 3.2.

#### RECONSTRUCTION ON PAPER

With the position of the components more or less certain, two attempts were made to make a conventional draught. When it became clear that there were several possible designs, none of which could be demonstrated to be right, these attempts were abandoned. Reconstruction of a three-dimensional shape on a flat sheet of paper meant that all corrections involved simultaneous changes in all three planes. The task of making and keeping track of these on

## MUTUAL LOCATION OF COMPONENTS



Strakes and Planks relative to each other

Strakes and Ribs relative to each other

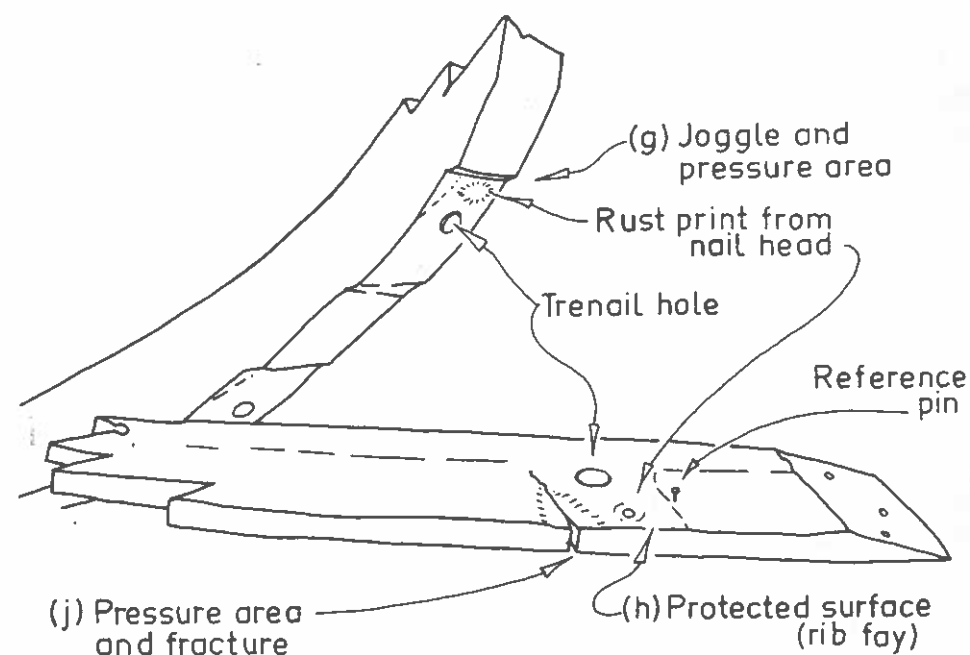


Fig. 9.1.1 MUTUAL LOCATION OF THE COMPONENTS

Drawn by Eric McKee  
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the sheer, body and half-breadth plans together was too forbidding and liable to all sorts of error.

A more flexible approach had to be found, closer to the one used by the original builder, who would not have used or understood ship draughts. Ideally the method would avoid important decisions having to be made too early, and allow corrections without disheartening repetitive work.

## RECONSTRUCTION WITH SCALE MODEL

A model certainly met the requirements of flexibility, deferred decisions and ease of correction. Even when it was well advanced, it worked like a three-dimensional pencil drawing, which could be easily modified when necessary. (Should a set of conventional drawings be required, the lines could be taken off in the usual way.)

If an accurate model was made of each part of the shell, which included planks, keel and sternpost, and they were joined through their original fastening-holes, it was hoped that some acceptable shape would result. The shell of a boat can adopt a number of different but related shapes. A simple shell can be made from a tram ticket and two paper clips (Fig. 9.1.2). The ends will come together if the sides are forced apart; if the rocker is increased the midship section will flatten. It therefore seemed to be necessary to try and find the variable form of the shell before attempting to settle its final rigid shape.

While a larger scale model would have given greater accuracy, so much 1:10 data was available that this scale was selected. For a natural visual appearance, the scale of a model should be equivalent to the reciprocal of its length in metres or yards. With a prototype 13.5 m long, the use of 1:10 scale was appropriate.

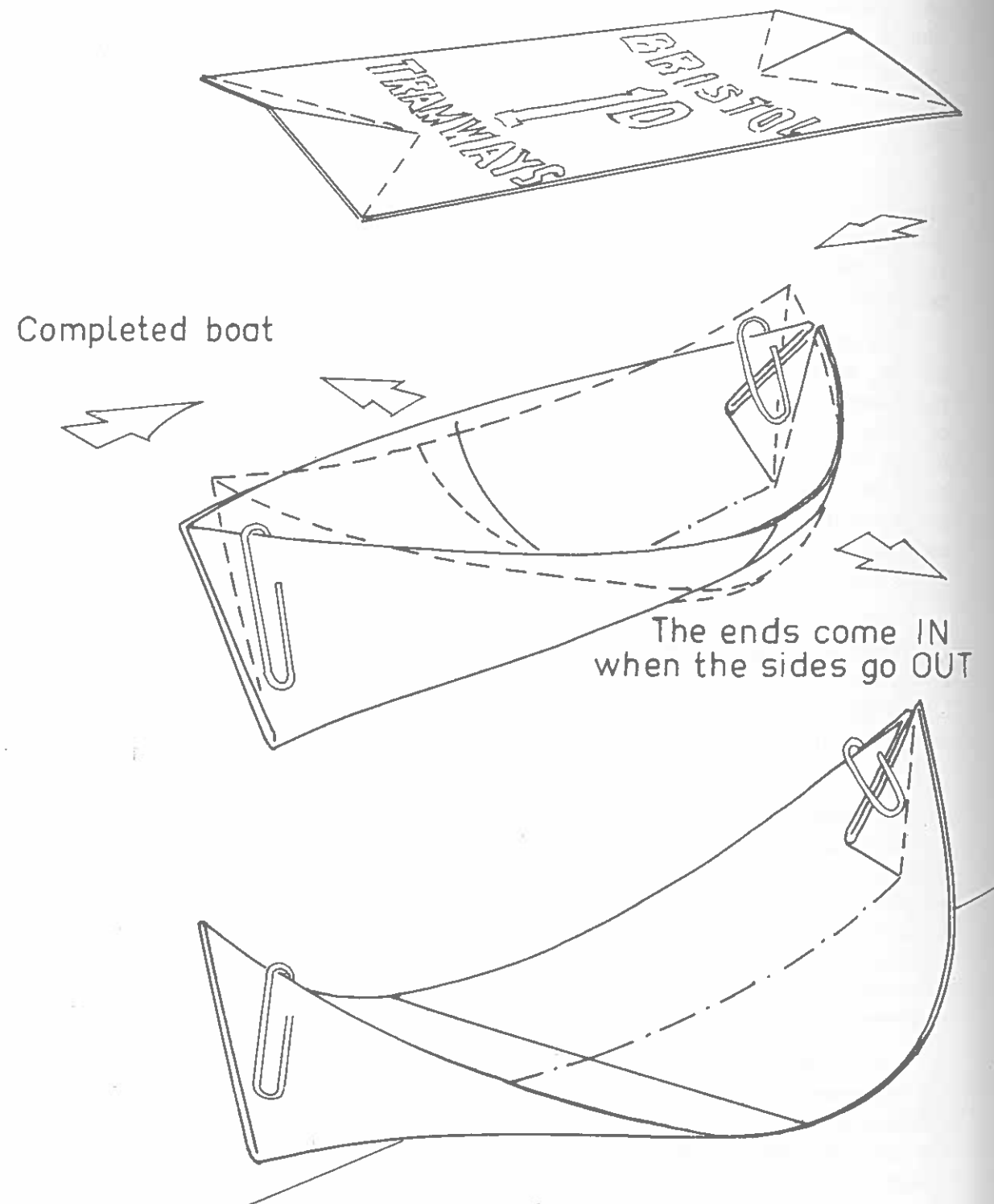
This scale was used for all dimensions except for plank thickness, which raised a special problem. Chap. 9.2 describes how much it varies. As it would have been difficult and even unrealistic to reproduce these varying thicknesses, it was decided to use marine plywood for its stability and reluctance to split. As it was springier than plain wood, a thickness of 1.6 mm was used in place of 2.5 mm, which would have been nearer to the scaled average size. Apart from cutting out the shape and boring the fastening-holes in their correct positions, only the hems or bevels in the laps, the scarfs and the peculiar hood-ends were worked to shape.

From the outset, an effort was made to find and follow the original building sequence. The keel was first modelled; to this the sternpost was added, followed by the strakes from the garboard to the sheer. Although this was the only possible building sequence, the order of assembling the individual planks in each strake remained unsettled. Chap. 10.3 gives the building sequence it is hoped to adopt for the replica.

Each part was modelled on what had originally been a single piece of wood, made up of fragments if necessary. The 1:10 scale drawings were cut out and put together on a drawing board, any small missing parts being restored. The whole keel was modelled in this way; the sternpost was

## VARIATIONS IN THE SHAPE OF A BOAT'S SHELL

### Folding a tram ticket boat



Increasing the rocker in the keel flattens the midship section

Fig. 9.1.2 VARIATIONS IN THE SHAPE OF A BOAT'S SHELL

Drawn by Eric McKee  
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extended upwards until it was long enough to accommodate all the strakes likely to have been fitted.

### The backbone (keel, sternpost and stempost)

The direct measurements of the keel showed that it was fair to assume that the portion forward of R6 was similar to the equivalent portion aft of it, as also were the ribs themselves. This assumption has been constantly checked throughout the reconstruction and except for differences between the profiles of the stern and stempost is now thought to be definitely correct.

Under R6 was a plugged hole 0.025 m in diameter, and there was another of the same size just inboard of the sternpost scarf. It is thought that there must have been a third in a similar position forward to the one aft. There is no obvious structural reason for these holes. Externally they could have been used to attach a false-keel, but they seem to be spaced too far apart and they are smaller than those for the standard trenail. They were more probably used to adjust the rocker and hold the keel in the building stocks, until ready for launching (pp. 201, 206).

As there was no reason for thinking that there had been any abrupt change in the profile of the missing part of the sternpost, the line of the recovered portion was extended upwards. Difference tables (Cobb, 1970:58-95), rather than ship's curves or battens, were used to give a fair line, and to find and mark the position of each strake in the sternpost rabbet and so give the total length of each strake.

In an attempt to reconstruct the bow, all the planks in the foremost position of each strake were extended to reach the assumed position of its scarf. After three strakes on both sides had been so extended the shape emerging appeared so lop-sided and ungainly that the attempt was abandoned and the strakes were cut back to their original limits. When the internal strongback was in position, a last attempt was made to reconstruct the bow by fixing a stempost to the strongback and so provide an ending for the strakes; once again it was unsuccessful.

### Shell

Planks fell into three categories; those which were either complete in one piece or of which all the fragments were available; those that left little doubt of the nature of the missing part; and those whose shape had to be more or less deduced. It was hoped that by the time that planks in the first two categories had been modelled and assembled, enough would have been learned about the builder's methods to finish the boat in a way he would have approved.

This called for varying degrees of assumptions, which could be permitted, provided it was known what they were. In order to distinguish what was real from what had been assumed a colour code was used. A black line was drawn at the limit of the parts as found—thus two thirds along the model keel was a jagged black line taken from the 1:10 scale drawing. A brown line was drawn where an obvious missing fragment had been replaced; corners of damaged scarfs were the most common examples of this. Green was used when the fragment of a recovered part could be completed with some certainty

## FINDING THE CORRECT ROCKER

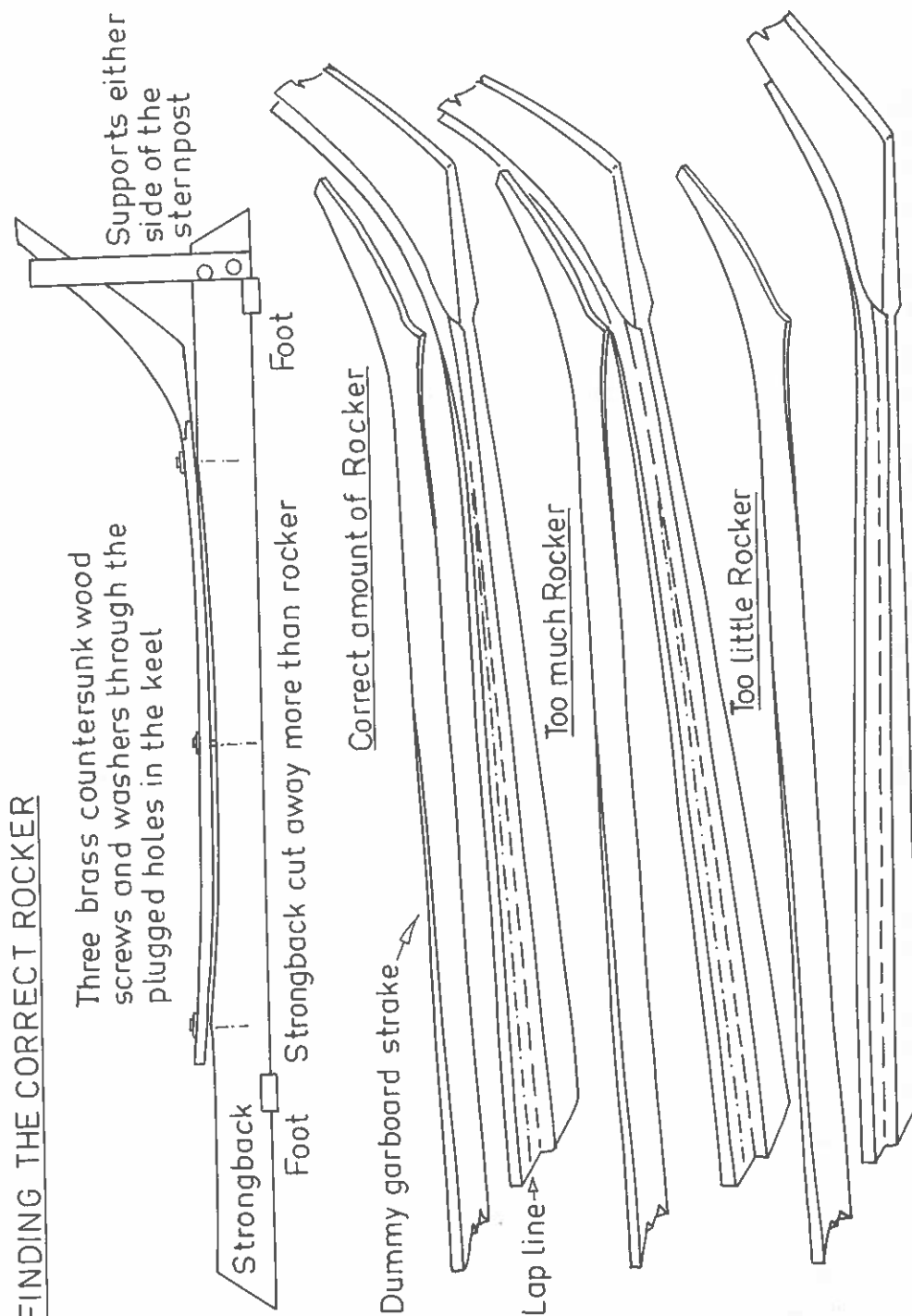


Fig. 9.1.3

FINDING THE CORRECT ROCKER

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and corroborative evidence for doing so could be produced (the forward end of the keel and some of the lower hood-ends aft). Components which could be deduced from surrounding evidence, even though no part of them had been recovered, were coloured blue (all the upper planking and the rising). Completely conjectural items like thwarts, mast-step and rudder were coloured red. This colour code makes it possible to see the degree of certainty with which any part has been reconstructed.

Starting with the keel, sternpost and recovered garboard planks, no attempt was made at this early stage to reconstruct the missing plank-ends forward. With one exception (p. 273) all fastenings were and still are temporary.

### The rocker

The site plan (Fig. 1.2.9) showed that the keel had been damaged; neither the original rocker nor the angle the sternpost had made with the keel was therefore clear. Although the line of the under side of the keel had almost certainly been an extension of that of the keel, this was hard to confirm. Both sides of the scarf between the sternpost and the keel were in pieces, and could only be reassembled with reservations. Although the under sides of the two parts met when the models of the keel and sternpost were joined, there was some angular misalignment. The whole profile (and therefore the set of the planks) depended on getting this angle and the rocker correct. The greater parts of both garboards survived and provided the solution of both.

As the keel was springy and the scarf fragile a strongback was made. This allowed the rocker to be adjusted and gave some support to the sternpost without straining the joint (Fig. 9.1.3). The rocker was varied by tension applied through the holes in the keel. This may have been the original method too (although screws would not then have been used). A continuous starboard garboard strake was reconstructed from the 1:10 scale drawings, checking the run at the scarfs from the planks of the strake above, and a scale model made. This strake would not fit until the keel had been given the correct rocker (Fig. 9.1.3). Furthermore the hood-end of this strake only lay snugly in its rabbet when the angle of the sternpost was right.

### Strakes.

The individual plank models (chap. 9.2) were next offered up, and it was found that the fastening-holes on the planks and the keel corresponded, and that small brass pins would hold them. More model planks were made, and in order to confirm the angle of the sternpost they were put on port and starboard much in the same pattern. Although the sternpost angle looked right, an incremental pitch error developed in the alignment of the fastening-holes, and the sternpost was being twisted out of the vertical.<sup>1</sup> Some other planking sequence had then to be tried.

The model was taken to pieces and checked for mistakes. Some of the model planks were remade with the benefit of the experience that had been gained of putting fragments together (summarized in chap. 9.2). A new strongback was made, more rigid than the first and better able to resist any tendency to twist. The keel to sternpost scarf was remade with glue as well as screws

# INTERNAL STRONGBACK WITH MOULDS

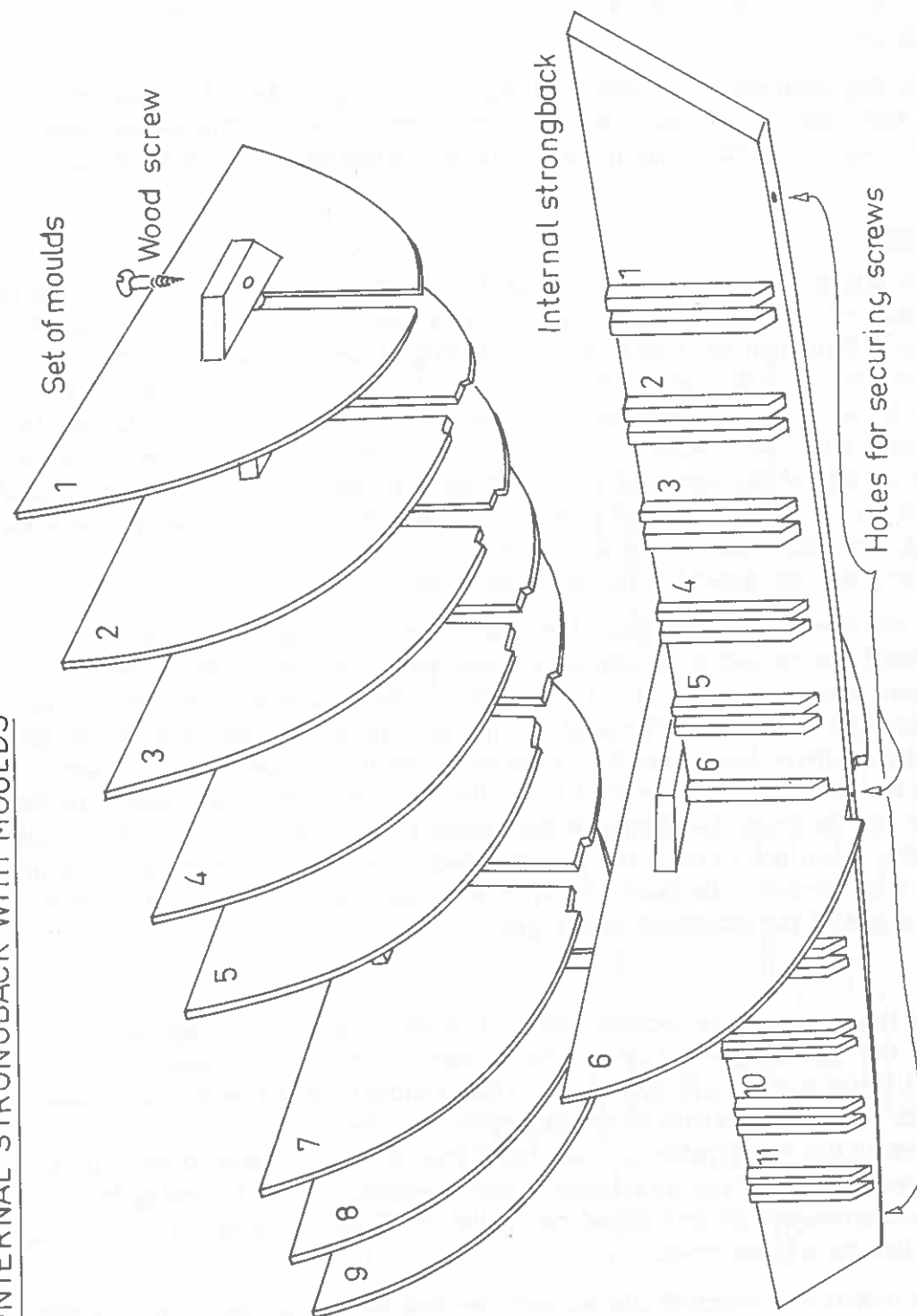


Fig. 9.1.4 INTERNAL STRONGBACK WITH MOULDS

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after checking with both the garboard hood-ends. This was the only permanent join in the model and was used partly for strength and partly to ensure that once the correct angle had been found it could not be altered.

Planking was then restarted, this time following a sequence of one plank at a time from aft to forward until a strake was complete. The strakes were completed in the following order: S1, P1, P2, S2, S3, P3 and so on, using a sequence still preferred by boat-builders. In this way each strake is settled into shape before any part of the next one is added, and the strakes are put on alternatively to starboard and port to nullify strains that could twist the boat in one direction. The exact procedure for making and fitting each plank is given in chap. 9.2.

There was less trouble than had been expected in locating and aligning fastening-holes. In the most damaged areas about one in four of the holes was out of position by more than half a diameter (0.5 mm) and in the undamaged areas fewer than one in ten. The distance of each completed strake from the keel varied from that on the site plan (Fig. 1.2.9), but never significantly.

Two signs gave confidence: with only the land-nails in position the scarfs were so secure that it was never necessary to fit any additional central fastening; the planks stayed in place held only by pins after the small clamps (Fig. 9.2.3) had been taken away.

When four pairs of strakes were in position, it was apparent that no more hood-ends could be started from the sternpost with complete accuracy, and a small amount of deadrise, which could not be justified by the evidence of the rib shape and the site plan (Fig. 1.2.9), was developing and would require control. In the face of this, free-hand planking had to stop and some discipline introduced. By this stage, the original boat-builder would have been controlling his sheers, or the heights of the top edges of the fitted strakes, by pegging or shoring them into place. When he was satisfied with the shape that was emerging, he would have fixed it by fitting, clamping and fastening the next strake above, knocking away any temporary locating devices as he went. In particular he would make sure that the sides of the boat were symmetrical. While some builders could rely on eye alone, it is likely that some form of planking aid would also have been at hand to ensure symmetry or resemblance to a previous design. Not knowing what had been in the builder's mind, nor what aids he had used, it was decided to work out a set of moulds and use them to control the rest of the planking.

The shape of these moulds was influenced by a number of factors. These were: the sections taken by Peter Marsden on site (Figs. 2.1.2-3), the projections of the ribs on the grid table, photographs, and the shape made by the first four strakes of the model. Each factor had its shortcomings, which taking them separately were: 1, the sections taken on site did not coincide with the rib stations, and the centre-line used did not follow that of the boat, which meant fairing and redrafting; 2, the rib projections were not necessarily square or plumb, which also called for judgement before use; 3, the photographs could not be accurately measured; 4, finally, the model could be forced back into other shapes, although it would spring back once released.

## RUN OF STRAKES

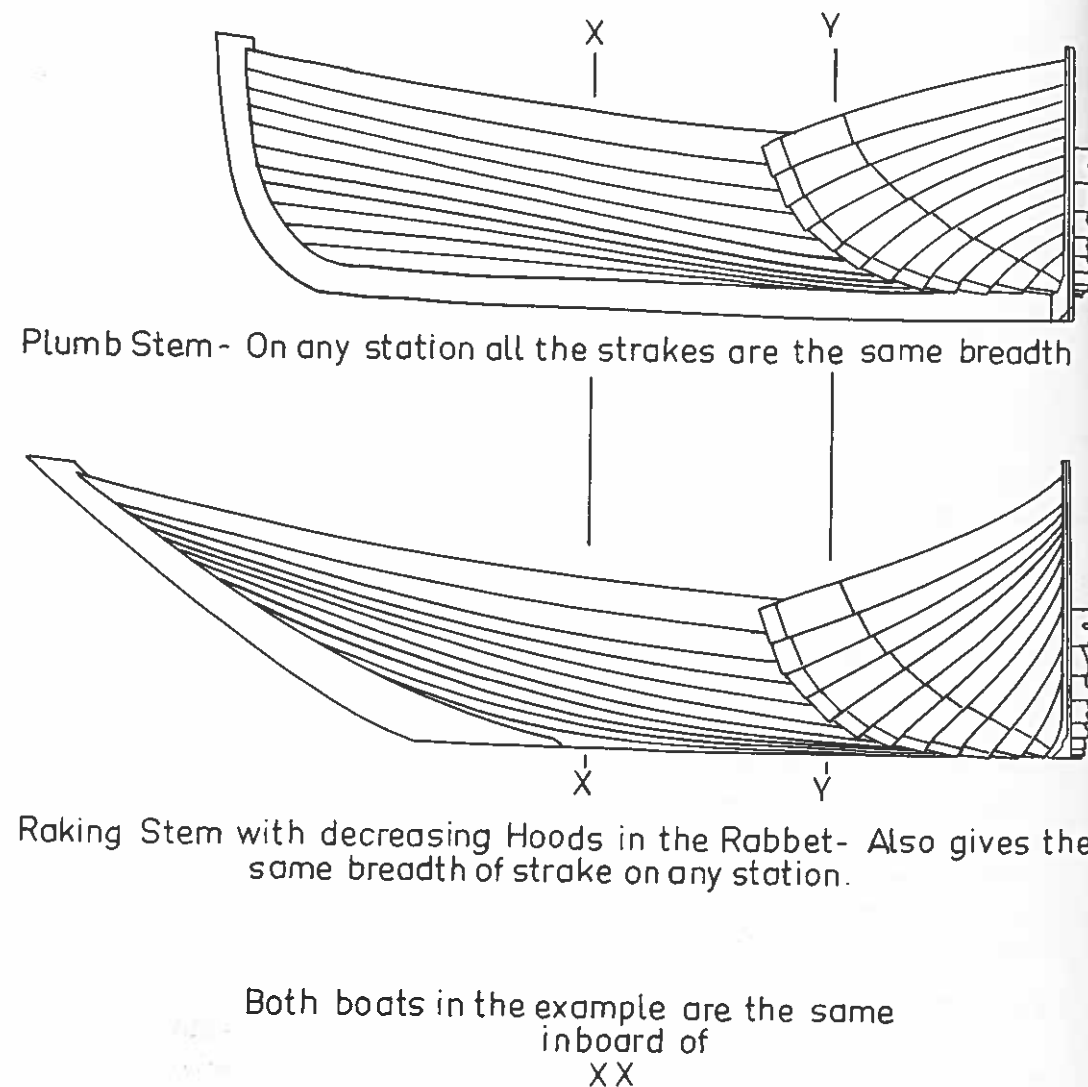


Fig. 9.1.5

RUN OF THE STRAKES

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An open shell, like a boat, is not rigid until transverse stiffening—ribs, beams or deck—has been added. In the same way, the discipline of a set of moulds would freeze the shape so they would have to be carefully chosen.

When the various factors were reconciled, the final shape had a little more deadrise than either that on the site plan or on the projected drawings of the ribs, but less than in the model. The moulds would therefore have to be forced into the model, pressing on to the top edges of the fourth strakes. Tests showed that all the moulds could not be inserted together, and that planking amidships was more flexible than towards the ends. The moulds would have to be fitted from amidships outwards, and some way found to prevent the rocker of the keel changing.

An internal strongback was made and supplied with a set of moulds, which could be put in or taken out at will (Fig. 9.1.4). This strongback was held in position by screws through the same three holes used for the external one. When the keel was released from the external strongback it flattened slightly, but this was corrected by fitting the internal strongback into place. Starting from amidships, the moulds were inserted one at a time. This gradually pressed the sides outwards, and also brought the sternpost into a more upright position. With the external strongback as a gauge it was found that the extremity of the sternpost lay 3 mm higher than before. The decrease in overall length was negligible; the model was moving more than this because of changes in temperature. It was decided that this new shape was as good as could be obtained within the limitation of the techniques employed.

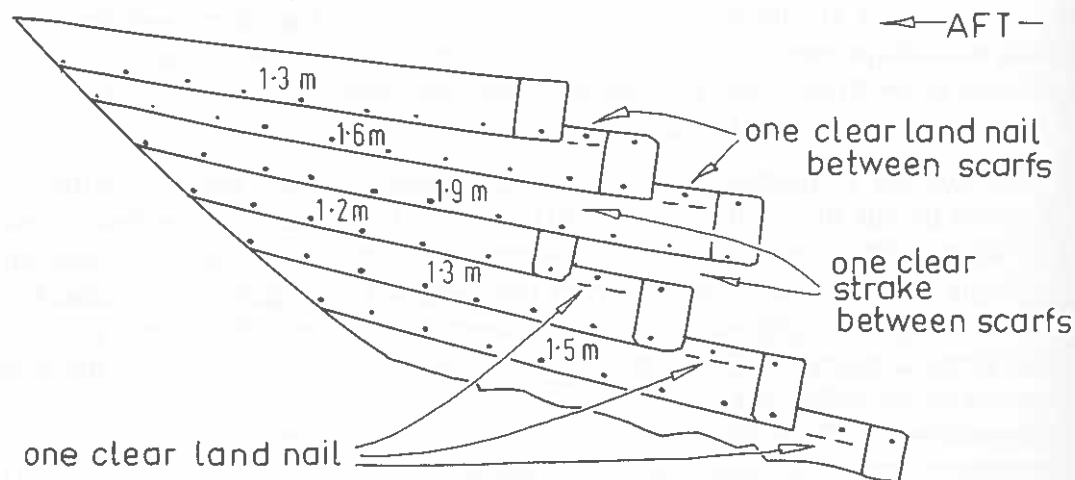
The fastening-holes in the rest of the model planks still lined up as before, partly because each strake recovered from the find was successively shorter. As each strake gave less complete evidence, more attention had to be given to what was being learnt from the building practice evident in the recovered parts, just as with the strake marks in the rabbet of the sternpost. This approach was used to find and line out plank breadths from the planks already in place. Fig. 9.1.5 shows that with a raking sternpost and decreasing strake widths in the rabbet the strakes are still of the same breadth on vertical stations as would be so with a plumb stern.

A reliable estimate of the total number of strakes was also needed.<sup>2</sup> Boats with from eight to twelve strakes were drawn and their weights plotted on a displacement curve based on the underwater shape of the find. Although an improved curve has since been drawn, this first approximation was good enough to indicate that eleven was the most likely number. More than this would have given either an excessive overall length in relation to the keel, or meant tapering the strakes so much that there would have been no room for fastenings.

The moulds like the sternpost had been made big enough to accommodate eleven strakes of similar breadth amidships. No attempt was made to line off a mould until the last model of a recovered part was in place and the rest of the strake had been faired round to the strake mark on the sternpost. Although only strakes 2 and 6, and to a lesser extent 4, show that an attempt had been made to match the sheers, it was decided that the final sheer-lines should be a pair. The fragments of strakes 7 and 8 show that thicker planks

## SHIFT OF SCARFS

### Hood end scarfs



### Intermediate scarfs

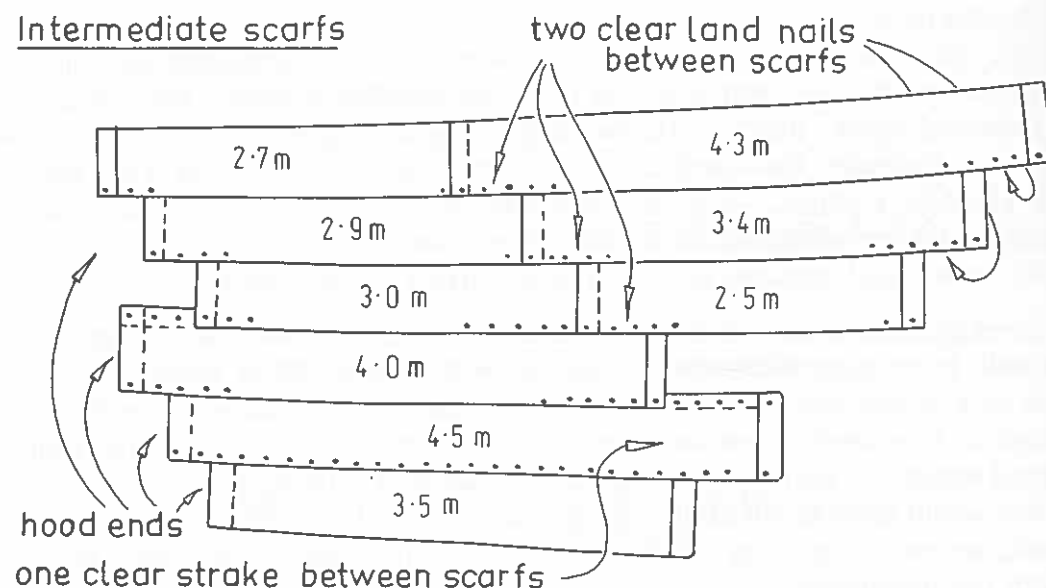


Fig. 9.1.6

SHIFT OF THE SCARFS

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had been used. The increase was not enough to recognize a change of scantling but it did look as if the builder had selected thick planks in a batch for this part of the boat. (Chap. 9.2 gives the actual sizes.)

Because the surviving upper planks amidships were at slightly different heights, the problem of closing the gap so that the two sheer strakes should have the same breadth without enlarging the boat had three solutions:

- plank up to the estimated sheer-line using only two more strakes (making ten in all), which would have to be broader than typical, S9 being broader than P9 to make them level. S10 and P10 would be alike but broader than usual.
- plank up two more strakes of average breadth, making the starboard ones a little broader to give a symmetrical sheer-line though less than the estimated one.
- plank up three strakes of below average breadth to give a symmetrical sheer-line as estimated.

As it seemed to offer a middle solution (but was not necessarily the final one), a was adopted so that ten not eleven strakes were fitted. When planked up the boat looked as if it could take more freeboard, but until more was known about the internal structure and propulsion requirements, it was decided to leave the planking as it was.

It had been noted that the builder had avoided weakness by not placing his plank scarfs too close together. The absence of unexplained short lengths indicated that the pattern of scarfs had not been interrupted by repairs. This meant that if the builder had had a rule to control the shift of scarfs, it should be possible to work it out. Two sorts of planks were used: the hood-end planks secured to the sternpost (and, it was assumed, the stempost), and the intermediate planks between. The hood-ends were short, normally about 1.5 m long, and carefully made to a quite elaborate design. Their scarfs were shifted by one clear land-nail or strake (Fig. 9.1.6). As a result the hood-ends become shorter as they rise, until it is necessary to work a 2 m plank and start the progression again. The arrangement on either side, though following the same rule, is slightly different. The intermediate planks are between 2 and 4.5 m long and are of a much simpler shape, often rather roughly made. Their scarfs are shifted by two land-nails or one strake. Within these rules planks are worked to keep the number of scarfs used as low as possible.

Strake diagrams had been constructed for both sides, both to work out the position of the missing scarfs and to record the shapes of the complete strakes. Fig. 10.1.1 consists of the drawings made for a replica and gives the complete strake diagram for the port side; views of the assembled strakes show the shift of scarfs on both sides. These arrangements can be regarded with some confidence, as they are the pattern fixed by the find. The variations possible within these simple rules are surprisingly small.

The arrangement of the scarfs in the model was rather different from that shown in the reconstruction drawings for the replica, mainly because only ten strakes were used, but also because the sheer strakes in the model were

worked in one piece. This was done to give strength; there is no original evidence for it.

Once the planking was complete, the moulds and the internal strongback were removed. The shell though flexible kept its shape, and when the model was replaced on the external strongback, it was found that the rocker of the keel had not changed.

### Ribs

The transverse stiffeners in this boat had been called ribs at the start of the excavation. This rather loose term has been retained deliberately as it avoids the too precise meanings of timber, frame or floor. Using formers based on the moulds, models of R1 to R9 were fabricated by glueing 1/32 in. (0.79 mm) silver spruce laminations. They were made square and in one piece from sheer to sheer, no attempt being made to copy either the twist or the joins in the original ribs. The difficulty of so doing would not have increased accuracy nor served any purpose for which the model was intended.

After the glue had set, the slightly oversized ribs were fitted into the hull. This involved joggling R1 and removing some of the excess wood from the rest. When all of them had been separately fitted, they were secured, one by one, with small steel wood screws passing through the pilot holes originally bored at the centre of every trenail. When the wind in the original was too much for a square rib to cover one of these holes, a new one was made to maintain the diagonal pattern of these fastenings. Next, one rib at a time was unscrewed and fitted closely to the shell before it was replaced. The heads of the ribs were cut flush with the sheer-line and rounded off. Finally the screws were replaced by snap-headed copper rivets, which represented the raised heads of the original trenails. Rib fays apparent on the inside of strakes had been drawn when the model was made; they can be seen as a continuous if crooked feature after assembly wherever ribs have not directly covered them. R5, 6 and 7 were given saddles like the originals.

By this stage the shape of the hull could no longer be altered without considerable rebuilding. Two simple, if inconclusive, tests were made to check the solution. During excavation, one rib had been found separated from the main find. A model was made of this and it was found to fit into the station of R10, its shape and the spacing of the trenail holes corresponding. A template was then taken of the forward side of the model of R1. This fitted tolerably well at the station at which a single trenail hole was found in P6, and indicated where R11 would have been. As this was a very damaged part of the find, a better fit was hardly to be expected. These two checks were reassuring; the model did not appear to be seriously at fault and confirmed the symmetry of both ends.

### The internal structure

Although there was some certainty that the original boat had had eleven ribs evenly spaced about amidships there was still a large part of the hull in the stern for which no stiffening structure had been recovered. Care had been taken to record any fay, print or hole which had no association with any of the recovered parts.

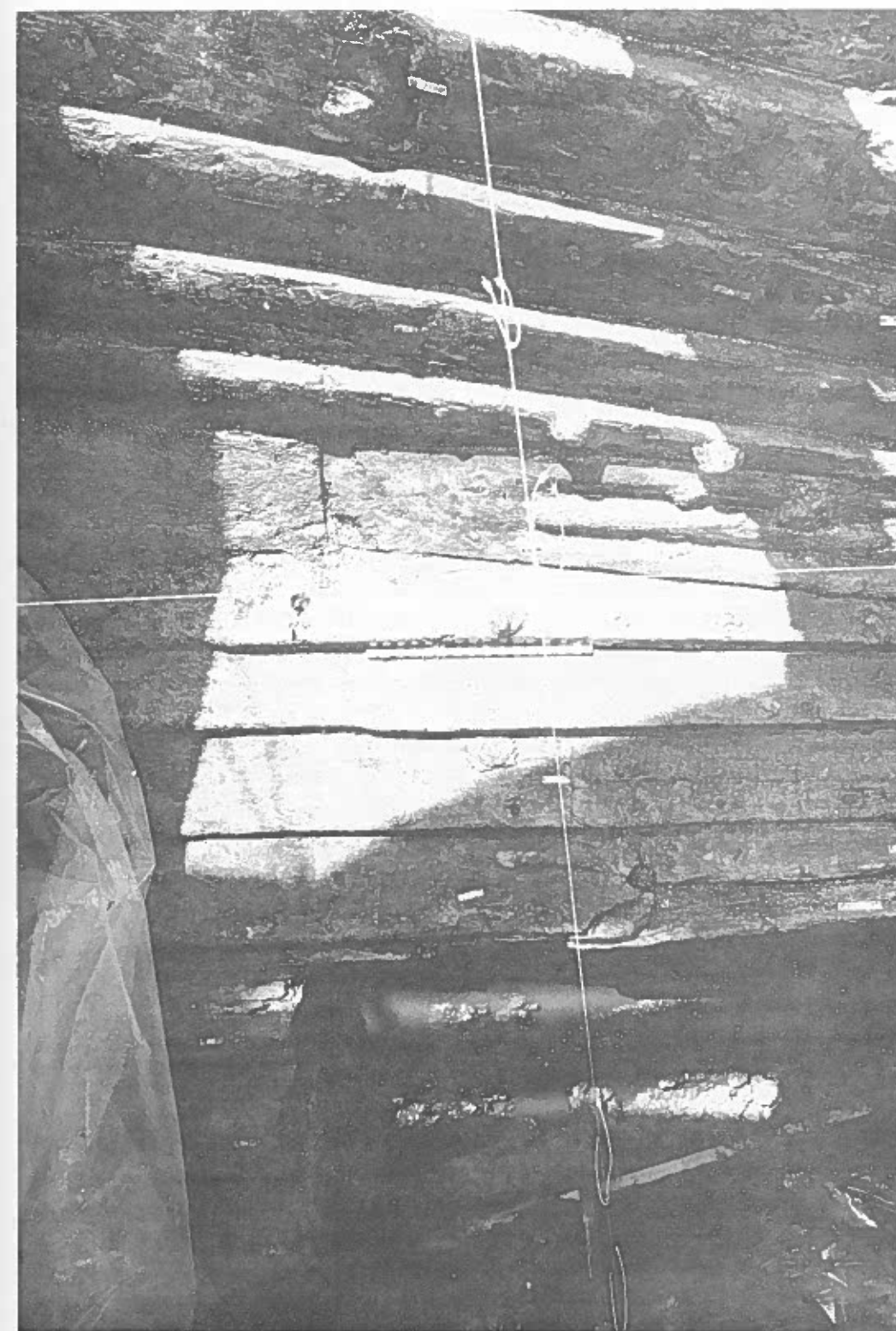


Fig. 9.1.7 Print of missing rib aft of R1  
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### Features in stern

Just aft of the sternpost scarf and on about the same station are two standard sized trenail holes, one in S5 and the other in P4. That some structure rested here is shown in Fig. 9.1.7, on which there is a print of a part which must have had a squared toe resting on S2. There is a similar but fainter example on the port side. The angle between these two prints perhaps indicates that there had been two separate cant timbers, rather than a single rib astride the sternpost. These two timbers were modelled and fitted into the model as green items. Their heads projected above the sheer-line, as this station would have been suitable for operating a sweep, locating a side rudder or turning up a mooring or tow rope.

No other specific evidence could be found for any other transverse members in the after part of the vessel. The narrowness of the upper hood-ends and the weakness of the sternpost in way of the clenching grooves indicated that the two sides would have needed to be tied together more firmly. It was thought that a breasthook at the level of the sheer-line, and a stamering, crutch or inclined frame at a lower level were necessary conjectural red items (Fig. 10.1.2).

All the ribs recovered stopped short of the estimated sheer-line, although the port extremity of R5 must have come very close to it; none of the ends had the appearance of being finished. The terminations were either fractures, fractures with a tooled step in them, or a tooled step. At first there seemed to be no pattern in the way that these tooled steps had been arranged, until it was seen that they were of two different kinds, some like scarfs and some like notches. With the possible exception of R1, each rib had been placed in the boat so that the natural taper of the wood was directed to port and starboard alternately, with the butt or thicker end reaching further up the side of the boat. This only seemed reasonable when it was realized that this gave the most material from which to cut the longer limb.

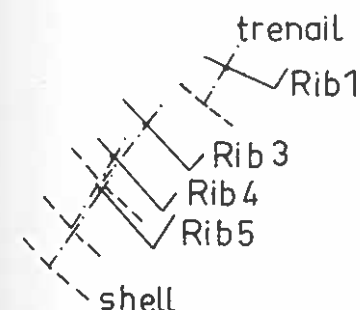
### Top timbers

When not broken off altogether, the tooled steps which looked like scarfs were only found in the thinner and shorter limbs of the ribs. It appears therefore that, when a branch could not be found long enough to span this beamy boat, a short top timber was used to complete the rib. R1 could have been an exception and a single branch from sheer to sheer. The nearest parallel is provided by the Utrecht boat,<sup>3</sup> the real difference lying in the use of scarfs in the Graveney boat, which point to a further member. Nothing was recovered that could have served this purpose. The use of the term futtock for this item has been avoided, as this is a word more suitable for a symmetrical component of an elaborate frame structure of later date, whereas the top timber has always been the last part to be made and fitted.

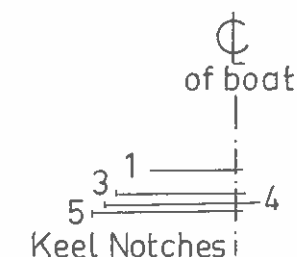
### Risings

The smaller notches in the ribs also indicate the existence of missing structure. When plotted on a body plan (Fig. 9.1.8), these notches lie on a continuous line, but each differs a little from its neighbour in the following respects:

### NOTCHES IN RIBS



Notches in Port After Face of Ribs  
(taken from 1/10 Drgs)



The Interlock formed  
by the Combination of  
a Notch and a Trenail

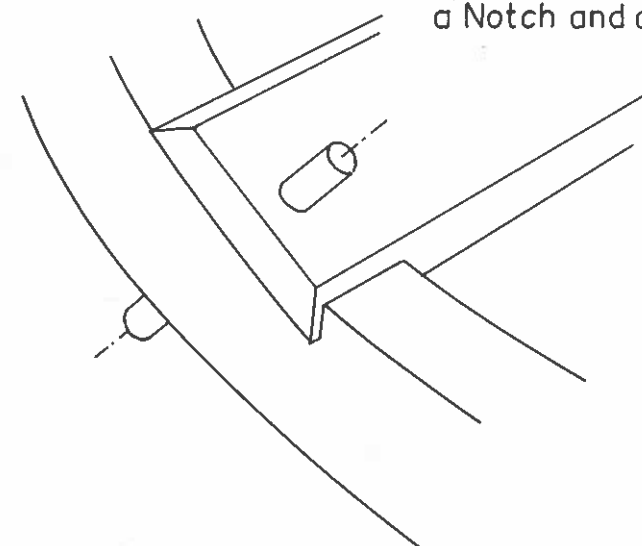


Fig. 9.1.8

NOTCHES IN RIBS

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- a, the angle the long side makes with the shell
- b, the distance of the trenail from the notch
- c, the included angle of the notch.

The differences are gradual and regular, the first two features getting less and the third squarer towards the stern. It appears that a pair of longitudinals lay in the line of these notches, which in turn give some indication of the nature of the cross-sections of the missing members. A large-scale model was made of an amidships notch together (Fig. 9.1.8) with a short length of longitudinal to fit it. It was found that the combination of the angled notch and the trenail formed an interlock, which held the parts together without relying on the tightness of the fit of the trenail for security. As it seems reasonable to assume that the trenails were fitted along the centre-line of each stringer or rising (as the longitudinals will now be called), the breadth was calculated as twice *b* above, which was greatest amidships and tapered off towards each end. Although the thickness could not be exactly calculated, it could hardly have been less than, or more than twice as deep as, the depth of the notch. A factor of  $1\frac{1}{4}$  was therefore chosen and a pair of model risings were made and fitted. These ends were of square section, otherwise there would have been no way of setting them into place. Clamps had to be used to spring them into their notches, but once trenails had been fitted the clamps could be removed safely.

There was a ship's member called *allangose* in Middle English, or 'end-long-tree' today (Sandahl, 1951). This is much what the risings in the Graveney boat would have been. Each would have been made from a pair of flitches, or tangentially cut boards, joined end to end by their butt-ends with the scarf near amidships. The natural bevel of the edges of such boards would have helped them to fit into the notches below and to make a level surface for thwarts above. A pair of such risings would have given longitudinal strength to the structure.

It is unlikely that the risings would have stopped short at the outermost ribs, or at the sternpost, as there is so little wood available in it for taking more fastenings. In the model, therefore, they were extended and trenailed into notches in the cants, running far enough past them to avoid short end-grain.

#### Holes in sternpost

In the sternpost three transverse holes are bored roughly in line and equally spaced above the waterline. Several suggestions for their possible use and for the similarly placed holes in the Nydam boat (Åkerlund, 1963) have been made. The most likely is that they were used for reeving ropes to pull the boat out of the water. As these holes seemed to be the same size as those for trenails, they could also have been used to secure some structure or fitting, which might have extended the sternpost upwards or increased its width. The first alternative suggests a decorative feature, but the boat does not appear to be of the type for such trappings. A pair of cheeks to widen the sternpost would have allowed the fashioning of an oarbed for a sweep right aft. As this seemed more likely than a decorative feature for a river vessel, the cheeks were modelled and the suggestion retained for a practical trial later.

In the angle of the heel of the sternpost is another transverse but smaller hole. This is only large enough to take a nail or a lanyard; no significant structure or use can be envisaged for it.

#### Saddles

The purpose of the irregular saddles in the floors of R5, 6 and 7 remains to be solved. Waney wood in the corners shows that the ribs were made of branches only a little larger than the finished items. It might have been expected then that the saddles had been fitted to replace waney patches, which would have been weak and might have decayed. But as the saddles themselves contain as much waney wood as the ribs, and as some of the trenail holes used to secure the saddles had been bored twice, the holes having slightly different centres, it seems that components other than plain saddles had once been fitted. The subsequent removal of these components left gaps which had to be filled to preserve an even surface in the hold. The models of these three ribs include their saddles, which can be removed as required.

Structurally speaking nothing further could be deduced from the find; the model of the stripped hull had reached a stage when it could be used to study the operation of the vessel and any additional fittings that might be involved.

#### Method of propulsion

To assist visual appearance and test theories, a man at 1:10 scale was made with articulated limbs, his assumed height being 1.7 m. A model oar, 5 m long, and a sweep, 6 m long, were made for him; the upper side of a cube represented the water level when resting on the same surface as the model on its strongback. One face of this cube was cut away to take the oar blade as it would be immersed during a working stroke. Together with thwarts and floorboards this gear was used to test various ways of propelling the boat.

Rowing from thwarts resting on the risings was first tested. It was found that oar-ports cut in the sheer strake (S10 in the model) would have been too low to allow the rower to make a safe recovery stroke if any sort of a sea was running, and would have weakened the sheer strakes and reduced the effective freeboard. The seating was satisfactory with the ribs well placed for use as stretchers, except at the limit of the main rib cage, where they were too far away for comfort.

Oarlocks at sheer-line level, either in the form of thole pins, ports in a wash strake or oarbeds in a saxboard, were all workable. The last was chosen for the model, partly because of the long tradition of its use in the Thames estuary, and more importantly because of the ease with which the oar could be shipped and boated in an emergency. With the oar pivoting at this level the boat could be rowed from any position in the square-ribbed part of the hull. As the rib spacing is about half a room (0.5 m), six, or more conveniently five, pairs of rowers could have been employed, but the shape and structure of the boat does not seem to be primarily that of a multi-oared rowing boat.

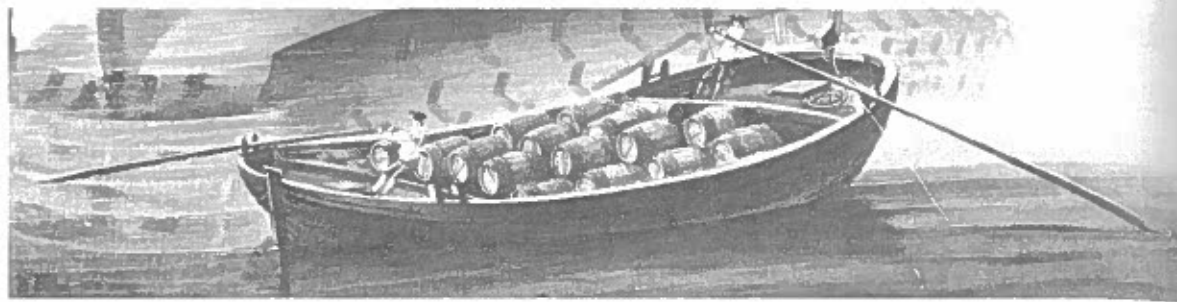


Fig. 9.1.9 Detail from 'The Royal George off Deptford, 1757' by John Cleveley the Elder, showing a Thames estuary lighter  
© National Maritime Museum



Fig. 9.1.10 Model of the minimum solution, or a reconstruction of the missing parts on the assumption that the vessel was an estuary lighter. Scale 1:10 Model by Eric McKee  
© National Maritime Museum

Stern sheets placed between the cants and R1 gave standing room to work a 6 m sweep, using a timber head as a fulcrum; a position which would still be clear when the hold was obstructed with cargo. A 7 m sweep and a platform aft of the cants for the steersman would have been needed to operate a steering sweep in a crutch at the top of the sternpost.

#### USE OF VESSEL

By this time it was imagined that the vessel's use must lie between so-called minimum and maximum solutions, i.e. it is unlikely she had been built as a ferry for crossing a river, where a raft would have sufficed, and it is equally unlikely that she had been a warship.

At the least the boat could have been an estuary lighter, mainly dependent on the tide for movement, but having oars as an auxiliary means of propulsion and turning, so that she could be taken into and out of the tidal stream. John Cleveley the Elder included what could be a descendant of the Graveney boat in his picture of the Royal George off Deptford in 1757 (Fig. 9.1.9). Although this lighter is more developed and has higher sides, she has much the same length and breadth as the Graveney boat, being as much as two men can conveniently handle. In the painting one of them is forward with two sweeps and the other aft with one, both standing on short decks and using timber heads as pivots. Fig. 9.1.10 shows the model in the equivalent or minimum state.

The maximum solution takes into consideration uses beyond which the boat would no longer have been safe. The upper limit of usage was therefore set at that of a small coasting trader with a choice of oars or sail, capable of crossing the Channel if the weather was settled fair. The structure appears to be too elaborate for a general lighter. The size and close spacing of the ribs in the main body suggest that concentrated heavy weights like large logs or stone blocks were the intended cargo. Further, the avoidance of scarfs in the floors makes for an open hold free from fixed cross-beams so that long items could be loaded. Even as a lighter she must have had a more or less specialized role, such as logging, which would have called for a mast to assist cargo handling.

Any mast would have been fitted amidships or just forward of it if a sail was to be set; its step would have had to spread the downthrust of the mast over several ribs, as the keel alone has no great strength. The step would also have had to be confined to prevent lateral movement in any direction. Fig. 9.1.11 shows two ways this might have been achieved so as to fit with the saddles in the ribs. The less primitive solution (Fig. 9.1.11, at bottom) in particular, shows that the absence of a central trenail hole in the saddle of R7 could be due to the presence of a vertical strut. The step has been lengthened so as to butt fore and aft on R8 and 4, not only to give positive location in this direction but also because examination of photographs of these ribs indicates that something had once pressed against them.

A mast-beam and stays would have been needed to support the mast; these would have transmitted horizontal forces, which otherwise would have been concentrated in the mast-step, out to the risings and the sides of the boat. As well as being a derrick or a support for a sail, the mast could have been used as a post for tracking. For this purpose and when a derricked

# SOME MAST STEP SOLUTIONS

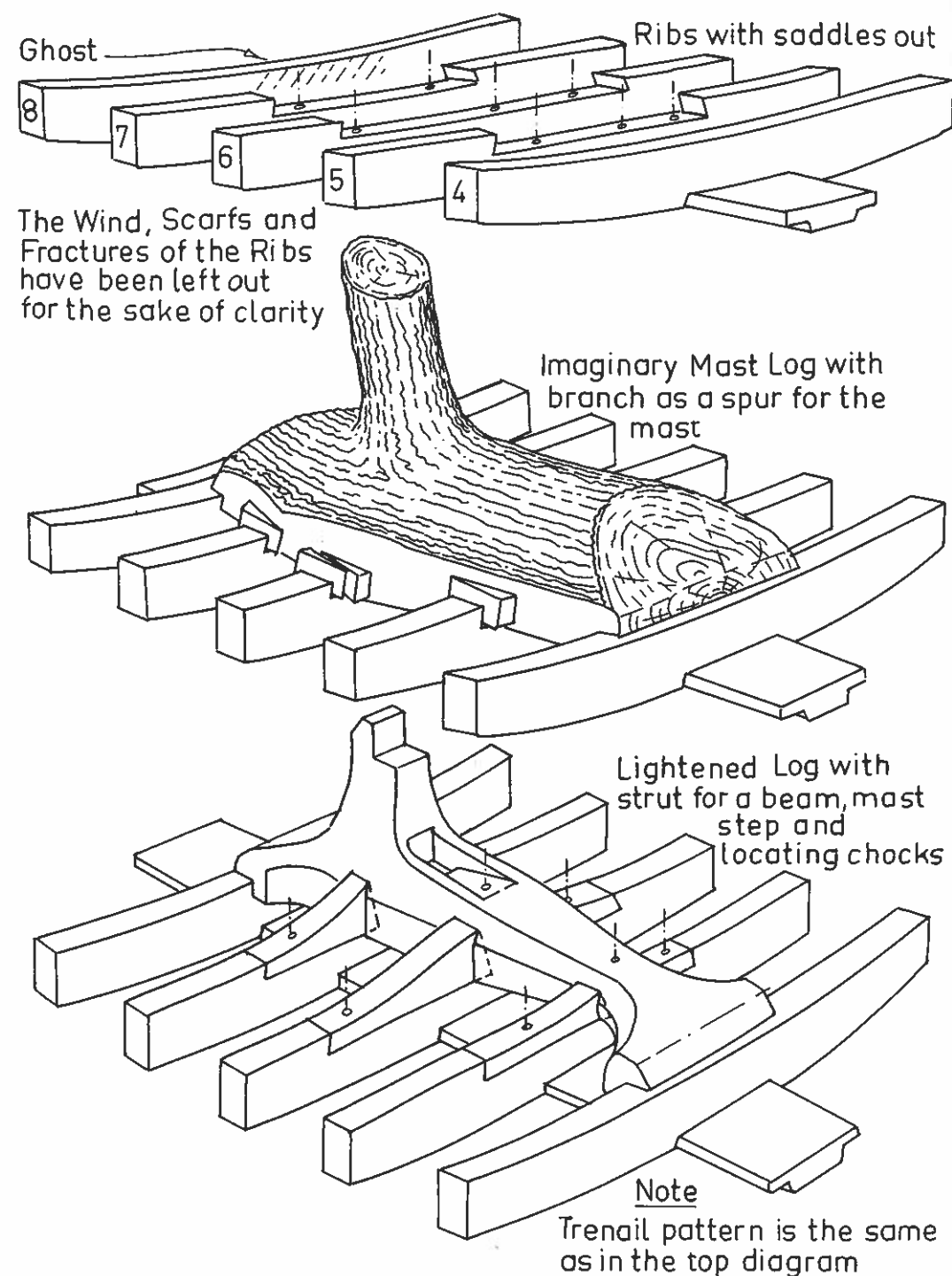


Fig. 9.1.11

SOME MAST-STEP SOLUTIONS

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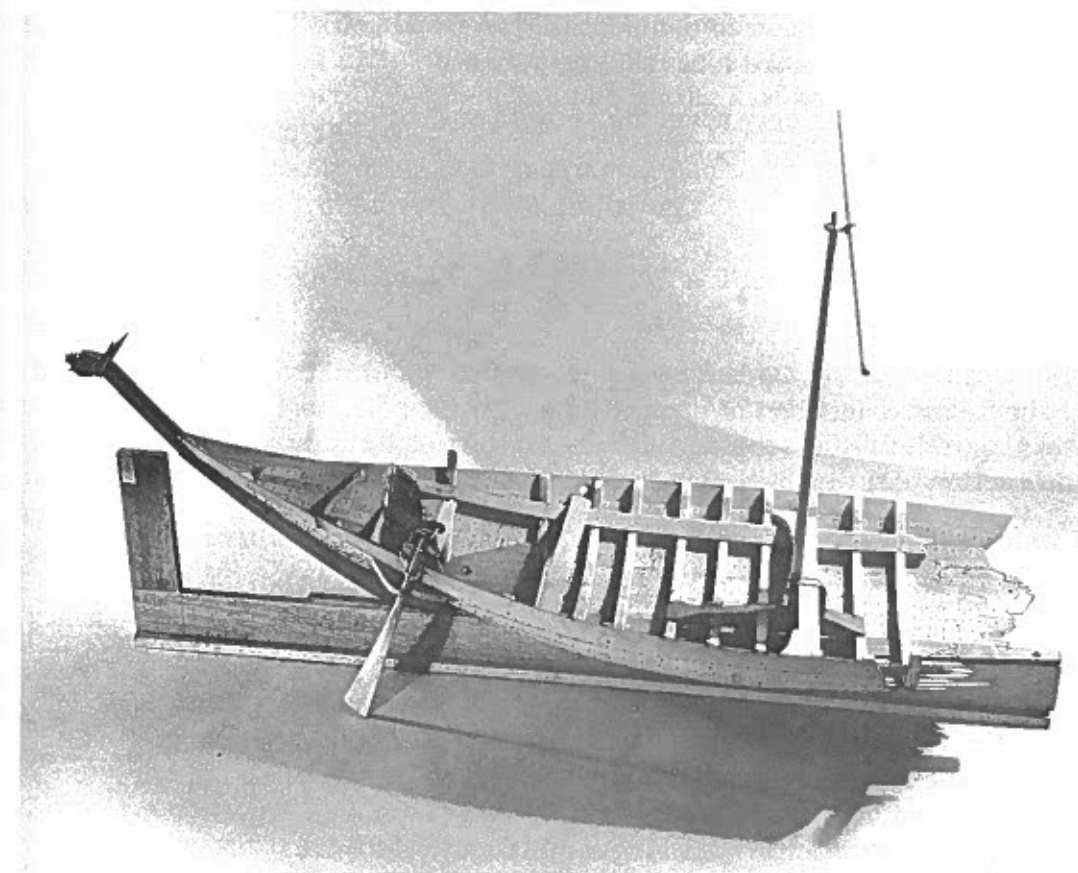


Fig. 9.1.12

Model of a maximum solution, or a reconstruction of the missing parts on the assumption that the vessel was a sea-going sailing barge. Scale 1:10 Model by Eric McKee  
© National Maritime Museum

load was over the sheer, the beam of the boat would have resisted any tendency to capsize.

Some form of steering gear would have been necessary with a sail. A steering oar over the quarter or the stern was probably employed in calm water, but a side rudder might have been needed in rougher conditions. The flaring side of the hull makes the provision of an adequate boss or sponson difficult. An exploratory model sponson was made to test if a side rudder could be fitted and was workable, though clumsy.

Fig. 9.1.12 shows the model with the maximum solution. A rather more generous sheer-line was added to compensate for there being one too few strakes, and to give the hood-ends more length in the rabbet.

The correct solution may never be known, but the solution proposed here is consistent with the remains found.<sup>4</sup>

#### NOTES

1. It occurred in situ; see p. 221.
2. J. F. Coates R.C.N.C. had suggested a year earlier that, as there could only be an exact number of strakes in a clinker-built boat and as each strake represented a substantial increase of weight and freeboard, the construction of a displacement curve should give an answer.
3. Of which von de Porten, writers (1963:51): 'The frames alternate in heights on opposite sides of the boat except at the ends.'
4. At a reconstruction progress meeting called by the Director of the National Maritime Museum in May 1972 it was decided that a replica should be built. Mr. Crumlin Pedersen said the boat followed a Frisian/Celtic rather than a Scandinavian tradition, and advised against trying to find a name for the type. No conclusion was reached on the nature of her cargo. Structurally it was agreed that there should be eleven strakes, and that the cants should be a single rib across the boat. It was decided to prepare conventional drawings of a replica of the minimum boat using moulds; details of gear to convert the boat into her maximum role should also be drawn. The measurements and rules of thumb the original builder might have used were discussed.

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## CHAPTER 9: RECONSTRUCTION

### PART 2. MODEL PLANKS

by Eric McKee

The exactness with which a dismantled boat can be put together again depends upon accurate placing of nail holes. This applies to full-size and model parts alike. Apart from clumsiness and carelessness the main sources of error are wrong assembly of fragments and slanting nail holes. As the full-size parts are awkward and fragile, methods using model planks were developed to minimize these errors. The fragments had to be assembled first to make a complete plank, which was the building unit.

#### ASSEMBLY OF ORIGINAL FRAGMENTS OF A PLANK

To begin with it was thought best to assemble all the pieces of a plank before it was traced. For reasons given on p. 35 this was not always possible, but more importantly it was found sometimes that the inside and outside tracings differed slightly, as it had not been possible to assemble the fragments in quite the same way after they had been turned. Better results were obtained by using undamaged nail holes in adjoining planks to show when the assembly was correct.

It will be appreciated that with slanting holes only positions on interfaces of a joint can be trusted. Drawings of both sides of the plank are necessary, the inside for holes in the lower lap, the outside for those in the upper lap, as are drawings of the corresponding holes in the mating surfaces of the planks immediately above and below.

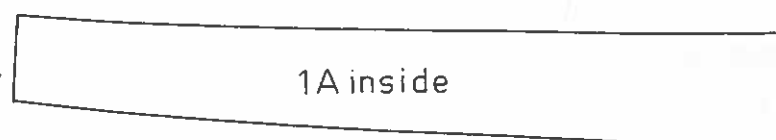
For simplicity, a plank broken into two pieces, 2A and 2B, has been chosen to illustrate the method (Fig. 9.2.1). The plank above is 3A and that below 1A.

- a. Take prints of the 1:10 scale drawings of the inside and outside of 2A and 2B, the inside of 3A and the outside of 1A. Write on each its identity, then cut them out. If the plank was traced from assembled fragments, the print must be cut into the original fragments.
- b. Place the cut-outs of the insides of 2A and 2B on a board, so that the holes either side of and nearest to the bottom of the fracture are the same distance apart as the corresponding holes in 1A. Pin the cut-outs to the board through these two holes.
- c. Pivot the cut-outs around these pins until a second pair of holes, this time about four or five holes away from the fracture, are the same distance apart as the corresponding holes in 1A. Check that the fracture line looks right and the edges are fair. Do not try to match the curvature of the edges with those of the next planks, which must differ.

## ASSEMBLY OF FRAGMENTS



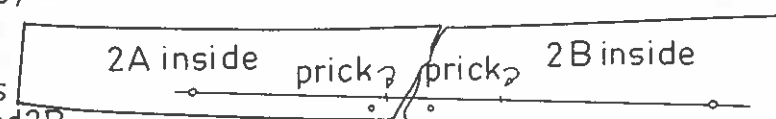
Stage (a)  
Cut out both sides of 2A&2B, inside of 3A and outside of 1A.



Stage (b)

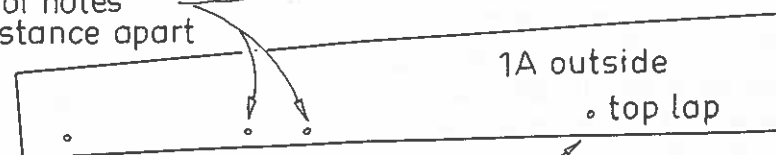
Pin the inside cut-outs of 2A and 2B

these two pairs of holes are the same distance apart



Stage (c)

Adjust the cut-outs of 2A and 2B so that the outer two pairs of holes are the same distance apart.

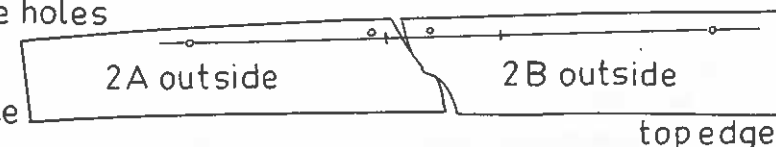


Stage (d)

Draw a straight line through the outer pair of holes as the edge is convex, or the inner if concave. Prick each cut-out on this line.

Stage (e)

Turn the cut-out over. Reversal is exact when the line is straight and the holes are the right distance apart.



Repeat for the holes in the other lap. Eliminate any wild holes.

Fig. 9.2.1

## ASSEMBLY OF FRAGMENTS

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- d. When a good initial setting has been found, draw a straight line through either the inner or outer pair of holes, and prick one more hole in each cut-out somewhere along this line.
- e. Use this line and four marks to reverse the cut-outs exactly.
- f. With the lower edge as a guide lay the cut-outs of the outsides on top of the inverted insides.
- g. Repeat a, b and c for the holes in the outside upper edges of 2A and 2B, this time with the holes in the inside lower lap of 3A as the guide. If this means a change of setting, resolve the cause by trying other holes, lest any of the first holes were wild.
- h. When satisfied, repeat d and reassemble the cut-outs of 2A and 2B on a sheet of stiff paper. Trace the edges and using the appropriate sides prick through all the nail holes, trenail centres, reference pins and other aids to location.

This will give a pattern for a model plank. If there is another major fragment of the same plank, then the process must be repeated with the pattern and a cut-out of the new fragment.

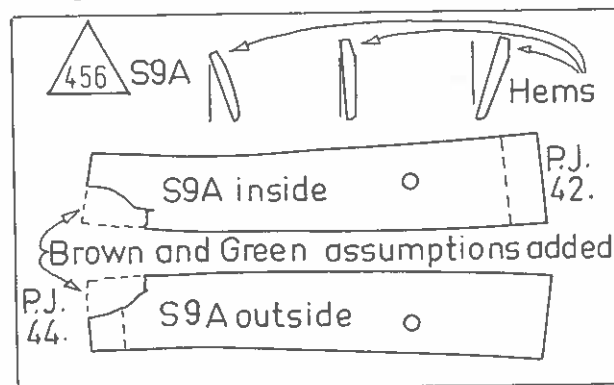
## MODELLING A PLANK

To make a model of a plank no more cutting out is needed with a complete pattern; the sequence follows that for an intact plank (Figs. 9.2.2-3).

- a. Take a print of the 1:10 scale drawing of the plank and add any of the brown and green assumptions described above (pp. 269, 271). Write on each side its identity.
- b. Cut out the shape of the inside and outside. Put them together, find the reason for and resolve differences.
- c. Use the inside cut-out to reproduce the shape of the plank in plywood. Identify this, showing which side is which.
- d. Replace the inside cut-out on the model and prick in the lower line of fastenings, trenail centres, nail holes in any exposed scarf face, and any location aids.
- e. Use an 0.66 mm awl to bore the marked nail and trenail pilot holes. Mark in the others with a sharp pencil.
- f. Turn the model over, position the outer cut-out and prick in the upper lap nail holes etc. Pencil these in.
- g. Shape any scarfs, hems and hood-ends from the drawings. Use sand-paper to smooth burrs and edges.
- h. Offer the plank up into place, with a number of pins through the holes in the upper plank, and check that they line up with the marks on the lower. Ring round any wild holes.
- i. Use the awl to bore every third or fourth hole in the lower plank. Start and finish with a hole at the end of the plank or next to a scarf but not in it. Check hem.

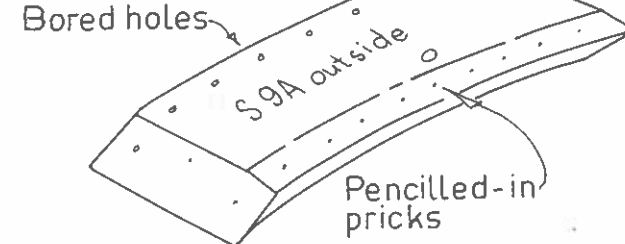
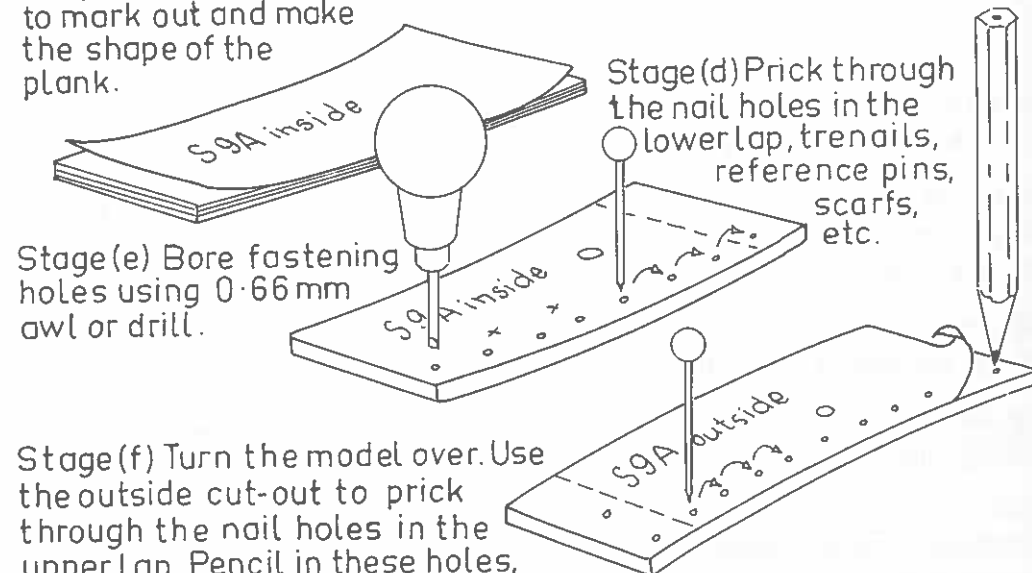
## MODELLING THE PLANK. Part I

Stage (a) Take a print of the 1/10th drawing of the plank and cut shape of the inside and outside edges.



Stage (b) Put cut-outs back to back and resolve any differences found.

Stage (c) Use the inside cut-out to mark out and make the shape of the plank.



Stage (g) Shape the plank. Cut the scarfs. Form the hems from the sections in the 1/10th print above. Sandpaper.

Fig. 9.2.2 MODELLING OF A PLANK, PART I

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## MODELLING THE PLANK. Part II

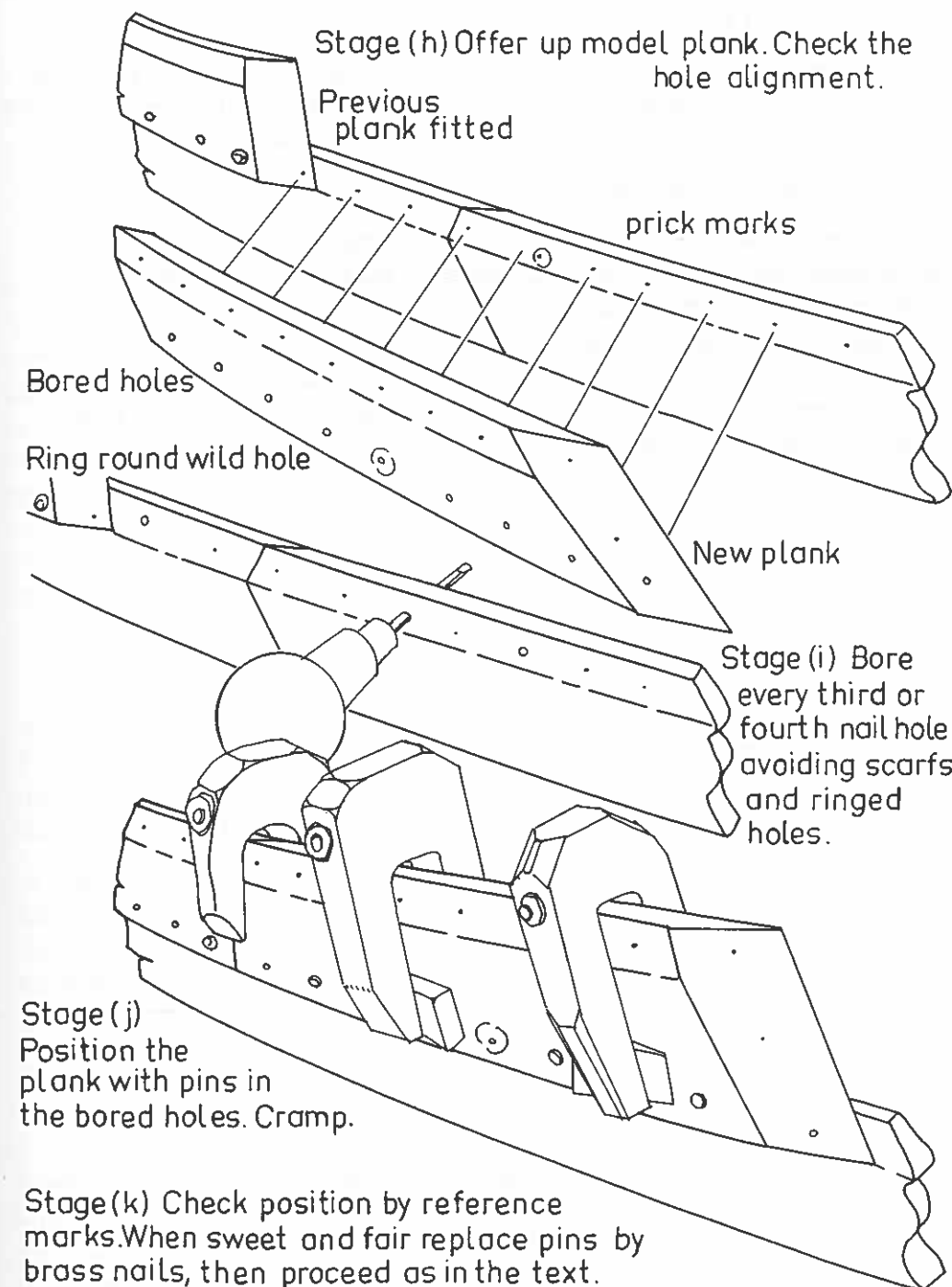


Fig. 9.2.3

## MODELLING OF A PLANK, PART II

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- j. Locate the model plank by pins in the holes bored through both planks and then cramp the lap and the scarf.
- k. Check by reference pin marks and other location aids that the plank is in its proper place, looking sweet and fair. One by one replace the pins with tightly fitting small brass nails.
- l. When all the planks in a strake have been cramped and nailed in this way, bore for and nail half the remainder. Remove all the cramps except those holding scarfs, which remain until the plank above takes its place.
- m. Finish the nailing of both sides together.

When there are several small fragments close together without many nail holes between them, or the fracture runs through three or more strakes, modelling is bound to be more inaccurate. This was so in the most damaged areas of the boat, on the port side aft and along the forward limit of the final. In the first a sloppy shape emerged, and in the second two attempts to find the shape of the bow failed. However, if the assumption that the boat was symmetrical is accepted, an alternative solution is available.

## CHAPTER 10: THE REPLICA

### PART 1. DRAWING THE REPLICA

by Eric McKee

Working from the model, accumulated detailed sketches, rough calculations and recorded data three sheets of drawings were prepared, from which a full-scale replica might be built. Although so far a 1:10 scale had generally been used, the final drawings were made to a 1:20 scale. At a 1:10 scale the draughts of the complete boat would have been very large, and, apart from the problem of producing them on available boards, they would have been costly to reproduce and inconvenient to use. Strictly, only half the boat needed to be drawn; the whole boat was depicted to aid visualization and clarify what small differences lay between the bow and the stern. Taking each sheet in turn the following notes may help interpretation.

#### SHEET 1: LINES (Fig. 10.1.1)

Conventional lines, to inside of plank, were taken off the model and faired, using five diagonals before converting them into a table of offsets. These were then redrawn to the 1:20 scale with the transverse sections spaced at 0.5m, buttocks at 0.4 m and level lines at 0.2 m.

1:5 scale drawings were made of the planking for displacement calculations. The run of strakes was tabulated from these and used to draw the planked views of the boat, which show the position of scarfs and trenails. In addition a set of transverse sections on the body plan makes it possible to compare the internal and external shape. It will be noted that the plank-ends have been drawn differently in the bow and the stern; this is discussed on p. 277.

#### SHEET 2: CONSTRUCTION (Fig. 10.1.2)

Sheet 2 shows how the boat was put together. The frames were spaced at 0.5 m to coincide with the stations used in the lines; this varies only slightly from the average actually used. The scarf details of each of the after frames were drawn separately, their forward counterparts being the same. Details of the canted frame, inclined frame and breasthook were also drawn. The rising was lengthened and notched into the inclined frame. This makes the component halves about 5 m long, but it is still possible that they were cut from the same tree trunk as the keel.

The plank diagrams were lifted from the model, the top three strakes being modified to give eleven instead of ten strakes. The sheer-line was

slightly altered at the same time. The port side appears on Fig. 10.1.2. The main difference between the port and starboard sides lies in the way the scarfs have been shifted. A constant lap width was used throughout; this was not so in the original boat.

Details of the hood-ends were drawn at a 1:10 scale to show the different ways they might have been worked. The double thickness of the lap had to be reduced to a single thickness to make a watertight face with the rabbet. This was solved by two methods, either by avoiding the use of a continuous rabbet, or by removing wood from one or both of the laps so that they merged into one (Fig. 10.1.3). Although the second method was somewhat harder than making a modern splay or chase, it should result in a stronger construction, as it avoids using the pointed end of the plank. The new end was made by cutting off the pointed end of the plank in the lap, and then excavating the inside of the plank above until it made a good joint along the lap and in the rabbet. The point might originally have been cut off either square with the rabbet line, or square with the top edge of the plank. In the lower strakes where the angle between the rabbet and top edge is small there is little apparent difference between the two methods of cutting; higher up the difference would have been considerable. It is impossible to detect which method had been originally used on the upper strakes, because only lower hood-ends remain. Both methods are shown on Fig. 10.1.3.

Another feature of the hood-ends was the use of a short reversed curve<sup>1</sup> in the end of the lower edge. In effect this increased the length of the plank in the rabbet and gave more room for fastening. As cutting off square with the top edge of the plank would have shortened the length in the rabbet, these two arrangements have been shown on the same drawing (Fig. 10.1.3) to indicate how one cancels out the other.

The hood-ends of strakes 1 and 2 were through-fastened with double clenching grooves cut into the inboard face of the sternpost, and the nails riveted over roves as securely as are the land-nails. The arrangement in the missing upper part of the post is uncertain, but a continuous system of grooves would have been a source of weakness.

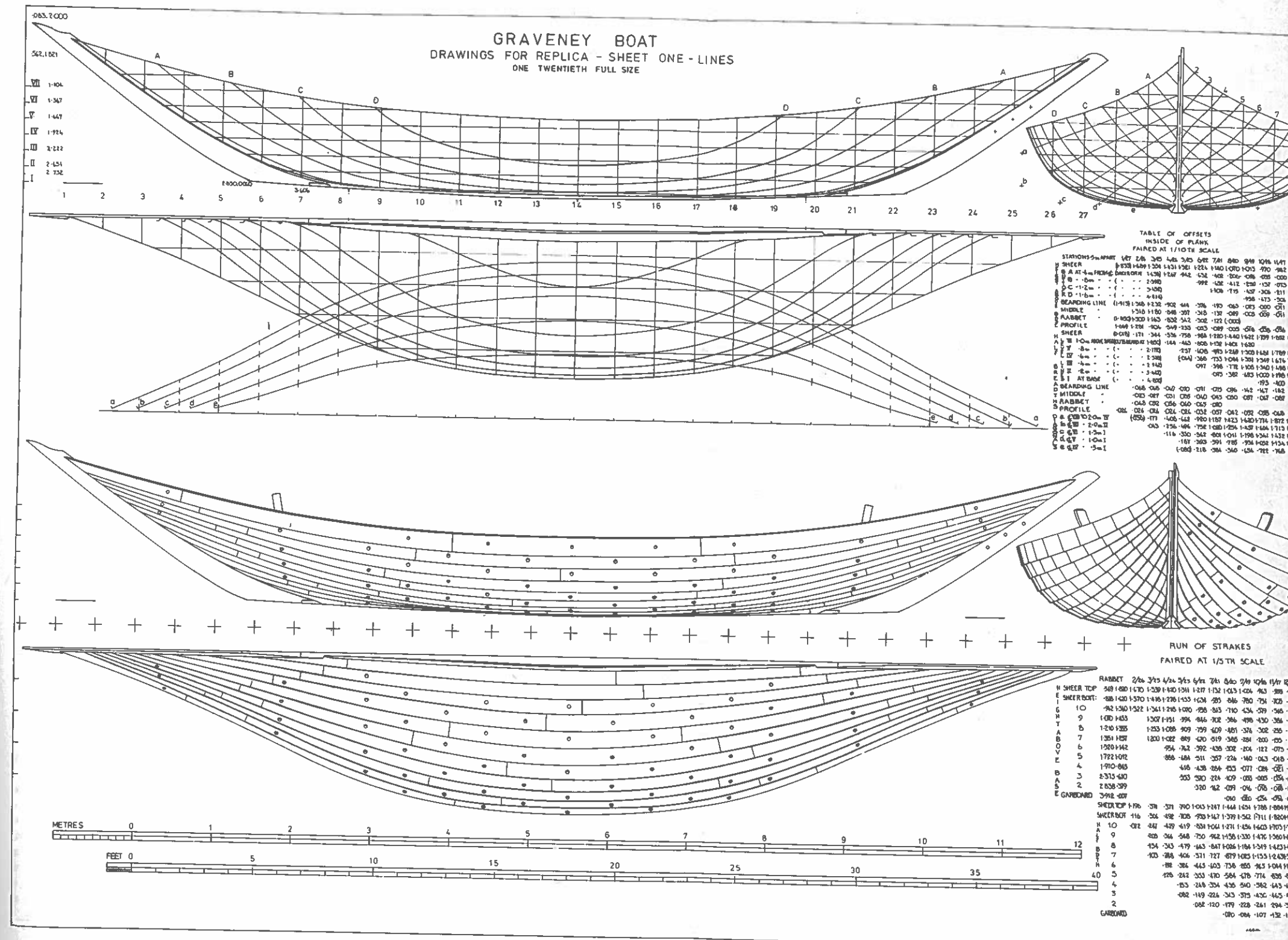
Remains of the sternpost and photographs taken during excavation show no grooves for strake 3. There may have been a single central groove serving both sides above that, as if for strake 4 on the evidence of Gr88,89. It was possible to avoid continuous grooves by using intermittent ones and still have at least one through-fastening in every strake; the rest would have had to be blind (none below water). Fig. 10.1.2, on left, illustrates how this could be done. Starting with strake 3, which has one through-fastening out of four, strakes 4 and 5 have two out of three, strake 6 has one out of three, and all the rest one out of two. Of twenty-four nails in the rabbet, therefore, eight would have had to be blind. Short grain in the sternpost was avoided; the solid and mutually supporting nature of this type of 'hidden' end makes the best of the reduced number of positive fastenings. For the safety of the replica, however, extra frames were added to prevent the bearding of the rabbet splitting away. This should be close to, if not exactly the same as, the original arrangement.

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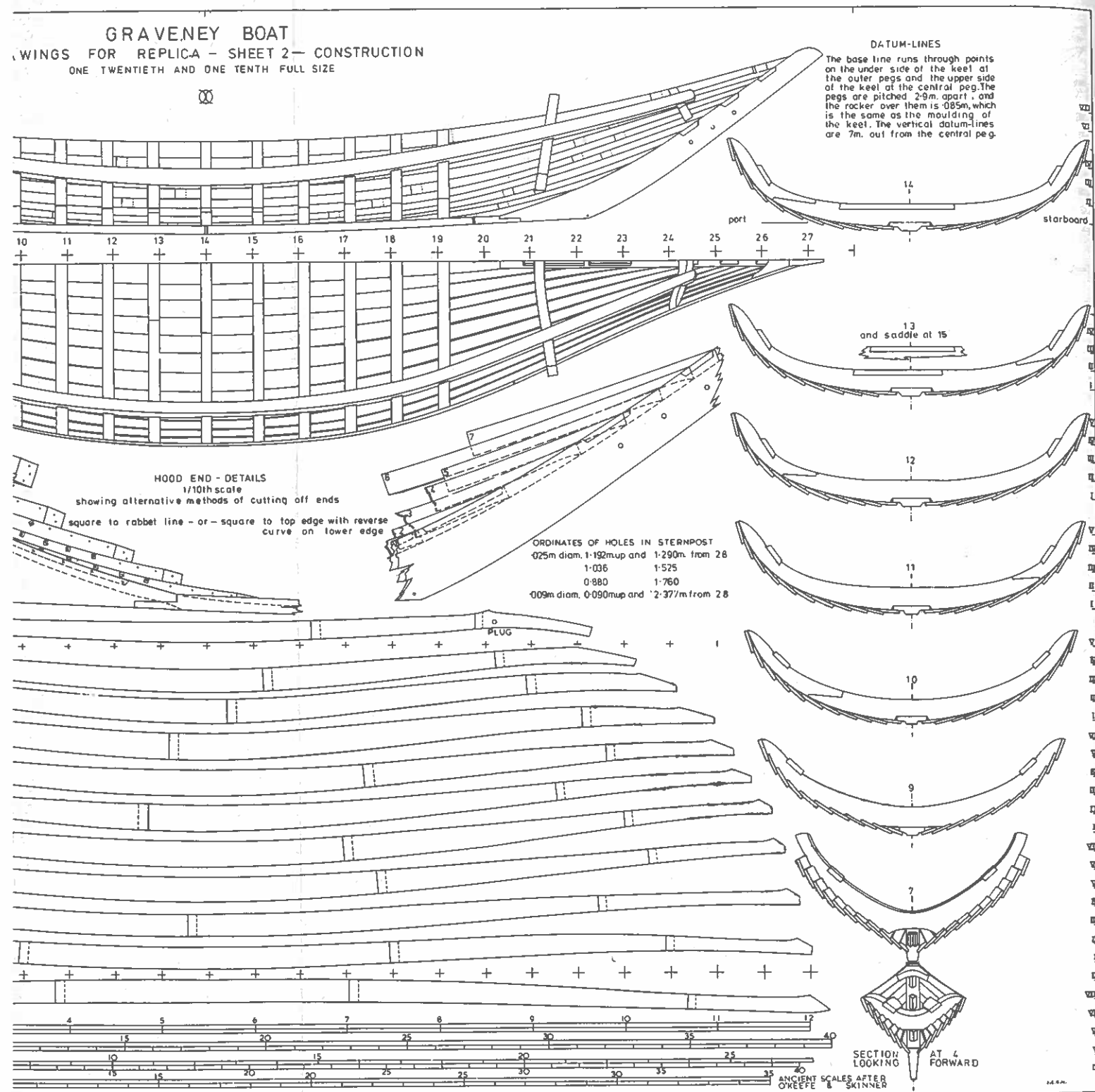
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This should be close to, if not exactly the same as,  
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## HOOD ENDS

### Sternpost

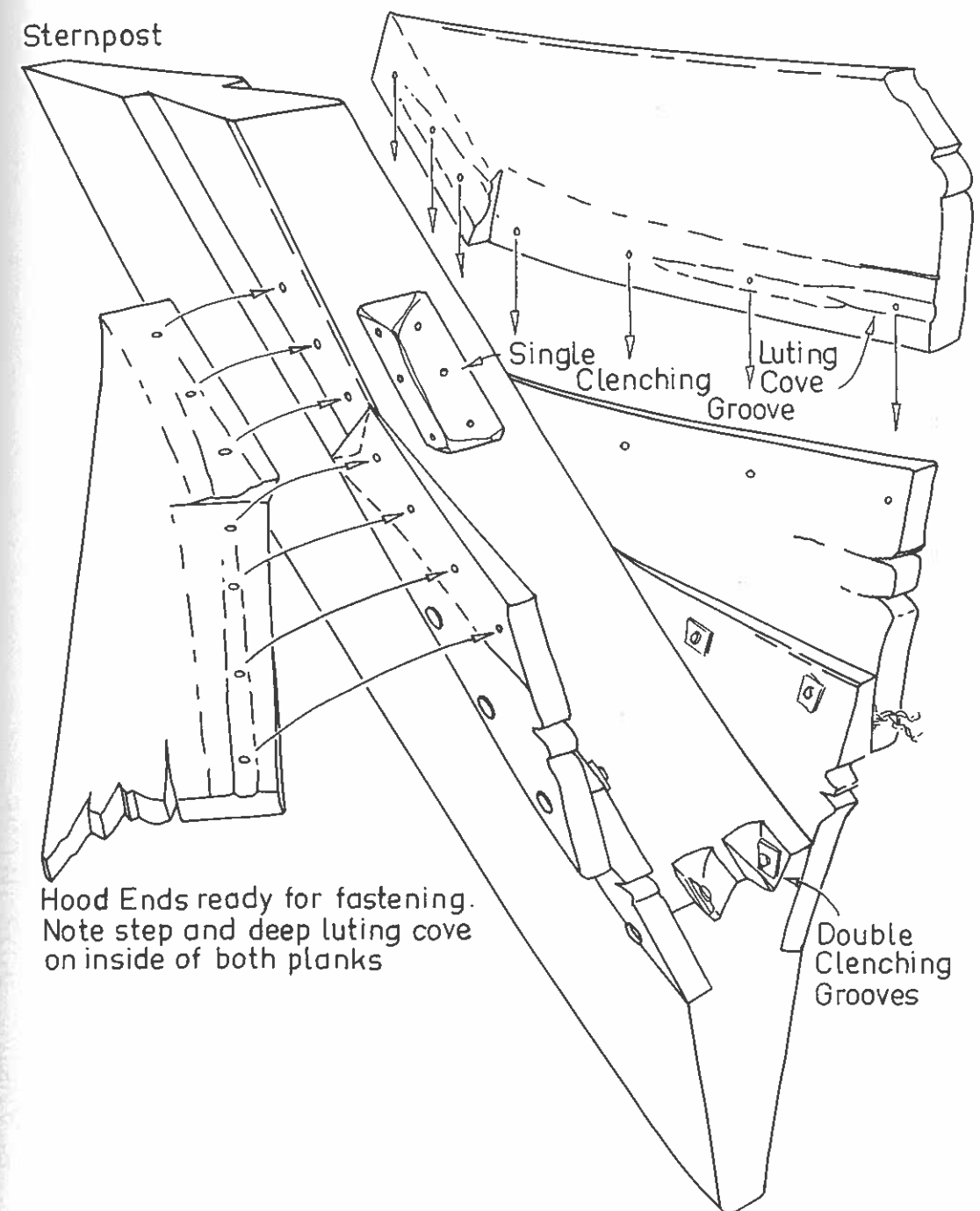


Fig. 10.1.3

HOOD-ENDS

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## 10.1.2 RECONSTRUCTION DRAWING OF THE BOAT AND THE STRAKE DIAGRAM

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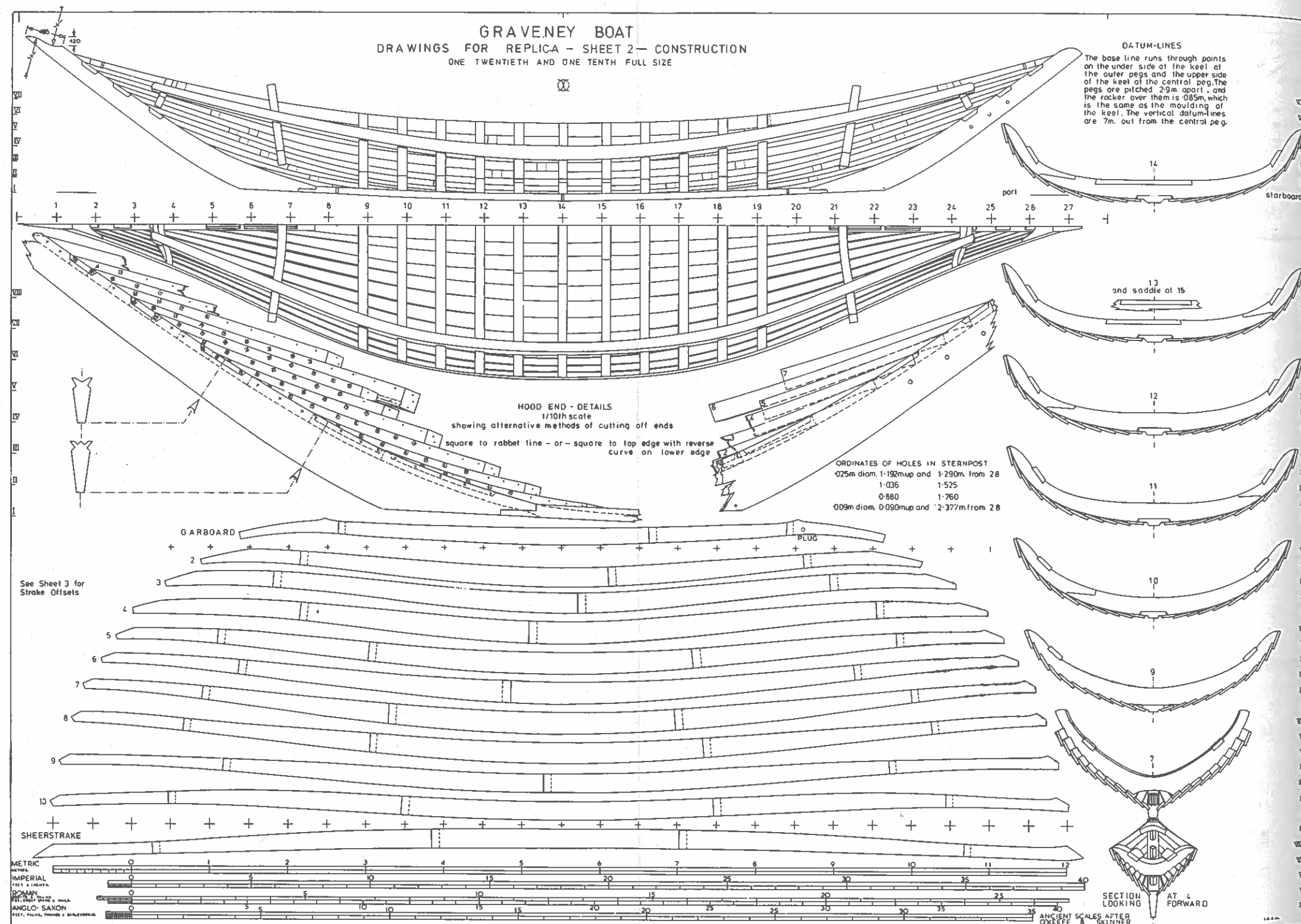


Fig. 10.1.2 RECONSTRUCTION DRAWING OF THE BOAT AND THE STRAKE DIAGRAM

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The hood-ends were described to a practising boat-builder. Although he saw their advantages, he quickly noticed that it would have been difficult to make them watertight along the interfaces between the cut corners and the steps in the outer planks. The deep luting coves close to the steps in strakes P2, S3 and P3 probably provided reservoirs, from which luting would have been squeezed into the interfaces as the planks settled into place. Although modelling the hood-ends gave little trouble it was not of course necessary to make them watertight. It is expected the reason for these deep luting coves may be clearer when they are made full-size.

### SHEET 3: MISCELLANY<sup>2</sup>

Although the scantlings and the displacement curve appear on sheet 3, the information on which the displacements are based appears on sheet 1 (Fig. 10.1.1) and the weights on sheet 2 (Fig. 10.1.2). Otherwise apart from the off-sets for the strakes and the risings, everything else on sheet 3 is mainly conjectural and connected with converting the replica from its minimum to its maximum role.

The rowing thwarts are movable being secured in place by lashings round the risings. The mast-beam however is located by lodging knees. Rather elaborate bottom boards have been drawn; experience with the replica of the Gokstad *faering* showed how important these are for the crew during trials.

A log mast-step with knees has been shown, with the mast lowering forwards. The yard has no halliard nor any braces as the running sail can be controlled by its sheets, and it rises with the mast. The sail specification attempts to give modern equivalents for obsolete materials.

The side rudder and its sponson were designed with ease of rigging more in mind than a precise reconstruction. It is hoped to learn more about the steering, by comparing a rudder in the side and aft positions with a sweep. The outfit of oars and sweeps allows several ways of rowing to be tested, even with ten rowers at a time; it is hoped to gain more information on the use of sweeps. To avoid weakening the sheer strake initially by cutting oar-ports, an adjustable wash strake with oarlocks has been drawn. If this proves to be too high, ports may then be cut and the gunwale stiffened.

To make the choice of timber easier the stem and sternposts have been kept as short as possible. For appearance sake, some form of simple finial might be appropriate for the replica in her maximum role.

Ground tackle which will be essential during trials has been included. The anchor and its chain stemmed from the Ladby find (Thorvildsen, 1957), while the killick, though ubiquitous, is based on the one from Newfoundland (Campbell, 1957:158).

### CONCLUSION

The replica has been drawn in such a way that it can be built with three moulds. If this method of construction is chosen, the master boat-builder will decide where to put them; stations 14, 10/18, 6/22 are suggested. A pair of planking aids have also been designed and drawn. It is not intended

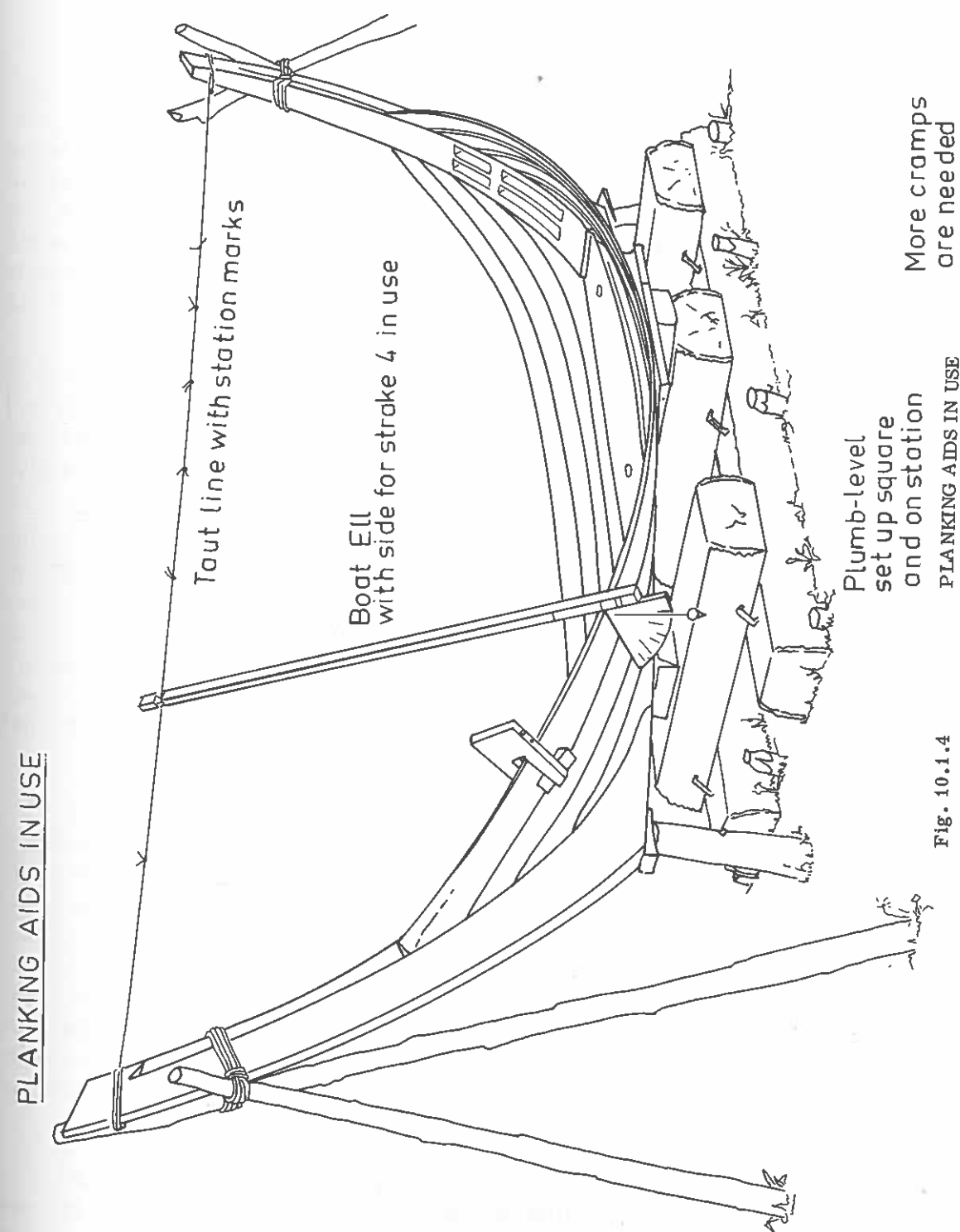


Fig. 10.1.4

Drawn by Eric McKee  
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that they should be used in conjunction with the moulds but to gain experience in working with them (Fig. 10.1.4). The information on the pair of planking aids is more than the original builder would have needed and more than on the three moulds. An unmarked ell and plumbevel can be used to check that the sides and ends of the boat are alike, and to compare with the marks on the planking aids to see how adequate and reliable the latter would have been.

These drawings are not necessarily to be taken as the basis for a final reconstruction of the Graveney boat, but it is hoped that they all are means to that end. More confirmation will be gained from the building and trials of the replica, and then a better reconstruction can no doubt be made.

#### NOTES

1. The reverse curves in the garboards are different. Here the edges had been shaped to present a smooth surface where the rabbet in the sternpost turns into the open flange of the keel.
2. Sheet 3 is available for study at the National Maritime Museum.

#### REFERENCES

- Campbell, 1957. R. W. Campbell, 'The killick in Newfoundland', Mariner's Mirror, XLIII, 158-9.
- Thorvildsen, 1957. K. Thorvildsen, Ladby-Skibet (Copenhagen).

## CHAPTER 10: THE REPLICA

### PART 2. APPRECIATION OF THE LINES

by Ewan Corlett,  
Trustee, National Maritime Museum

It is interesting to consider the basic naval architectural characteristics of the lines of the hypothetical minimum or simplest reconstruction of the Graveney boat, the probable stability of the vessel in service, its efficiency as a hull form and its likely characteristics as a sea boat. The 1:20 lines drawn by Eric McKee have been used for this purpose together with the hydrostatics prepared from them by Burness, Corlett and Partners Ltd., Naval Architects and Marine Transport Consultants.

The method of construction naturally gives a boat of easy lines with a rather slack midship section and easy buttocks, waterlines and diagonals. The general proportions are interesting. It is considered that a boat in service would probably operate between waterlines 3 and 4, namely at drafts of between 0.45 and 0.65 m.

Working on waterline dimensions the length to breadth ratios at these two drafts are the same, namely 2.56, while the beam to draft ratios are 7.3 for the lighter draft and 5.6 for the deeper. The boat is therefore very short and beamy, and with a considerable beam/draft ratio. Such values of these coefficients certainly suggest that the vessel was designed for a specific purpose. Further, the relatively full midships body, the large beam and the presence of heavy floors amidships lead to the conclusion that she was probably designed for carrying heavy and not very voluminous cargo.

#### STABILITY

It is reasonable to estimate the maximum height of the centre of gravity of the cargo, which would be heaped amidships, as approximately 0.96 m above the moulded base line,<sup>1</sup> and that of the hull at rather less, say 0.80 or just over. This being so, the overall centre of gravity of the loaded vessel would be approximately 0.9 m and, as the height of the metacentre<sup>2</sup> is 2.23 m at the lighter draft and 2.09 m at the deeper draft, it is obvious that the vessel would be operating at all times with well over 1 m of metacentric height. This is considerable for a boat of this size. No stability problems would ever be experienced with this vessel and she would also be capable of carrying a considerable amount of sail.

#### CHARACTERISTICS OF LINES

Because of the high beam/draft ratio it is to be expected that a significant amount of the water flow would be under the hull along diagonals such as E, D and C (Fig. 10.2.1). These are of a very satisfactory character with a reasonably small half-angle of entrance (about 20° for diagonal D and as low as 14° for diagonal E). The waterlines are less satisfactory. This is likely with a



3½ knots by half a dozen men, while under special conditions with flat water and a fairly strong wind aft of the beam she might be expected to reach 7 knots.

#### SAILING BALANCE

The hull is such that when heeled the longitudinal centre of buoyancy<sup>3</sup> would hardly move at all. This means that, as the above water characteristics of the section are balanced also, the ship should not carry much weather or lee helm when heeled. This is an important point as the method of steering, which presumably was by a steering oar from the starboard side, would not be very satisfactory if the ship had a tendency to carry appreciable constant helm at sea.

#### CONCLUSION

On the assumption that the boat was intended to be a fairly efficient, moderately fast carrier of heavy concentrated cargoes, e.g. stone in wicker baskets or perhaps salt, the design is good. If a barge for only moving around on a river was required, then the boat is extravagant; it would have been much cheaper and easier to have built a full-bodied vessel without overhanging ends. The basic boat as reconstructed would be seaworthy, reasonably fast, capable of making sea-going voyages under sail carrying a cargo of probably about 6 or 7 tons. But on sea-going voyages it would become wet amidships, indeed perhaps dangerously so; it is likely therefore that some form of hide or canvas dodger would have been arranged amidships to prevent water slopping on board.

#### NOTES

1. The moulded base line is the base line from which the lines to the inside of the planking are drawn.
2. The metacentre is the point where the line of the upward force through the centre of buoyancy cuts the centre plane of the vessel.
3. The longitudinal centre of buoyancy is the fore and aft position of the centre of gravity of the water displaced by the boat.

#### CHAPTER 10: THE REPLICA

##### PART 3. TENTATIVE SEQUENCE<sup>1</sup> FOR BUILDING THE REPLICA

by Eric McKee

This section describes a tentative procedure for building a replica of the Graveney boat, and makes suggestions for materials and tools. As experience is gained by the replica builders, they may wish to modify aspects of it.

#### PROCEDURE

Clear site and erect log gantry. Level top, strike in centre-line and fit chocks for rocker each end. Make keel, with box scarfs and rabbets left full. Place keel on gantry, bore for and secure with three trenails. Make both stems, with box scarfs and bearding left full. Offer up stems, close fit scarfs, lute and clamp. When plumb and true, spall and shore, and fasten both box scarfs.

Make shams and shores for midships and stations 2 and 4 m each side of midships. Erect shores, pivot shams and stretch taut line. Fair with battens and mark strake heights on stems and shams.

Cut rabbets for garboard hood-ends to size. Spile for lower and rabbet edges of port after hood-end, and measure twist in plank with plumbevel. Cut out two planks to this spiling, over long and full on top edge. Steam one to shape. If it breaks, cut twist from solid blank. Offer up plank, close fit, mark laps, take down, gouge luting coves and cut plank scarf. Lute laps and clamp into place. Bore for hood-end fastenings only. Use these holes to locate clenching grooves, cut grooves and nail.

Taking copies for other side, in succession make, fit, lute and clamp port intermediates and forward hood-ends. Fit, lute and clamp all starboard garboard planks. Check lie of strake, bore for and nail scarfs and lands. Run batten to pick up strake marks and cut top edge to fair line.

Bore hole for bung in port after hood-end for drainage and sweep boat clear of chips daily.

Repeat sequence for strake 2, but start on starboard side. Check final upper plank edge with planking aids as well as sheer marks, noting any difference. Plank on up, check every strake by strake marks, and strakes 4, 6, 8 and 11 (sheer) by planking aids. Pick out and use thicker planks for intermediates of binding and sheer strakes, 6, 7, 8 and 11. After strake 4 shore bilge and put sacking over nail points. At turn of bilge, make template to find and shape longer legs of ribs 3 and 9, and for taking spilings of ribs between. Make separate templates for ribs 1 and 2, and use for 10 and 11 as well. As planking proceeds rough out as many ribs as possible.

When planked up, remove shams and shores, rove, crop, and clench nails in order of driving. Clean and paint out boat with mixture of Stockholm tar, linseed oil and turpentine.

Starting amidships close fit long leg of each rib, only joggling ribs 1 and 11. Cut top timber scarfs short of risings and temporarily secure ribs. Starting with strake 3 on even and strake 4 on odd numbered ribs, bore for trenails from inboard to include alternate strakes up to but not including any scarfs or risings. As each hole is bored, place tarred grommet on trenail and drive it home from outboard, cut off flush inboard, split and wedge. Make fit, but do not fasten saddles. Make and temporarily secure bottom boards. Make and fit top timbers, canted and inclined ribs, and breasthooks. Bore for and fit all remaining trenails clear of risings.

Make half risings and scarf them together. Mark out and cut notches in ribs. Position and clamp risings. Bore for fit trenails in every rib. Trim off ends of all ribs either level with sheer or as timber heads. Remove bottom boards, clean out boat and apply second coat of preservative. Find stripped weight of hull from weight book and check with Duckham's Hook.

As convenient make or procure all accessories needed for boat and trials, checking off list by noting weight of each item.

Chock boat to top tier of gantry and knock away bilge shores. Cut off keel trenails flush with bottom. Chock up top tier and remove lower tiers, before chocking down on to ways at ground level. Cut across to launching slip and apply third coat of preservative. Equip boat, make and fit bung. Launch.

#### MATERIALS

These notes amplify the cutting list held in the National Maritime Museum. Wood felled the same year should be used for the planks and risings. If the timber is sawn, the cut should be radial, with the growth rings at an angle of not less than  $75^{\circ}$  to the surface of the plank. About 100 m run of this plank should be 30 to 35 mm thick for the intermediate binding and sheer planks.

The keel, stems, ribs, and other crooks must have had at least a year to dry. The keel is to be tangentially cut so that the heart side is underneath. The blanks for the trenails may be cleft from well-seasoned willow or oak, and should be made and stored in a dry place as soon as possible. Tests are needed to find the sizes best suited to the available augers.

Thwarts, oars, spars and other gear are to be of any suitable material available economically. Luting and grommets are to be twisted from animal wool and Stockholm tar only just before use.

Iron dogs and roughly sided logs are needed to build up a gantry about 1 m high. Poles are required for stakes, spalls and shores. Stout boards about 5 m long should be used for cutting across skids and launching ways, with a 50 kg drum of tallow for greasing them.

#### TOOLS AND EQUIPMENT

These items should be as similar as possible to those originally used.

Augers for boring 25 and 30 mm holes for trenails  
Awls for boring 3 mm holes for nails  
Axes various i.e. hand, felling and bearding  
Battens long, flexible, with graduated straight edges  
Boat ells marked as on Fig. 10.1.4 and plain  
Chisels 50 mm for paring and 25 mm for trenails  
Chocks built up, tapered and solid square  
Clamps as used by boat-builders, made on site as needed  
Cold sets for cutting out roves and cropping nails  
Dividers for marking out  
Dollies for holding up and as hand anvils for cropping  
Gouges for cutting luting coves  
Hammers for driving and clenching  
Mallets carpenters' and for driving trenails  
Mauls for driving stakes and wedges  
Pinch bars for manhandling baulks  
Plumb bobs for gauging and marking out  
Plumbevels marked as on Fig. 10.1.4 and plain  
Punches for making 2 mm holes in roves and for roving  
Ropes for lifting and lashing  
Scrapers for finishing lap and scarf surfaces  
Scribers for marking out  
Snips for cutting out roves, if cold sets are not adequate  
Squares sets and tries for marking out  
Steam box improvised from cauldron and planks  
Tackles for slinging and cutting across  
Wedges of hard and soft wood, for cramps and chocks

#### NOTE

1. The sequence given is for building indoors; it would have to be modified if building is to be done in the open.

## CHAPTER 11: CONSERVATION AND DISPLAY

### PART 1. MAKING A FIBRE-GLASS MODEL OF THE BOAT FOR DISPLAY

by Christopher Gregson,  
Conservation Officer, Archaeological Research Centre,  
National Maritime Museum

The Graveney boat will be an important feature in the new archaeological gallery being developed in the National Maritime Museum. As it was recognized that the conservation of this craft would exceed the time scale allowed for the opening of the gallery by several years, an alternative was sought, so that the size and structure of this 10th-century boat could be seen exactly as she was found during excavation.

Building a wooden display model of the boat as found presented formidable difficulties in finding suitably seasoned timber, craftsmen with the appropriate skills, and so forth. A simpler solution presented itself in the form of the plaster mould made of the interior shell of the boat whilst she was *in situ* (pp. 17, 19). This mould was visualized as a three-dimensional record. Its value as a base for a model for display was not then considered. The most stable material which could be used in conjunction with the plaster mould to form the model was fibre-glass. There is a precedent for this, on a somewhat larger scale, in the British Museum's fibre-glass cast of the impression of the Sutton Hoo ship (van Geersdaele, 1969).<sup>1</sup> The fibre-glass work was undertaken by Cory's Barge Works of Charlton, an application of their skills which was a new venture for them.<sup>2</sup>

At the time of writing (October 1975) the display model is not complete. The interior of the craft has been formed, but the frames are only in the process of being moulded in plaster. The following account covers progress so far, the problems which have arisen and been overcome, and indicates some possible sources of distortion which cannot be fully evaluated until work is complete.

#### SETTING UP PLASTER MOULD

Setting up the plaster mould was not an easy process. In all it is composed of nineteen pieces each about .90 m square, with irregular edges to help key them together in the correct alignment. Their arrangement was as a central row covering the line of the keel and the first two planks, and sections on either side to complete the planking. Where the planking narrows to join the sternpost one central section was sufficient. These pieces of the mould were set up upside down, the sternpost and keel sections supported on a massive wooden beam, the side sections by two or three wooden legs wedged

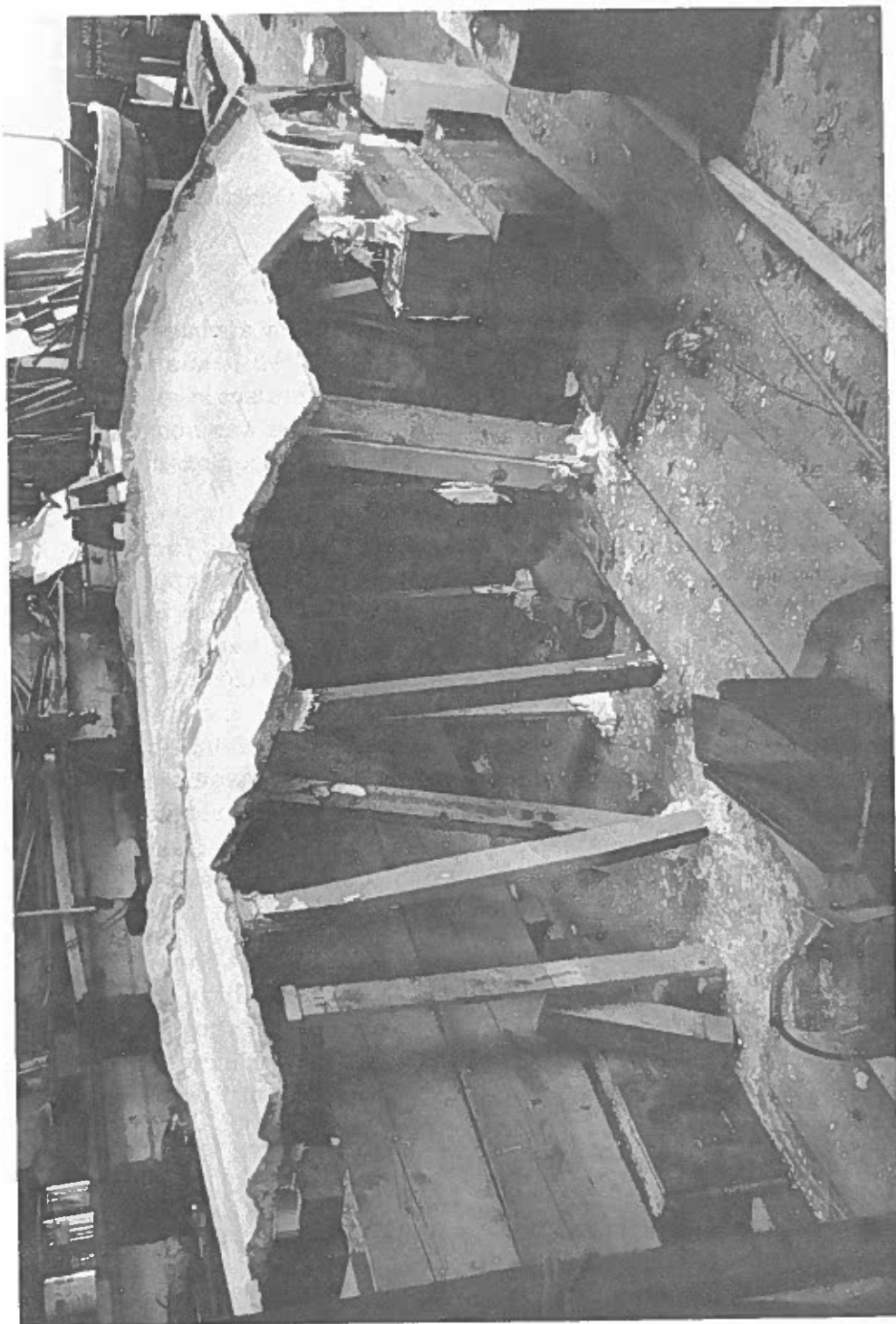


Fig. 11.1.1 Oblique view showing the central beam and wooden legs to support the plaster mould  
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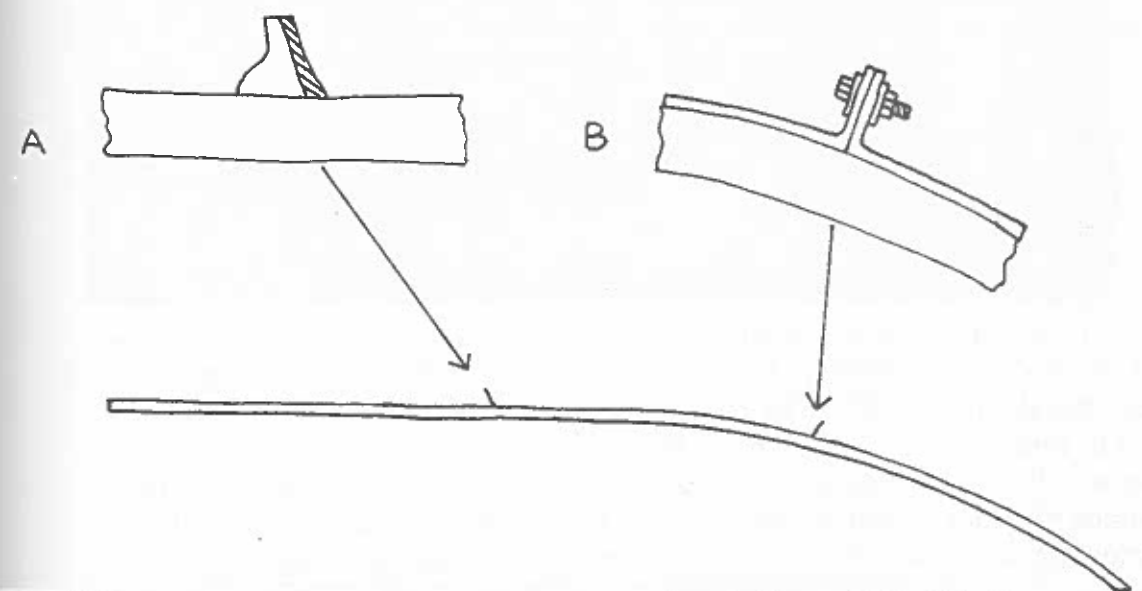


Fig. 11.1.2 Diagram of longitudinal section of the keel (sternpost on r.) showing three sections of the fibre-glass cast.  
A, plaster wall against which a flange to be formed;  
B, two sections of the fibre-glass cast bolted together (the plaster wall having been removed after right-hand section laid up). Drawn by C. W. Gregson  
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into position and fixed with plaster and scrim. This may seem a primitive, even precarious (Fig. 11.1.1), method of support, but it was essential for each section to be correctly aligned in three planes to produce the lines of the craft. The smallest initial error became progressively more exaggerated as more sections were added; the mould was erected and dismantled twice before an acceptable form was found. A degree of error of 6 mm (maximum) had to be tolerated at some of the joins between the individual sections. It is difficult to explain why there were any discrepancies. But there is the possibility of slight distortion of some of the mould sections during drying, which was quite prolonged, or there may even have been some movement in the craft as she lay in the ground. In all, nearly 3 tons of plaster was applied to make the mould.

The paper towelling, which had been used on site as a release agent to separate the plaster mould from the wood, had caused wrinkles in the surface of the mould. These wrinkles had to be filled not only to prevent under-cuts which would lock mould and cast together, but also to create a more wood-like appearance. Plaster delicately skimmed over the surface filled the wrinkles, and left salient features visible; whilst still soft, the plaster was wiped with a damp cloth to enhance the wood effect.

#### MAKING FIBRE-GLASS CAST

It would have been impracticable to make the fibre-glass cast in one piece, not only for its lack of rigidity, but also for the practical restrictions of doorways and storage facilities. The cast was therefore made in three sections, each 1.8 m long. Where the sections meet, a 50 mm flange was formed on each piece. These flanges provided lateral stiffening and a means of joining the sections together. Whilst the cast was still on the mould, 12 mm bolts were fitted through holes drilled at .46 m intervals along the flanges.

To form the flanges (Fig. 11.1.2) angled plaster bands were laid across the mould, and the clay walls used to set the angle of the plaster bands were removed after the plaster had set. Two coats of a polyvinyl acetate<sup>3</sup> release agent were applied before the plaster bands were laid to facilitate their removal.

The whole surface of the mould was sealed with two coats of polyurethane and waxed with a non-silicone wax, to prepare it for casting. Two gel coats were followed by one layer of surface tissue and six layers of 1 oz chopped strand matting bonded with polyester resin. The cast was further braced laterally by paper ropes laid .35 m apart across the cast, and bonded with three layers of chopped strand matting over them. After hardening, the fibre-glass sections were raised from the mould with the aid of small wooden wedges. The only damage was adhesion to the fibre-glass of some of the plaster used to fill the wrinkles in the mould, but this was easily washed off. When turned and bolted together the joins of the sections are scarcely visible, and the realization of the interior surface of the boat is very impressive.

#### MOULDING FRAMES

The frames will also be made up in fibre-glass; at present their tops, sides, and if thickness demands, ends are being moulded in plaster. It must

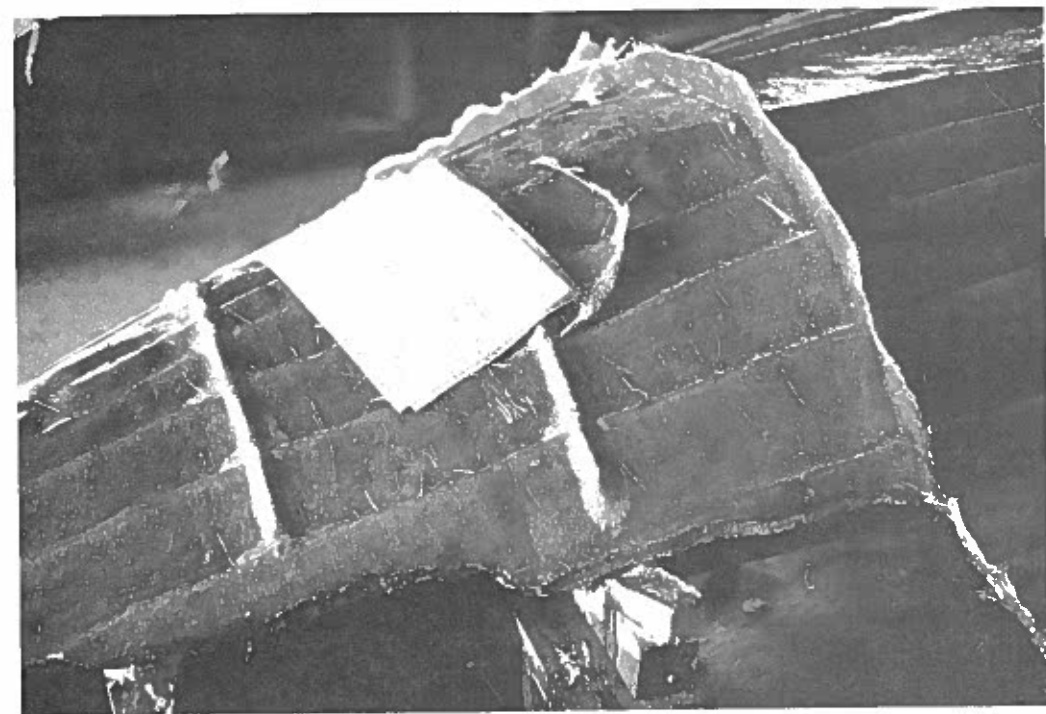


Fig. 11.1.3 Sternpost section after removal of the plaster wall; a flange and the paper rope stiffeners are clearly visible.  
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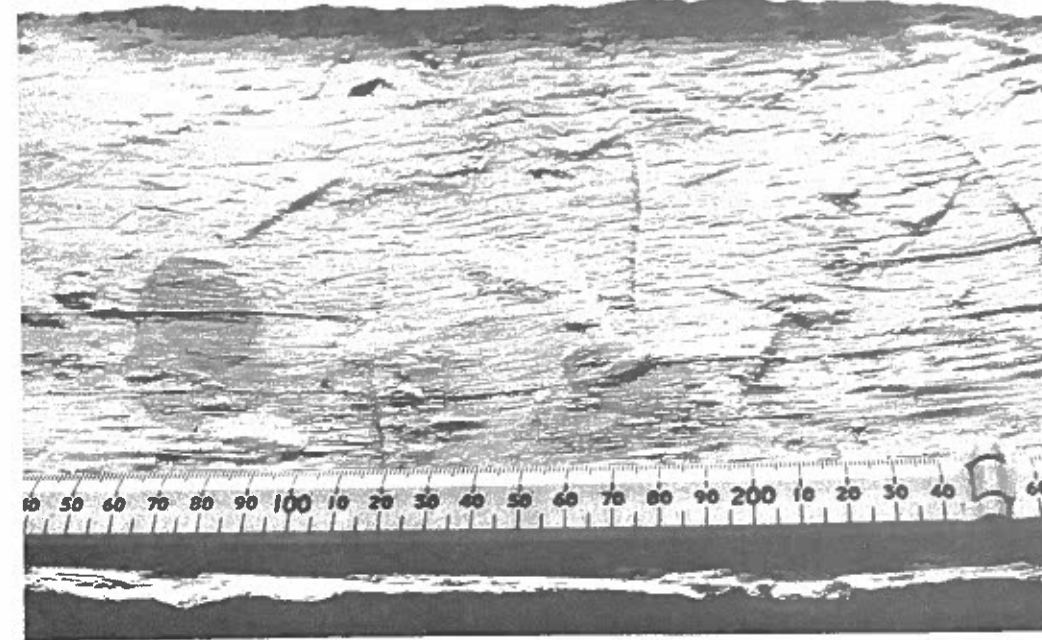


Fig. 11.1.4 Mould of one side of frame R8 showing the wood grain and tool marks. Scale in cm  
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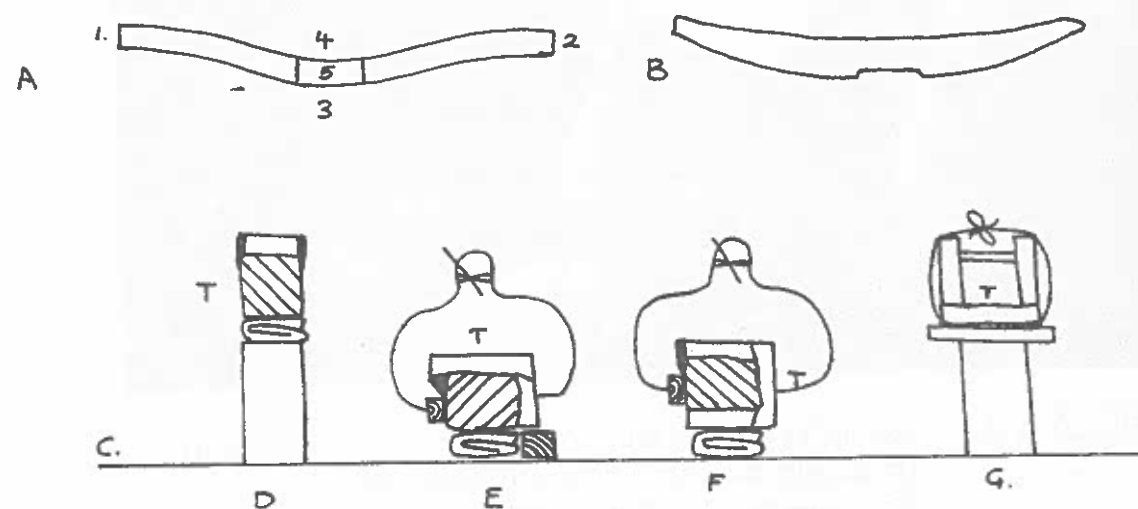


Fig. 11.1.5

#### MOULDING FRAMES

A, view of a frame from above showing the moulding sequence; B, side view of frame; C, moulding sequence D-G (T = top of frame, clay walls in black); D, an end is followed by the convex side (a high support is necessary in the centre); E, the top (a mild steel clamp with a tourniquet prevents movement of the side); F, the concave side; G, the mould is reassembled and left to dry; the slight inclination of the edge of the top section keeps sides in place; wedges inside combined with binding keeps the mould rigid. Drawn by C. W. Gregson

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be remembered that the frames are waterlogged and every precaution has to be taken throughout the moulding to prevent their drying and shrinking. As the moulding takes nearly three days, the plaster and wood has to be kept constantly wet; it is covered with water-saturated plastic foam and polythene at night.

It had been found when moulding the sternpost that clay slip was an extremely good release agent (van Geersdaele, 1975b), so that after filling large fissures with clay, all that is required is a thorough application of clay slip (Fig. 11.1.3). The moulds taken using this release agent show quite clearly the wood grain and tool marks (Fig. 11.1.4). There has been some loss of detail around trenails, where they had to be filled with clay to prevent undercuts, but the gross structures are still quite clear. Each frame has presented its own unique problems, but it is possible to show the general approach (Fig. 11.1.5). The frames are not only shaped to fit the curvature of the hull, but are also curved along their longitudinal axis. The ends were moulded first, then the more convex side; this formed a bed which could be securely wedged to retain the shape of the frame when the other side was moulded and the weight of plaster at its greatest. Although the frames are substantial, averaging .17 m by .23 m in cross-section, their length and loss of structural strength because of waterlogging can lead to movement and cause some distortion. The first frame moulded, R8, has only slight longitudinal curvature and is quite sturdy. After its mould had dried, it was found on reassembly to have discrepancies along the seams in the order of 12 to 19 mm. This indicated that the constant dampening of the plaster, despite scrim and iron reinforcing, was allowing it to move and distort. It was therefore decided that each mould should be reassembled immediately after removal from the wood. The moulded top section of the frame was turned and well-supported and the side pieces were laid on it (Figs. 11.1.5-6). As the side pieces dried they dropped to meet the supported top section and formed a tight seam. Binding around the mould combined with spacers inside maintained the width of the frame.

#### CONCLUSION

It has become very clear that accurate detailed copies of waterlogged wood can be made if the wood is fairly sound, by using clay slip as a release agent, and taking the precautions outlined. In dealing with isolated objects such as frames which can more easily be distorted, it is clearly advantageous to reduce the weight of the mould. The possibility of using a very thin plaster mould backed with expanded polyurethane foam is now being investigated.

Much remains to be done. The shell (Fig. 11.1.7) will be reassembled in the gallery, and the sternpost, which was cast separately, will be set in place. Then the frames will be placed in their correct positions, checked for fit, and fixed into place. Finally the whole cast will be coloured to simulate the appearance of the Graveney hull as it was found in the ground.

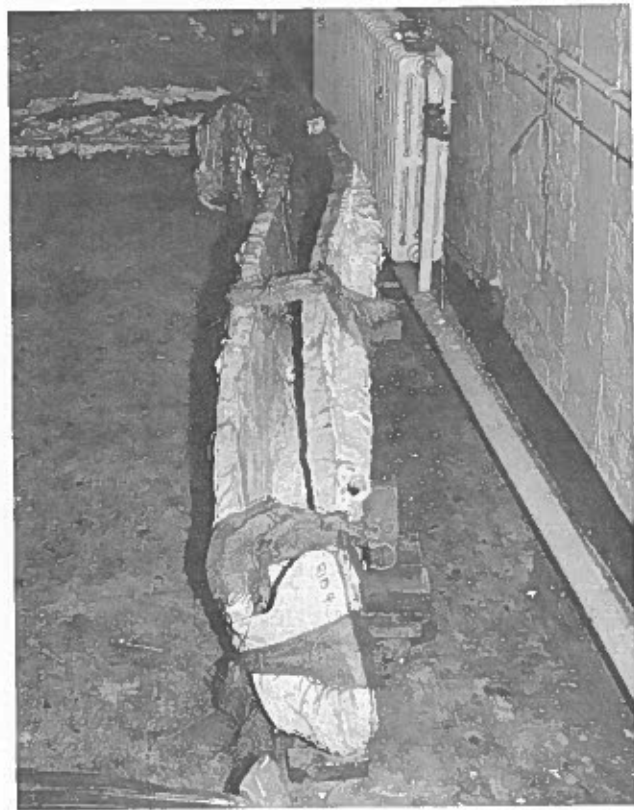


Fig. 11.1.6 Oblique view of interior of the mould of frame R4. Note the curvature along the longitudinal axes.  
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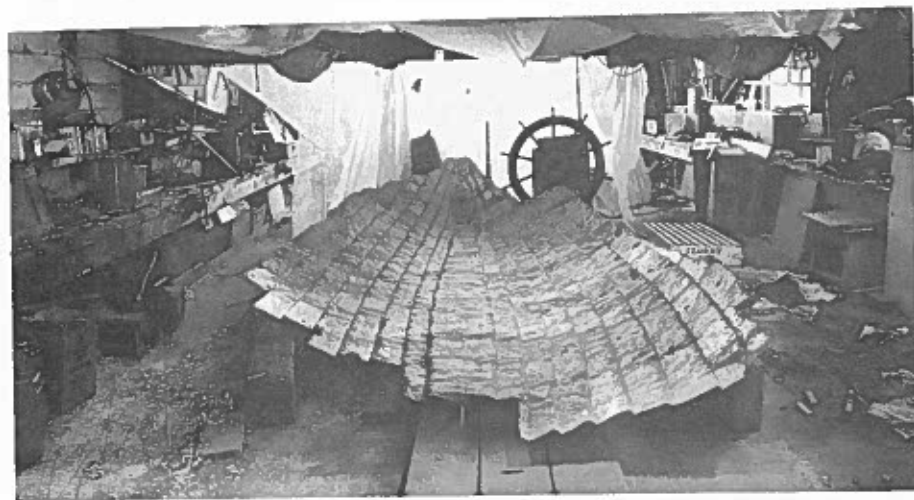


Fig. 11.1.7 Fibre-glass model for display removed from the plaster mould and reassembled  
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#### NOTES

1. It was at the instigation of Dr. R. Bruce-Mitford that these techniques were developed by the British Museum, so that a plaster mould could be made at Sutton Hoo before excavation beneath the ship impression. I should like to thank Mr Peter van Geersdaele of the Department of Medieval and Later Antiquities, British Museum, who was involved in the moulding of Sutton Hoo; without his advice, expertise and practical help building the Graveney mould would have been much more difficult.
2. Their cooperation and recognition of the degree of accuracy required for a gallery display were vital in the successful forming of the boat shell.
3. Details of the materials used are as follows: non-silicone wax supplied by Johnsons; APVA release agent, Gel coat epoxy resin B, polyester resin hardener, metyethyl ketone peroxide 50%, surface tissue, 1 oz chopped strand matting, and paper rope, all supplied by Strand Glass; clay (throwing marl) supplied by Fulham Potteries Ltd.

#### REFERENCES

- van Geersdaele, 1969. P. C. van Geersdaele, 'Moulding the impression of the Sutton Hoo ship', *Studies in Conservation*, XIV, 177-82.
- van Geersdaele, 1975b. P. C. van Geersdaele, 'Note on the direct application of plaster of Paris to waterlogged wood', *ibid.*, XX, 35.

## CHAPTER 11: CONSERVATION AND DISPLAY

### PART 2. CONSERVATION OF THE WATERLOGGED WOODEN HULL

by W. A. Oddy, Research Laboratory, British Museum,  
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British Museum, and Christopher Gregson,  
Archaeological Research Centre, National Maritime Museum.

Fig. 11.2.1, which shows a slice cut from a waterlogged silver birch log of the Roman period with a water content of 83% (based on the wet weight), clearly demonstrates why degraded waterlogged wood needs treatment to conserve it. The extensive shrinkage, which occurred over several days as the wood was allowed to dry out, is clearly visible, and is caused by the weakened cell structure, consisting mostly of lignin, collapsing as the water evaporates.

### CONDITION OF THE WOOD FROM GRAVENEY

After the wooden parts had been unpacked and cleaned during the early months of 1971 an assessment was made of the problems presented by their conservation. Identifications of the wood at the Royal Botanic Gardens, Kew (p. 153), had shown that the boat was made of oak (*Quercus robur*), except for the trenails which are of willow (*Salix*). In order to obtain information upon which recommendations for the most suitable methods for conservation could be based, the condition of the wood was first investigated. Careful probing with a needle showed that the frames consisted of a soft outer layer of very degraded wood and a hard core of undecayed wood. Christensen (1970: 48) has distinguished three zones of degradation in waterlogged wood, which he designated A, B and C; layer B cannot be defined by probing with a needle and is only evident on cut sections. The frames of the Graveney boat were found to consist of about equal amounts of layer A and layer C, that is, the relatively undecayed core consisted of about half of the total remaining timber. However, the strakes, generally between 25 and 35 mm thick, were much more extensively decayed, and usually strips of undecayed core were present only at the edge of a plank where it had overlapped with its neighbour (Fig. 11.2.2).

The water contents<sup>1</sup> of the outer decayed layers of samples taken from the keel, a frame and a strake, were determined gravimetrically and found to be 86%, 80% and 82% respectively, revealing a very extensive loss of solid matter (mostly cellulose) from these outer parts. A similar determination of a fragment of a willow trenail gave a water content of 89%.

Chemical analysis of samples from one of the frames showed that the wood contained sulphide and about 0.9% of iron (expressed as a percentage of  $\text{Fe}_2\text{O}_3$  based on the dry weight of the wood). The moisture content of the wood near the surface was about 70%. In the core it was only about 50% although the iron content did not vary with the depth of the sample from the surface.

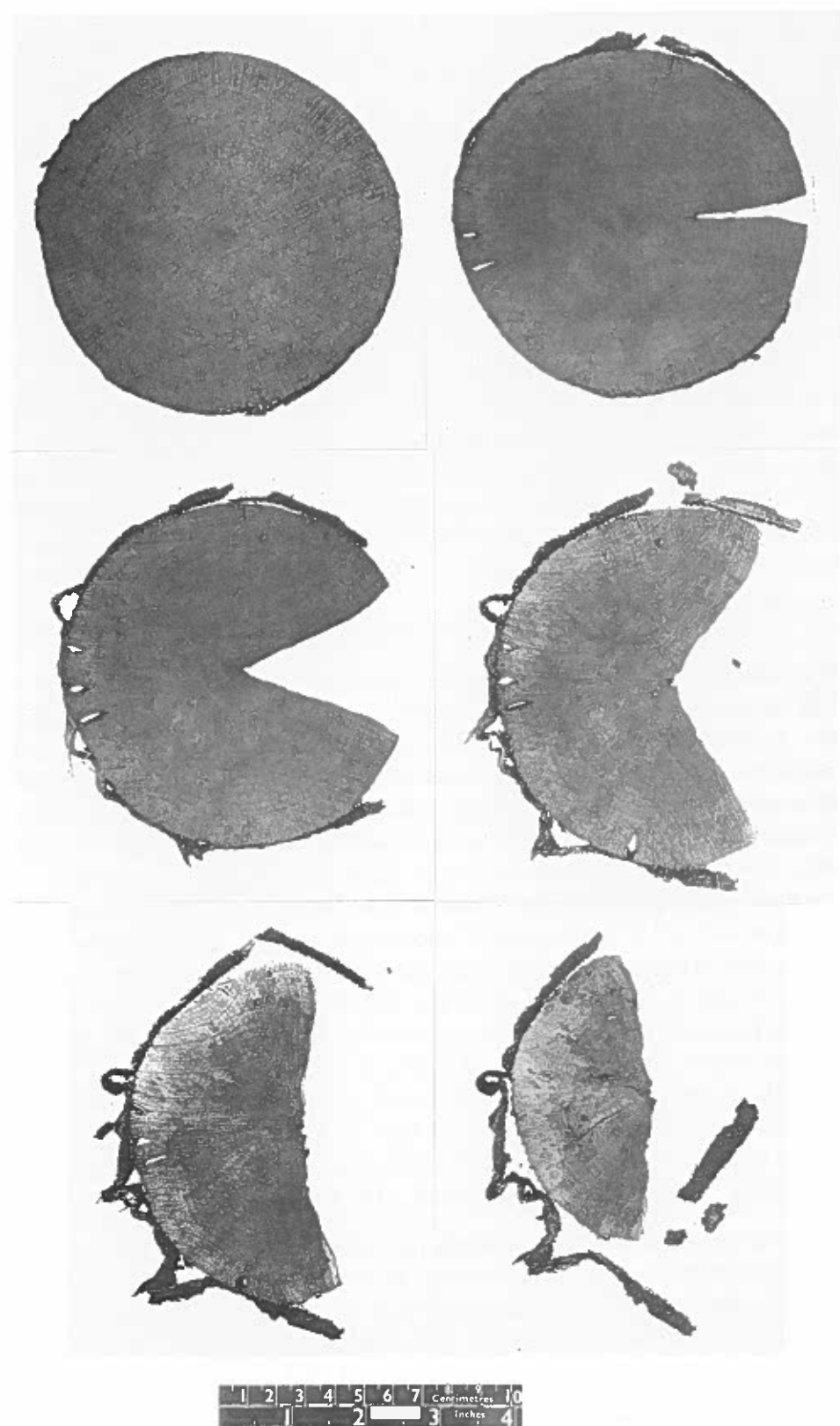


Fig. 11.2.1 Slices from a waterlogged silver birch log of the Roman period  
© A. Oddy

Sections sawn across two of the frames showed that the wood of the central core was light in colour and appeared very similar to fresh oak. Microscopic examination of the surface layers, however, showed that considerable breakdown had occurred in the structure of the cell walls.

#### METHODS FOR CONSERVATION OF WATERLOGGED WOOD

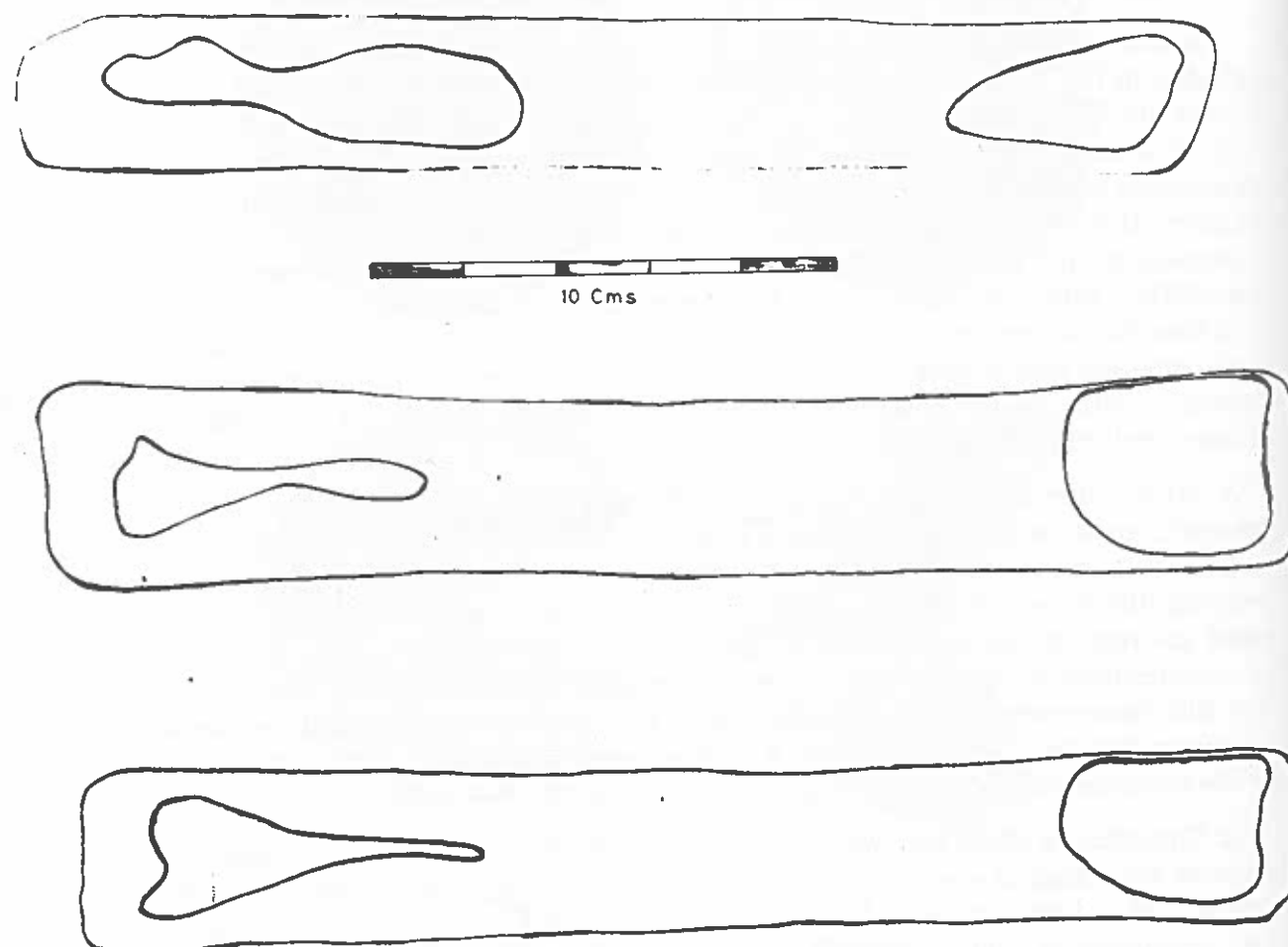
Facilities for large-scale conservation of waterlogged wood were not available in the United Kingdom when the vessel was discovered. Indeed discoveries of boats in recent years (Marsden, 1965, 1967) had resulted in little or nothing being preserved, and previous attempts at preservation by dehydration of waterlogged wood in glycerol had been totally unsuccessful (Barker, 1975). Only two small craft have been conserved with any degree of success in this country. The successful preservation of the Kentmere boat (CIBA, 1961), however, may be attributed more to lack of decay of the wood than to the methods used to treat it, but the more recent conservation of an Iron-Age boat by the polyethylene glycol (PEG) process has been more scientific, although the maximum length of the timbers was only a little over a metre (Suthers, 1975).

A survey of methods in use in western Europe revealed that, except in Denmark, most attempts to preserve boats or ships were using, or planning to use, PEG, either by immersion (the Bremen cog: Pohl-Weber, n.d.) or by spraying (the Wasa: Barkman, 1975). Recent work in Norway has also relied entirely on the use of PEG for large timber objects, although work on the conservation of small finds has employed freeze-drying from solutions of PEG 400 (Rosenqvist, 1975). Considerable research at the Wasa Laboratories has shown that the use of PEG with a molecular weight around 1500 is better for the treatment of oak than the usual grade of 4000.

In Copenhagen there has been a long and continuous history of the conservation of waterlogged wood, stretching back over a century (Christensen, 1970). Until the late 1950s the method was based on potash alum; the Hjørtspring boat, excavated in 1920-2, was so treated. Unfortunately glycerine, which was added to the alum bath, caused further decay of the wood, so that the boat has had to be conserved again in recent years. When the Skuldelev ships were excavated in 1962, PEG 4000 was chosen for their conservation and timbers of ash and pine were successfully treated. Problems were, however, encountered with oak, which failed to absorb sufficient PEG into the core of the wood to prevent shrinkage. Experiments using cold solutions of PEG were carried out, but in the end this method of conservation has been abandoned for treating hard wood and a process of freeze-drying with tertiary butyl alcohol is being used.

In the U.S.A. PEG 1000 has been used to conserve small boats of the Colonial period, which were made of pine and oak (Seborg and Inverarity, 1962), and in Canada there are plans to treat boats of a similar date by the same method, although the higher grades of PEG are in use.

Apart from variations on the freeze-drying principle, several other methods for the conservation of waterlogged wood have been published. These include dehydration with acetone or alcohol followed by diethyl ether and then impregnation with a suitable resin, and *in situ* polymerization of melamine-formaldehyde



**GRAVENEY BOAT**  
**Strake 7PB**

**Fig. 11.2.2** Sectional drawings of plank P7B taken at intervals along its length. Undecayed parts are indicated by shading. Drawn by C. W. Gregson  
© National Maritime Museum

or methacrylate resins by the use of peroxide catalysts or ionizing radiation (Mühlethaler, 1973). None of these methods is very convenient for use on a large scale because of the risk of fire or explosion.

After careful study of all these methods it was concluded that within the constraints posed by the site and money available there was no option but to select the PEG method for the conservation of the Graveney hull.

#### PEG PROCESS

As first published by Organ (1959) the PEG process consists of immersing the waterlogged wood at room temperature in a tank containing a 12% solution of PEG 4000 in water and gradually increasing the temperature to 60°C over a period of weeks. This temperature is maintained until all the water has diffused out of the wood and evaporated from the tank. The timber may then be removed from the tank and allowed to cool, when excess PEG can be cleaned from the surface with a sponge moistened with warm water. Variations in the process have suggested using a mixture of water and alcohol as a solvent for the PEG, or even dehydrating the wood with alcohol and then dissolving the PEG in alcohol. However there is obviously a fire risk with these modifications and very quickly a 'standard' method of using PEG was established, in which the waterlogged wood is placed in a tank containing a 10% solution of PEG 4000 in water. This is immediately heated to 60°C and maintained at this temperature until dehydration of the wood is complete. These experiments have been summarized by Mühlethaler (1973).

The failure of this method to conserve oak which has an undecayed core has led to experiments in Stockholm and elsewhere on the use of a grade of PEG with a lower molecular weight. But as the molecular weight is decreased hygroscopicity increases, so that wood treated with, say, PEG 600 is permanently sticky. It is generally agreed that a grade of PEG with a molecular weight of about 1500 is best; this grade has been used successfully for the conservation of oak planks in Stockholm. One great advantage of this method is that, within certain limits, the wood can be reshaped after conservation by warming it to about 60°C and gently manipulating it to the required shape. Consequently for the conservation of the Graveney hull it is planned to use grade 1500 of the PEG made by either Mado Kemi (U.K.) Ltd. or Shell Chemicals Ltd., or grade 1540 of the PEG made by Union Carbide Corporation.

Comparative experiments have been carried out on small fragments of planking, trenails and sticks found beneath the boat. Using the standard PEG method with initially a 10% solution of grade 4000, various pieces of wood, including a piece of strake about 20 cm square, were successfully conserved in just under a year, with transverse shrinkages of 3.9 to 4.4% and longitudinal shrinkages of 0 to 0.1%.

Other small fragments of strakes and trenails from the Graveney boat are also being conserved by a modified PEG process, in which the wood is placed in a tank of water at 60°C and additions of solid PEG are made daily. Separate tanks, in which PEG 1500 and PEG 1540 respectively are added at the rate of 0.1% per day, are in use and care is taken to see that the liquid level is maintained by the addition of distilled water if necessary. With this modified process

it is not usual to continue the addition of PEG until complete dehydration has been effected; a final PEG concentration of about 70% was thought to be sufficient, followed by a short period of spraying or soaking in a concentrated solution of PEG 4000.

Some of the pieces of wood conserved in this way with Carbowax 1500 (i.e. a mixture of grades 600 and 1540, made by Union Carbide) were removed from the bath when the PEG concentration reached 68%. They were allowed to dry and significant shrinkage took place. Their surfaces were unpleasantly sticky. It was clear that the final concentration of PEG should be in excess of 70%, and experiments on further pieces of wood suggest that a final concentration of about 75% of PEG is sufficient to prevent shrinkage.

#### The effect on PEG of changes in relative humidity

In order to obtain information about how wood treated with PEG will behave when exhibited in a museum, the hygroscopic nature of the main types and grades of PEG which are available in the United Kingdom has been investigated and compared. Each of the manufacturers mentioned in the previous section produces grades of 1000, 1500, 4000 and 6000. The Union Carbide 1500 is however a mixture of two other grades, and their grade 1540 is actually comparable with Mado and Shell 1500.

The amount of moisture (calculated as a percentage) taken up at a constant relative humidity by samples of PEG as received from the manufacturers was determined by drying samples of the polyglycols to constant weight over a desiccant at room temperature. The samples were then weighed at intervals, initially of one day, but later of one week, during exposure to a constant relative humidity (RH), until equilibrium was achieved. At an RH of 55% the average water contents of the samples were 3.5% for grade 1000, 1.6% for grade 1500 (or 1540), 0.9% for grade 4000 and 0.7% for grade 6000. The same samples of PEG were then exposed to an RH of 75% and the respective average maximum water contents were found to be 27.1%, 7.0%, 2.3%, and 1.7% respectively. All grades of PEG 1000 or below are thus unsuitable for conservation of waterlogged wood in countries with climates where the RH may exceed about 60%, while grades 1500 and above are obviously suitable. When the RH was decreased to 55%, different equilibrium water contents were recorded, demonstrating that the absorption and desorption of water by polyethylene glycol exhibits a hysteresis effect (see also Rosenqvist, 1975). These measurements were all carried out on samples of PEG in a flake form. When they were repeated with solid blocks of PEG, the maximum amount of water absorbed at any given RH is understandably decreased, because of the relatively smaller surface area available for water absorption.

Similar measurements were also carried out on blocks of balsa wood which had been impregnated with all grades of PEG, as they are more likely to behave in a fashion representative of treated waterlogged wood. At 50% RH an untreated block of balsa wood, which was originally dry, increased in weight by 4.0%, while one impregnated with PEG 4000 only increased in weight by 0.3%. At 80% RH the respective figures were 10% and 0.5%. These results show that the presence of higher molecular weight polyglycols actually decreases the tendency of wood to absorb and desorb moisture with changes in ambient

RH. Similar results may be expected with PEG 1500, which remains the most promising grade of polyethylene glycol for the conservation of waterlogged oak.

All grades of PEG made by Union Carbide and Shell are slightly acid, the pH of a 10% solution of the available samples ranging between 4.2 and 6.1. The grades of PEG made by Mado Kemi were consistently nearer to neutral, the pH of a 10% solution being in the range 6.0 to 7.2. The recommended final pH for treated wood is in the range 6 to 8.

#### Corrosion of construction materials by PEG

The immersion of waterlogged wood in heated solutions of PEG requires suitable tanks. Economic circumstances will usually dictate whether to choose temporary tanks, such as wooden structures lined with plastic sheeting or glass fibre and resin, or permanent metal ones. Many successful treatments have been carried out in temporary tanks, but as it is hoped to establish a national centre for conservation of waterlogged wood at Greenwich, permanent tanks are necessary in order to guard as far as possible against tank failure while treatment is in progress.

The corrosive effect of aqueous solutions of PEG on materials which might be used for the construction of tanks has been investigated. Weighed test pieces (measuring approximately 80 by 30 by 3 mm) of several different materials were partially immersed in 10% aqueous solutions of PEG 4000 at 60°C for up to 100 days. At weekly intervals these test pieces were washed with distilled water, dried and weighed (Blackshaw, 1975). The materials tested were stainless steel, mild steel, tin-plated steel, zinc-plated steel, brass, copper, Dural (an aluminium alloy), lead, fibre-glass and polyester resin, polystyrene, polypropylene and epoxy resin. Of the materials which are suitable for permanent tanks, Dural, lead, mild steel and the plated steels were significantly corroded, copper and brass were affected less, and stainless steel was hardly affected at all. However tinned copper (Christensen, 1970: 48) and zinc-plated steel (Suthers, 1975) have been used successfully as tank materials, but there is a serious risk of corrosion if the surface coating is damaged in any way. The plastic materials which were tested are only suitable as linings for rigid wooden or mild steel structures; only epoxy resin was seriously affected. Polypropylene and fibre-glass/polyester resins have been used successfully elsewhere for PEG treatment tanks. Glass was also quite unaffected by PEG. It is not suitable as a tank material only because of the difficulties of construction, although enamelled iron or steel vessels could obviously be used.

The most convenient material, therefore, for the construction of permanent tanks is stainless steel. Many different types are available; the one used in these tests was a nickel/chromium steel containing some molybdenum.

#### OTHER TECHNIQUES FOR CONSERVATION OF WATERLOGGED OAK

Although it is planned that the Graveney boat will be conserved with PEG 1500 in stainless steel tanks, some pieces of waterlogged oak have been conserved by other methods for comparative purposes. The techniques used

were the acetone/rosin method (Bryce *et al.*, 1975), the alcohol/ether/dammar resin method and the melamine formaldehyde resin method (Mithlethaler, 1973). 15 cm cubes of oak were cut from a waterlogged Roman beam and treated by each of the three methods. The beam had a badly degraded outer layer, but the core was in good condition and very hard. The tangential, radial and longitudinal shrinkage of each cube was estimated by measuring the distance between marker pins, which were driven into three faces of the cube, both before and after conservation. The initial water content of the beam was found to be 54%, and the shrinkage of the wood was 15% radially, 25% tangentially and zero longitudinally, when allowed to dry untreated.

In the acetone/rosin method the wood is initially immersed in a 1N aqueous solution of hydrochloric acid. This improved the colour of the wood and its ability to take up impregnating materials by removing some of the decomposed organic matter and iron salts from the cell structure. The wood is then washed in running water for at least one week to remove all traces of the acid. It is then dehydrated through several changes of acetone and finally immersed in a saturated solution of rosin (colophony) in acetone at 52°C. On removal from the tank excess resin is removed from the surface and the wood allowed to harden at room temperature. The oak cube treated by this method exhibited a shrinkage of only 1% in the radial plane and zero in the tangential and longitudinal planes. A small plank of more degraded oak treated by this technique showed shrinkage of 5.0-5.4% in the radial plane, 6.2-8.6% in the tangential plane and 0-2.0% in the longitudinal plane.

In the alcohol/ether/dammar method the wood is first dehydrated through several changes of industrial methylated spirits, and then this alcohol is replaced with diethyl ether; two to three changes of ether are usually required. The wood is then transferred to a tank containing a saturated solution of dammar resin in ether. When impregnation is complete, the wood is taken out of the tanks, excess resin is removed from the surface using ether as a solvent, and the wood is then allowed to harden at room temperature. The shrinkage exhibited by the cube treated by this method was 4.0-6.8% in the radial plane, 3.4% in the tangential plane and zero in the longitudinal plane. A thin (20 mm thick) plank of wood from the Graveney boat which was treated by this method did not suffer any measurable shrinkage. One of the problems with the PEG treatment of wood is that the final colour is usually almost black. Removal of excess PEG from the surface will sometimes reveal the grain, and the PEG treatment of the wood from the Skuldelev ships has been particularly successful in this respect. However the alcohol/ether/resin method invariably results in a more natural colour for the surface of the conserved wood. The treatment of trenails by this method has revealed bitumen or pitch stains on their heads; these marks are not distinguishable on trenails conserved with PEG.

The melamine formaldehyde method involves the *in situ* polymerization of a pre-polymer, using hydrogen peroxide as a catalyst. The wood is immersed in a 25% w/w solution of the pre-polymer and after several days in this solution 0.2% of '100 volume' hydrogen peroxide solution is stirred into the tank to initiate polymerization. The wood remains in the polymerizing solution until the resin has become fairly hard. It is then removed from the tank, and excess resin is washed from the surface with hot water. The wood is wrapped first in tissue paper, then in cotton wool and finally sealed

in a polythene bag and put into an oven at 60°C for 48 hours to complete the polymerization of the resin. The treatment of the cube by this method was not successful because the soft outer layer split away from the hard inner core over a period of several weeks after completion. Several 25 mm cubes of hard oak have been successfully treated by this method with no shrinkage occurring.

#### PRETREATMENT OF WATERLOGGED WOOD

McKerrell, Roger and Varsanyi (1972) have shown that the penetration of PEG into oak is facilitated by first soaking the wood in a bath of diluted hydrochloric acid for several days, then washing it with water and finally with acetone. These processes remove iron sulphides, gallates and tannates from the cells of the wood and make it easier for the PEG molecules to diffuse inwards. This procedure also somewhat lightens the colours of the wood. Further experiments have been carried out at the British Museum Research Laboratory on the treatment of waterlogged wood with dilute solutions of ethylene diamine-tetracetic acid (E.D.T.A.), hydrochloric acid and hydrogen peroxide in order to try and regain the natural colour.

The wood samples were impregnated with PEG 4000 after these treatments, but the final colour was not detectably lighter than wood which had been conserved without any pre-treatment. However the E.D.T.A. and the hydrochloric acid treatments did enable the PEG impregnation to take place more rapidly. The use of hydrogen peroxide cannot, however, be recommended because, in spite of prolonged washing, traces of the peroxide remained in the wood during the impregnation and brought about oxidation and depolymerization of the PEG.

#### NOTE

1. All water contents are based on the weight of the wood as excavated.

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## GLOSSARY<sup>1</sup>

Barde (OE ceole, bile) Beard, ram. ON for sharply projecting stems on Viking-period ship representations (e.g. Gotland stones)

Bearding Bevel worked on stems to provide watertight landing for strake  
Bearding-line Inboard limit of bearding and rabbet

Bevel Surface angled to make fit with another

Bilge (OE baelz, belz, bielz-belly) Part of hull beneath bottom boards or ceiling; outside, curved surface between bottom and side

Binding strake, see Strake

Blind (of fastening, nail) Not transpiercing second member. Dependent on interference fit, unlike through-fastening

Boat (OE bāt) Small open oared or sailed vessel

Bonnet Additional strip of sail fastened with lathings to foot of square sail

Bottom boards, see Ceiling

Box scarf, see Scarf

Bugruder (German, literally 'bow rudder') Oar worked either through port or over gunwale forward to assist steering in strong currents (Ellmers, 1978, 77). No English equivalent known

Butt Manner in which one member meets another squarely; butt of log broader end from lower end of tree

Buttock-line Vertical fore and aft section of hull

Cant Timber or frame which meets keel other than square, normally to avoid excessive twist or bend

Carvel Controversial term. Often used to mean smooth-skinned, although many techniques result in smooth exterior. Also used to describe plank-ing added to pre-erected framework of ribs

Caulking (ME calfatyng) Material forced between seams of shell after assembly to make it watertight. Cf. Luting

Ceiling (OE flōr) Bottom boards. Lining of planks over floor timbers

Chin, see Gripe

Chine Line of intersection between sides and bottom of hull

Clench Deform end of fastening, so that it will not work loose

Clinker Arrangement of strakes so that they overlap

Clove-board Plank produced by splitting log along medullary rays

Cold sets Smith's chisel with handle to cut cold metal

Cotter Key, wedge or bolt

Cove, see Luting cove

Crook Curved timber which has grown into shape useful for boat-building

Crutch Loose fork or pivot for oar fitting into socket at gunwale level

Cutwater Leading edge of stem

Deadrise Angle between bottom of vessel and horizontal; none on flat floor

Deckbeam Thwartship member supporting deck planking and acting as strut or tie to connect sides of vessel

Dodger Temporary canvas screen rigged to shelter helmsman, passengers and cargo from spray

Dolly Metal billet to hold up nail while it is being cut or clenched

Draught Distance from bottom of keel to surface of water; plan of vessel

Drift Tool harder and slightly thinner than fastening; used to knock fastening out of hole

Duckham's hook Hook showing weight being carried

Dump Blind-fastening; like spike and nail driven 'dead', i.e. without point emerging

Dunnage Pieces of wood or other material used in hold to pack and protect cargo

Ell (OE eln) Measure of length varying regionally and according to material measured. (Commonly) stick

Fair Descriptive of lines of vessel when level lines, half-breadths, buttock-lines and diagonals correspond

False keel, see Keel

Faying Fitting closely; faying surface coated with luting before being fastened to keep watertight

Feather edge Shim edge, tapering to nothing

Flair Increase in width of hull as it is planked up

Flam Convex overhanging topside of vessel

Flat Descriptive of flatness or discontinuity in fair curve

Floor, floor timber (OE wrang) Lowest component of frame

Forefoot, see Gripe

Frame Transverse assembly of timbers, called rib when of one piece; from keel, components = floor timbers, futtocks and top timbers

Freeboard Distance from load waterline to gunwale

Full, full-ended With ample buoyancy in entry and run

Futtock, see Frame

Garboard Strake adjoining keel

Gripe Forefoot, chin. Curved juncture of stem and keel

Grommet Strands of animal or vegetable fibre laid as ring

Gudgeon Fitting used to support rudder, which has corresponding fitting = pintle

Gunwale (ME thole-beam?) Upper edge of side of vessel; sometimes longitudinal strength-member fitted round top edge of sheer strake

Half-breadth Ordinate perpendicular to vertical longitudinal plane, which divides hull into two symmetrical halves

Halliard (halyard) Tackle for raising and lowering sail

Hammer up Tighten fastening by hammering point further over rove

Heel Lower and after end of component

Hem As noun, bevel on upper outer edge of strake; as verb, to bevel upper edge of strake to provide good landing for one above

Hog Distortion causing ends of hull to drop

Hood-end End of strake fitting into rabbet of stem or sternpost; hood-end plank (ON hals), first or last plank in strake (ON hufr being middle

Horn Upper outer extremity of rib or frame

Interference fit Of nail, tightly held by material being displaced

Joggle Cut out notch; frame joggled to fit clinker overlaps

Kaupskip ship (ON) (OE hlaest-scip) Merchant

Keel (OE botm, bytme) Main longitudinal strength-member<sup>2</sup>

False-keel Addition to lower edge of keel

Keel (cont.)

Keel-plank Plank in keel position, e.g. in flat-bottomed boat

Plank-keel Used when type or form of keel being discussed, being keel broader than it is deep

Keelson Long internal beam usually fitted over floor timbers above keel, to increase its longitudinal strength and distribute stress, e.g., of mast

Killick Anchor of stone in wooden casing

Knee (OE cnēo, cnēow) Member with angular bend and shaped from fork of tree; used as bracket

Lodging knee Horizontal, worked in corners subject to side loads

Land, landing Area of contact between two clinker strakes

Run of the lands Way in which strakes relate to each other in vessel as a whole

Land-nail Fastening to secure two clinker planks together

Lap Amount one plank overlaps another

Leeway Drift of vessel to leeward of course

Leg Longer arm of green crook

Level line Horizontal section of hull normally parallel to waterline, which itself may be level line

Limber hole Cut in lower side of frame to allow bilge water to drain into lowest part of hull

Lines Interrelation of sections in different planes which show shape of hull

Lodging knee, see Knee

Luting (ME syē) Stopping placed in joint before fastening. Cf. Caulking

Luting cove (Swedish tätningssrånna) Word coined in this report to describe groove cut in lower land of radially cleft oak strake to hold luting material in place

Mast-beam Transverse member to support mast at deck level

Mast-partner (ME lere) Framing or pieces of planking fitted at deck level to support mast

Mast-step (OE staepe; ME mast-spore) Wooden or metal fitting to locate heel of mast; if large beam spanning several frames = Keelson

Maul Heavy iron hammer for driving trenails or bolts; one end faced, other pointed (whence often called 'pin maul')

Medullary rays Pith rays which, in oak, form strong radially orientated planes

Meginhúfr (ON, literally 'strong plank') Extra thick strake on waterline on which ribs terminate

Mould loft Part of boat-yard where line-drawings of vessel transformed into full-size shapes to be cut out of material used

Mute Plane-like tool used to trim wood to cylindrical section

Nail-line Mark on strake, equal to half lap, as guide for position of land nails

Nail sickness Condition of hull resulting from loose fastenings

Nail spacing Average distance between land nails

Nibbed Cut off

Notch V-shaped indentation, nick

Oar-port Hole cut in upper strake through which oar worked

Painter (OE baeting) Mooring rope

Parrel Rope, chain, or iron collar, by which running yard kept against mast, allowing vertical movement

Pinch bars Used for manhandling baulks of timber

Pintle, see Gudgeon

Plank (OE bord)<sup>3</sup> Component of strake, where latter not in one piece

Plank-join(t) Scarf between components of strake

Plank-keel, see Keel

Plumbevel Plumbline with bevel measuring capability—clinometer

Port Hole

Rabbet Channel, groove. Recess worked in member to accept another without lip being formed; in particular, channel of triangular section cut in stem to house plank ends. Cf. Rebate

Rabbet-line Line marking outer extremity of rabbet

Raking Projecting; of stem and sternpost, making very obtuse angle with keel

Raking groove Line of wear on ledges of lands, as result of cleaning in clinker-built vessel

Ram, see Barde

Rebate Distinguished from rabbet in this report. Used with more general meaning of reduction, subtraction, diminution

Rib (OE rib, ribb) Transverse strength-member in one piece. Cf. Frame. Since only one component of frames survived in Graveney hull, 'rib' not 'floor timber' used for convenience during rescue and recording

Rising (ME endlangiow—endlong-tree?) Longitudinal strength-member fitted inside frames to support transverse members, such as thwarts or beams, but not usually running full length of side. Cf. Stringer

Rocker Fore and aft curvature of keel or bottom of vessel

Room (OE last; ON rum) See p. 175.

Rove Small plate or ring, on which point of nail beaten down to form rivet

Rowlocks General term for various devices serving as fulcrums for oar in rowing

Run of the lands, see Land

Saddle (ME lask-patch) Member inserted into rebate (cf. Åkerlund, 1951: 153)

Saxboard Board above gunwale, into which oarlocks cut

Scarf Joint by which ends of two structural pieces of timber united to form continuous piece

Box scarf Joint made by cutting away equal portion of two parts to be joined, faying surface being parallel with outside of parts

Scribe Mark and fit one piece to edge of another

Sham Half-mould

Sheer, sheer-line Curve of upper edge of hull

Sheer strake Strake below gunwale

Shell Part of structure which keeps water out, i.e. keel, stem, sternpost and planking

Shift Alteration of position, as of scarves in planking, to distribute points of weakness

Shim edge, see Feather edge

Ship (OE scip) Sea-going medium to large vessel; scyp used of river-craft in OE gloss of Aelfric's Colloquy, written in 10th or 11th century (Garmonsway, 1967)

Shore Prop fixed under side or bottom of vessel

Skeg Additional timber(s) fastened under stern to act as partial keel to keep vessel on straight course

Skin Planked outer surface of hull

Snips Scissors for cutting sheet metal

Spall Lightweight shore used when boat-building indoors to brace components from rafters

Spile Transfer line curved in two planes into flat pattern

Splay Bevelling of upper and lower planks, so that joint is thickness of only one plank

Sponson Used in chap. 9.1, p. 228, of timber fitted to outside of hull

Stamering (modern Shetland word) Inclined hook at ends of vessel

Steam box Container large enough to hold timber to be softened by steam before being bent

Stem (OE stemn, stefn) Trunk of tree. When sternpost matches stempost, two collectively called 'stems'

Stem-piece Stem or stern constructed from single piece

Stepped stem Stem without continuous rabbet, but with series of steps, to which hood-ends scarfed

Stockholm tar (OE scip-teora) Softwood tar obtained by carbonizing resinous root-stumps

Stopping Material put in seam to make it watertight; hard or soft depending on whether or not it sets hard after use

Stopwater Dowel driven into seam between keel and adjoining parts

Strake Single plank or combination of planks stretching length of vessel

Binding strake Strake beneath sheer strake; sometimes main distributor of transverse stresses

Sheer strake, see Sheer

Wash strake (ME boying) Strake fixed above gunwale

Strength-member Member which strengthens hull

Stretcher Piece of wood fitted athwartships between cleats or in movable frame for rower to brace feet

Stringer (ME weyre?) Longitudinal strength-member running from stem to stern inside timbers and normal to them, therefore higher at each end than amidships

Strongback Rigid support

Sweep Long and heavy oar used in small boats and barges for steering; also used to assist motion of becalmed vessel

Tabernacle Wooden or metal mast-housing, fastened between mast-step and sailing thwart or deckbeams

Thole (OE thol) Pin inserted in gunwale to provide fulcrum for oar or sweep

Through-beam (ME transyn) Transverse member piercing shell to which secured, thus preventing tendency to flair; ends visible on medieval seals, sometimes with large cotters securing them outboard

Thwart (OE thofte) Transverse member used as seat

Top timber, see Frame

Transom Stern terminating in transverse board

Trenail Wooden peg or through-fastening, sometimes with expanded head and secured by insertion of wedge

Wale (OE walu-ridge or stripe) Strake thicker than rest

Wane, waney edge Rounded edge originally beneath bark of living tree and often possible to distinguish as edge which is not square; represents date of felling

Wash strake, see Strake

Yard Spar to which square sail bent

#### NOTES

1. As explained in the Introduction, the Glossary lists and defines nautical terms used in this report and elsewhere, often with references to Old English (OE), Middle English (ME) and Old Norse (ON) equivalents. The principal work consulted is McKee, 1972; other definitions are derived from Sandahl, 1951 and 1958, Toller, 1972, and Kerchove, 1954.
2. Sandahl, 1951:s.v. bottom, observes: 'The keel was unknown in early Anglo-Saxon ship-building and the Norsemen probably introduced the thing and the word.' If so, keel-plank is perhaps a better translation of OE botm.
3. 'Wealdish bord' came from the Kentish Weald, SW. of Graveney, which was an important source of English oak.

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