CBA Research Report 138

The Barland's Farm Romano-Celtic Boat

Nigel Nayling and Seán McGrail

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with contributions by
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Summary

The site of Barland's Farm is in a previously agricultural part of the Gwent Levels, the coastal plain on the northern shore of the Severn Estuary in south-east Wales. Survey work in advance of construction revealed traces of Roman activity in the form of a timber and stone structure in the bed of a former watercourse buried under later alluvium. During construction work on the site, a further, more substantial Roman structure was encountered. This consisted of a stone abutment from which three lines of oak piles ran out into another buried water course. When boat timbers were discovered while recording and sampling this structure, the excavations were extended to expose over 9m of a well-preserved boat. Following *in situ* recording, the boat was dismantled and recovered for detailed recording of individual timbers prior to conservation.

The overall dimensions of the remains in the ground were *c* 9.7 × 2.6 × 0.7m. The oak timbers from which the boat was constructed comprised:

- a plank-keel consisting of two tangential oak planks positioned side-by side;
- the lower part of a stem post, fastened to the inner face of the forward end of the plank-keel;
- oak framing timbers consisting of floor timbers and associated side timbers, pairs of half-frames, and inter-frame side timbers in the vicinity of the mast step;
- oak planking consisting of two complete outer bottom planks, two bow bottom planks, parts of five port strakes, and parts of three starboard strakes;
- a short mast-step timber about one-third the waterline length of the boat from the bow.

The Barland's Farm boat exhibits many features characteristic of the Romano-Celtic boatbuilding tradition including: relatively massive and closely spaced framing; sawn planking, flush-laid, edge-to-edge but not fastened together; planks fastened to framing timbers with large iron nails driven through treenails and clenched over the upper face of the frames; caulking of macerated wood applied or nailed to plank edges during construction.

Theoretical reconstruction through the use of scale models suggests the boat's original overall dimensions were 11.40 × 3.16 × 0.90m. The bow and stern were similar, although the stern as reconstructed is slightly fuller than the bow. The near-flat bottom of two plank-keels and two outer bottom planks was extended forward and aft by pairs of bow and stern planks attached to the posts. These planks and the five strakes of planking on each side were fastened to framing timbers at eighteen stations. The use of at least three crossbeams high on the frames is proposed, the foremost one also acting as a mast beam. A lug-sail rig may have been most suitable for the forward position of the mast step, although other methods of propulsion such as oars and the use of poles in shallows were probably employed. Given the absence of contemporary evidence for median rudders, a steering oar or side rudder was probably used to steer the boat. Computer analysis of the boat's form indicates that the vessel was clearly suited to operating in the Severn Estuary and, with the boat's relatively slight draft, in its marshy margins and tidally drying tributaries. Fitted with a lug sail and loaded with 2.5 to 6.5 tonnes of cargo, the boat could have made 4 to 5 knots in favourable conditions.

Examination of a range of environmental indicators point to the location of the boat in a tidal channel, with a range of vegetation types in the vicinity including salt-marsh, grassland and arable communities, and woodland stands of oak, ash, alder, and hazel in the hinterland. The presence of numerous taxa associated with both arable and pastoral farming practices could be taken as indicative of local agricultural activity, although there are difficulties of interpretation where salt-marsh communities also occur.

Integration of the evidence suggests that the boat had rested on the bank of a tidally influenced channel adjacent to a timber bridge providing road access to the dry hinterland, but also into other areas of the wetland. The stern of the vessel appeared to have been

intentionally dismantled, possibly to allow use of the hulk as a form of pontoon. Its location close to the dryland edge of the Levels suggests that in late Roman times substantial parts of the Caldicot Level was subject to tidal influence and accessible via estuarine tributaries of the Severn running deep into the wetland.

Crynodeb

Lleolir safle Fferm Barland mewn ardal a fu unwaith yn amaethyddol ei natur yng Ngwastadeddau Gwent, sef gwastadedd arfordirol glan ogleddol Moryd Afon Hafren yn ne-ddwyrain Cymru. Yn sgîl gwaith arolygu a gynhaliwyd cyn y broses adeiladu datgelwyd olion gweithgaredd Rhufeinig ar ffurf adeiladwaith pren a charreg yng ngwely hen ddyfrffordd a gladdwyd o dan lifwaddod diweddarach. Yn ystod y gwaith adeiladu ar y safle, daethpwyd o hyd i adeiladwaith Rhufeinig mwy sylweddol. Ateg o garreg ydoedd ac oddi yno gwelwyd bod tair llinell o byst sylfaen derw yn rhedeg i ddyfrffordd claddedig arall. Pan ddarganfuwyd pren cwch tra'n cofnodi a samplo'r adeiladwaith hwn, ymestynnwyd y gwaith cloddio i ddatgelu dros 9m o gwch a oedd wedi goroesi'n rhyfeddol o dda. Yn dilyn cofnodi in situ, datgymalwyd y cwch a'i adfer er mwyn cofnodi'r darnau pren unigol cyn y broses gadwraeth.

Roedd yr olion yn y ddaear yn mesur tua 9.7 × 2.6 × 0.7m. Ymhlith y pren derw yr adeiladwyd y cwch ohono roedd:

- trumbren-estyllod o ddwy astell dderw dangiadol ochr yn ochr â'i gilydd;
- rhan isaf postyn blaen, wedi'i gysylltu â wyneb mewnol rhan flaen y trumbren-estyllod;
- pren fframio derw gydag estyll llawr ac estyll ochrau cysylltiedig, parau o hanner fframiau a phren ochr rhwng y fframiau gerllaw gwadn y mast;
- estyll derw yn cynnwys dwy astell waelod allanol gyfan, dwy astell waelod blaen y cwch, pum astell llaw chwith a rhannau o dair astell llaw dde;
- pren gwadn mast byr tua thraean o hyd llinell ddwr y cwch o ran flaen y cwch.

Gwelir llawer o nodweddion traddodiad adeiladu cychod y cyfnod Rhufeinig-Geltaidd yng nghwch Fferm Barland gan gynnwys: fframio enfawr a chlos; estyll wedi'u llifio, wedi'u gosod minfin, ymyl wrth ymyl ond heb eu cysylltu; estyll wedi'u cysylltu â phren fframio gyda hoelion mawr haearn wedi'u hoelio drwy hoelion pren a'u cau dros wyneb uchaf y fframiau; calcio pren wedi'i deneuo wedi'i osod neu'i hoelio i ymylon yr estyll yn ystod y gwaith adeiladu.

Mae gwaith ail-greu damcaniaethol drwy ddefnyddio modelau wrth raddfa yn awgrymu mai 11.40 × 3.16 × 0.90m oedd mesuriadau gwreiddiol y cwch. Roedd y blaen a'r rhan ôl yn debyg, er bod y rhan ôl, wedi'i hail-greu, ychydig yn llawnach na'r blaen.Ymestynnwyd gwaelod y ddau drumbren-estyllod, a oedd ymron yn wastad, a'r ddwy astell waelod allanol o'r naill ben i'r llall gan barau o estyll blaen ac ôl wedi'u cysylltu â physt. Cysylltwyd yr estyll hyn a'r pum astell o boptu iddynt i bren fframio mewn deunaw safle. Bwriedir defnyddio o leiaf dair croeslath yn uchel ar y fframiau, gyda'r blaenaf yn gweithredu fel trawst i'r mast hefyd. Hwyrach mai hwyl lusg fuasai'r rig mwyaf addas ar gyfer safle gwadn y mast ym mlaen y cwch, er mae'n bosibl i rwyfau gael eu defnyddio ynghyd â pholion mewn dûr bas. Yn sgîl y ffaith nad oes tystiolaeth gyfredol o unrhyw lyw canolog, mae'n debyg mai rhwyf lywio neu lyw ochr a ddefnyddid i lywio'r cwch. Mae dadansoddiad cyfrifiadurol o ffurf y cwch yn dynodi ei fod yn addas iawn ar gyfer Moryd Afon Hafren a chyda drafft cymharol fach y cwch yn yr ymylon corslyd a'r isafonydd llanwol. Gyda hwyl lusg a 2.5 i 6.5 o dunelli o gargo, mae'n debyg y gallai'r cwch fod wedi teithio 4 i 5 not mewn amodau ffafriol.

Mae archwilio ystod o ddangosyddion amgylcheddol yn dynodi lleoliad y cwch mewn sianel lanwol, gydag ystod o fathau o lystyfiant yn yr ardal gan gynnwys cymunedau morfa heli, glaswelltir ac âr, a chellïoedd o dderi, ynn, gwern, a chyll yn y cyffiniau. Gellid ystyried presenoldeb nifer o yw yn gysylltiedig ag

arferion ffermio âr a bugeiliol fel arwydd o weithgaredd amaethyddol lleol, er bod anawsterau dehongli yn bodoli mewn lleoliadau cymunedau morfa heli.

Mae integreiddio'r dystiolaeth yn awgrymu i'r cwch orffwys ar lan sianel lanwol gerllaw pont bren a ddarparai ffordd fynediad at y tir sych, ac i rannau eraill o'r gwlyptir. Ymddengys i gefn y cwch gael ei ddatgymalu'n fwriado, a hynny hwyrach er mwyn galluogi i gorff y llong gael ei ddefnyddio fel rhyw fath o bont. Mae ei leoliad yn agos at ymylon tir sych y Gwastadeddau yn awgrymu yr effeithiwyd yn sylweddol ar rannau helaeth o Wastadedd Caldicot ar ddiwedd cyfnod y Rhufeiniaid gan y llanw ac roedd modd cyrraedd ato drwy isafonydd llanwol Hafren a lifai'n ddwfn i'r gwlyptir.

Résumé

Le site de Barland's Farm se trouve dans une partie auparavant agricole des Gwent Levels, la plaine côtière de la rive nord de l'estuaire de la rivière Severn, dans le sud-est du Pays de Galles. Un levé exécuté en avance de la construction a révélé des traces d'activité romaine sous la forme d'une structure en pierre et en bois dans le lit d'un ancien cours d'eau enfoui sous une alluvion subséquente. Au cours du travail de construction sur le site, une structure romaine plus substantielle fut découverte. Cette structure était composée d'une butée à partir de laquelle trois alignements de pilotis en chêne s'avançaient dans un autre cours d'eau enfoui. Lorsque des membrures furent découvertes au cours du travail de notation et d'échantillonnage de cette structure, les fouilles furent poussées de manière à exposer plus de 9 mètres d'un bateau bien préservé. A la suite de l'enregistrement *in situ*, le bateau fut démantelé et récupéré dans le but de noter dans le détail les membrures individuelles avant le travail de conservation.

Les dimensions totales des vestiges dans le sol étaient environ 9,7 × 2,6 × 0,7 m. Les membres de chêne dont était construit le bateau comprenaient:

- une quille en planches composée de deux planches en chêne tangentielles placées côte à côte;
- la partie inférieure d'un montant de proue, attaché à la face intérieure de l'extrémité avant de la quille en planches;
- des bois de carcasse en chêne, comprenant des varangues et bois latéraux connexes, des paires de demi-couples et des bois latéraux entre les bois de carcasse près de l'emplanture du mât;
- des planches en chêne comprenant deux planches entières de l'extérieur de la carène, deux planches de l'avant de la carène, des parties de cinq virures de bâbord, et des parties de trois virures de tribord;
- un court bois de l'emplanture du mât, d'environ un tiers de la longueur de la ligne de flottaison du bateau à partir de la proue.

Le bateau de Barland's Farm présente de nombreuses particularités caractéristiques de la construction navale traditionnelle des Celtes romanisés, y compris: une carcasse relativement massive aux membres très proches les uns des autres; des planches sciées, mises à niveau bord à bord, mais non pas attachées ensemble; des planches attachées à des bois de carcasse par de grands clous en fer cloués au travers de gournables et placées contre la face supérieure des couples; des calfatages de bois macéré appliqués ou cloués sur les bords de planche pendant la construction.

Une reconstruction théorique par le biais de modèles à échelle suggère que les dimensions globales d'origine du bateau étaient 11,40 × 3,16 × 0,9 m. La proue et la poupe étaient similaires, bien que la poupe reconstruite ait fini par être un peu plus large que la proue. Le fond presque plat de deux planches de la quille et de deux planches de l'extérieur de la carène était prolongé vers l'avant et vers l'arrière par des paires de planches de proue et de poupe attachées à des montants. Ces planches et les cinq virures de planches de chaque

côté étaient attachées à des bois de carcasses à dix-huit endroits. L'utilisation d'au moins trois traverses haut placées sur les couples est proposée, celle d'avant servant également de barrot de mât. Un gréement de voile au tiers était peut-être ce qui convenait le mieux pour la position avant de l'emplanture du mât, bien que d'autres méthodes de propulsion avaient probablement été employées, telles que des rames, ainsi que les perches dans les bas-fonds. Etant donné l'absence d'indices contemporains de gouvernails médians, une rame de pilotage ou un gouvernail latéral était probablement utilisé pour gouverner le bateau. Une analyse informatique de la forme du bateau indique que le vaisseau convenait très bien pour l'estuaire de la rivière Severn et, le bateau ayant un tirage relativement faible, pour ses rives marécageuses et ses cours d'eau tributaires secs à marée basse. Equipé d'une voile au tiers et chargé d'une cargaison de 2,5 à 6,5 tonnes, le bateau aurait pu faire 4 à 5 nœuds dans des conditions favorables.

L'examen de divers indicateurs environnementaux indique que le bateau se trouvait dans un chenal soumis à l'influence des marées, avec divers types de végétation aux alentours y compris la végétation de marais salant, de prairie et de terres arables, ainsi que des bosquets de chênes, de frênes, d'aulnes et de noisetiers dans l'arrière-pays. On pourrait supposer que la présence de nombreux taxons liés aux pratiques agricoles arables et pastorales indique une activité agricole locale, bien que l'interprétation soit parfois difficile là où il y a également des marais salants.

L'intégration des indices suggère que le bateau avait été appuyé contre la rive d'un chenal soumis à l'influence des marées et adjacent à un pont en bois qui donnait accès par route à l'arrière-pays sec, mais également à d'autres parties des terres humides. La poupe du vaisseau semblait avoir été démantelée exprès, peut-être de manière à utiliser l'épave comme une sorte de ponton. Sa situation près du bord des terres sèches des Levels suggère que, à la fin de l'époque romaine, de grandes parties du Caldicot Level étaient soumises à l'influence des marées et étaient accessibles par des tributaires estuariens de la Severn qui pénétraient profondément dans les terres humides.

ZUSAMMENFASSUNG

Die Ausgrabungsstätte von Barlands Farm befindet sich auf ehemalig landwirtschaftlich genutztem Gebiet der „Gwent Levels", eine Küstenniederung am nördlichen Ufer der Severn Mündung in Südost Wales. In einem versandeten ehemaligen Flussbett kamen bei Geländeuntersuchungen Holz und Steinstrukturen zutage, die auf Spuren römischer Siedlungsaktivität hinweisen. Während der Bauarbeiten wurde eine weitere, noch größere römische Baustruktur entdeckt. Diese bestand aus einem steinernen Stützpfeiler von dem aus drei aneinandergereihte Eichenpfosten in ein weiteres versandetes Flussbett verliefen. Bei den Aufzeichnungen und der Probeentnahme dieser Pfosten wurden Bootplanken entdeckt, die Ausgrabungen wurden erweitert, und brachten ein gut erhaltenes 9m langes Boot zutage. Nach den Aufzeichnungen vor Ort wurde das Boot abgebaut, und die individuellen Balken im Detail aufgezeichnet, ehe die Konservierungsarbeiten begannen.

Die Überreste an der Fundstelle maßen ca. 9,7 × 2,6 × 0,7m. Die Eichenbohlen aus denen das Boot konstruiert wurde bestanden aus den folgenden Teilen:

- Ein Plankenkiel der aus zwei schräg nebeneinander liegenden Eichenbalken bestand;
- Der untere Teil eines Stevenpfostens, der an der Innenseite des Vorderteils eines Plankenkiels befestigt war;
- Ein Rahmengerüst aus Eiche, das aus Bodenbohlen und dazugehörigen Seitenbohlen, Paaren von Halbrahmen, und Seitenbohlen eines Zwischengerüstes in der Nähe der Mastschwelle;
- Ein Bohlenbelag aus Eiche, der aus zwei kompletten äußeren Unterplanken besteht, zwei untere Vorschiff Planken, Teile von fünf backbord Stringern, und Teile von drei Steuerbord Stringern;

- Ein kurzer Teil einer Mastschwelle, der sich ungefähr entlang ein Drittel der Länge der Wasserlinie vom Bug aus befand.

Das Boot von Barlands Farm besitzt viele charakteristische Merkmale der Romano-Keltischen Schiffsbautradition, die aus folgenden Elementen bestehen: relativ massives und dicht aneinanderliegendes Rahmenwerk; gesägte, bündig abgeschlosse aber nicht befestigte Planken; Planken die mit großen Eisennägeln durch Verdübelungen am Rahmenbalken vernagelt und über den oberen Teil des Rahmens vernietet werden; Abdichten von mazeriertem Holz das bei der Konstruktion vernagelt oder aneinandergefügt wurde.

Die theoretische Rekonstruktion durch maßstabgetreue Modelle lässt darauf schließen, dass die ursprünglichen Maße des Boots 11,40 × 3,16 × 0,9m betrugen. Das Vor- und Achterschiff waren ähnlich geformt, im Modell war das Achterschiff allerdings etwas breiter als der Bug. Die fast flache Unterseite der zwei Plankenkiele und die äußeren Planken der Unterseite wurden nach vorne und hinten durch Paare von Bug und Achterplanken verlängert, die wiederum an Pfosten befestigt wurden. Diese Planken und je fünf Stringer auf jeder Seite wurden an achtzehn Stellen an das Rahmenwerk befestigt. Es wurden mindestens drei Querträger am oberen Teil des Rahmenwerks angebracht, wobei der vorderste gleichzeitig als Mastträger genutzt wurde. Die Takelung für ein Sturmsegel hätte am besten am vorderen Tel der Mastschwelle angebracht werden können, aber vermutlich wurden in Untiefen andere Antriebsmethoden wie Ruder oder Stangen benutzt. Das Fehlen zeitgenössischer Hinweise auf den Benutz von Mittelrudern lässt darauf schließen, dass das Boot mit einem Steuerruder oder Riemen gesteuert wurde. Computeranalyse der Schiffsform zeigt, dass dieses Boot mit seinem geringem Tiefgang hervorragend für die Navigation der sumpfigen Ränder und austrocknenden Prielen der Severnmündung geeignet war. Mit angebrachtem Sturmsegel und mit 2,5 bis 6,5 Tonnen Fracht hätte das Boot unter günstigen Bedingungen bis zu 4 bis 5 Seemeilen hinter sich legen können.

Detaillierte Auswertung einer Reihe von Umweltindikatoren deuten darauf hin, dass das Boot in einem Priel versandete, in dessen Nähe sich verschiedenartige Pflanzengemeinschaften befanden, wie zum Beispiel Salzsumpf, Wiese, Ackerland und im Umland Wälder aus Eichen, Eschen, Erlen und Haselsträuchern. Die Anwesenheit zahlreicher Arten die mit Ackerkultur und Weidewirtschaft in Zusammenhang stehen, könnten als Hinweis auf örtliche Landwirtschaft interpretiert werden, Schwierigkeiten gibt es bei dieser Interpretation allerdings, wo Pflanzengemeinschaften die typisch für Salzsümpfe sind, vorkommen.

Wenn alle Beweisstücke zusammen betrachtet werden, wird deutlich, daß das Boot an der Böschung eines Priels neben einer Holzbrücke gestrandet war, die in das trockene Hinterland und in andere Gebiete des Feuchtgebietes führte. Das Achterschiff ist anscheinend absichtlich demontiert worden, vielleicht um den Hulk als eine Art Pontoon zu benutzen. Die Nähe des Fundortes am trockenen Rand des Feuchtgebietes lässt vermuten, dass in der späten Römerzeit ein Großteil der Caldicot Levels den Gezeiten unterworfen war und durch Mündungsarme des Severn, die tief in das Feuchtgebiet vordrangen, erreichbar war.

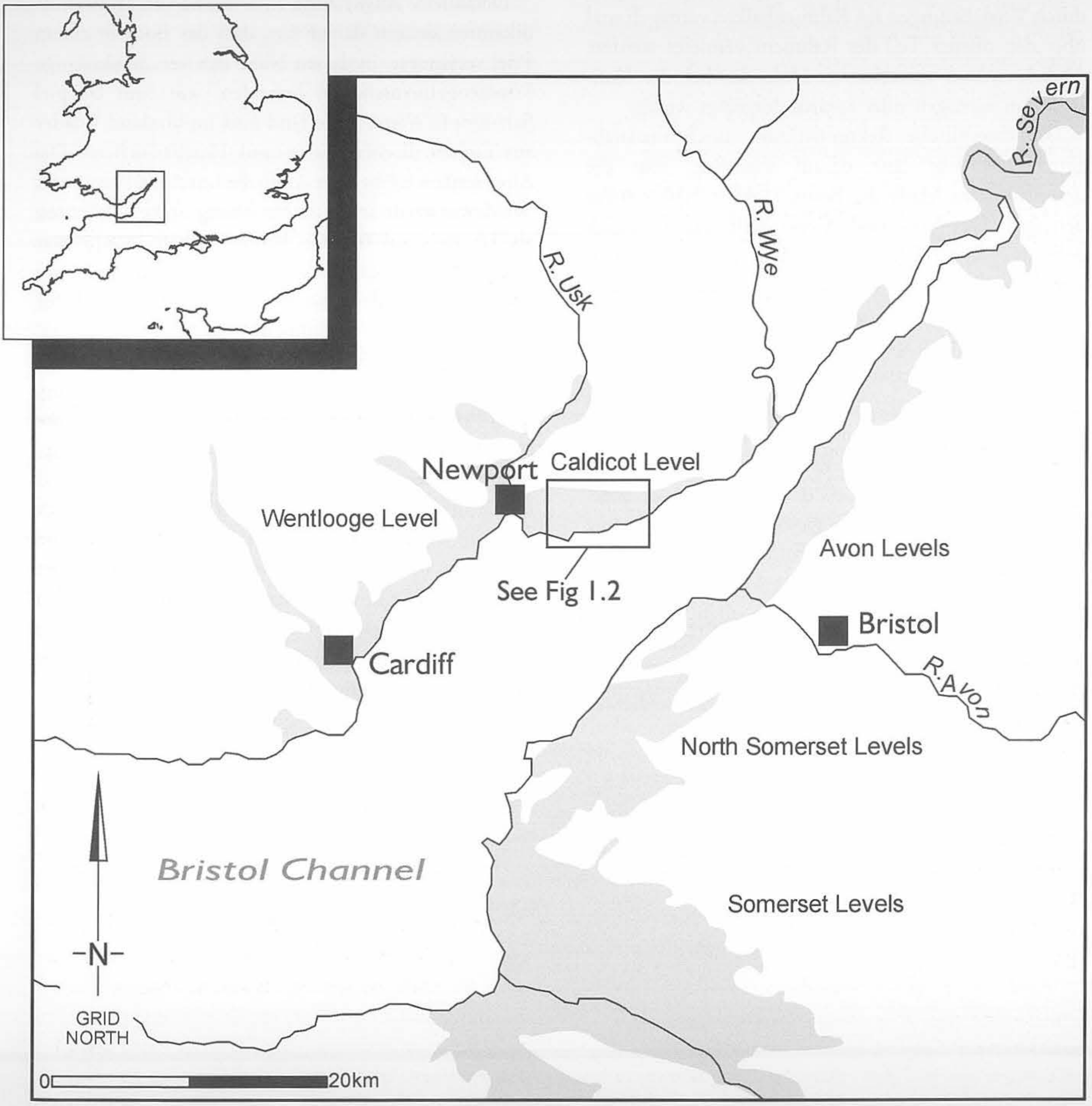


Figure 1.1 Map showing the location of Barland's Farm in relation to the Severn Estuary. The major levels are labelled and the alluvium is shaded.

1

INTRODUCTION

This report presents the results of excavations carried out in advance of and during the first phase of a major development known as Gwent Europark on the former site of Barland's Farm on the Caldicot Level, part of the extensive coastal plain fringing the northern shore of the Severn Estuary in south-east Wales (Fig 1.1). The report is restricted to discoveries dating to the Roman period, excluding analysis of the palaeoenvironmental evidence for prehistoric landscape and vegetation that has been published elsewhere (Walker *et al* 1998). Attention is focused on the discovery and subsequent investigation of a well-preserved boat securely dated to the Roman period. The aim is to present the primary archaeological and environmental data for this find and its immediate context and consider its place in the study of contemporary boatbuilding traditions and the cultural landscapes of the Severn Estuary in the Romano-British period. It has been necessary to use technical nautical terms throughout the report. Many of them are defined in a glossary (Appendix 1).

1.1 Structure of the report

In this introductory section, a brief description of the present topography and geomorphology of the Caldicot Level in the environs of Barland's Farm is followed by background information on the response to the threat to archaeology in the development area.

The excavated evidence is then presented, commencing with description of a deeply buried stone and timber structure encountered prior to development and associated with a minor palaeochannel and late Roman pottery. Initially identified during pre-disturbance geotechnical trial pitting and borehole surveys, this feature provided the first indication that evidence of Roman activity might be encountered in the area. Thereafter a more substantial stone and timber structure along with the associated boat find is described, set in a palaeochannel to the south-west of the first site and encountered during groundworks. The disposition of the boat itself is considered in some detail, based in part on a photogrammetric survey.

A substantial programme of environmental sampling was carried out in both excavated areas in order to characterise the nature of the contemporary landscape and vegetation and the palaeochannels encountered in them. Additional environmental samples were also taken during the dismantling and subsequent detailed recording of the boat itself. The results of analysis of a selection of these samples are presented in individual reports. An overview follows that places a synthesis of these specialist studies in the broader context of our present understanding of the Romano-British landscape of the Gwent Levels.

The finds section discusses relatively small assemblages of pottery, bone, leather shoes, and coins derived from both excavated areas. The pottery in particular highlights the trade in which the boat may have played a part.

The first part of the report concludes with an overview of Roman settlement and economy, synthesising the results of excavations and surveys in the region. Many of these discoveries, made during more recent developments on the Levels, have significantly added to our understanding of the nature of Roman exploitation of the Caldicot Level.

The second part of the report comprises a detailed description of the boat itself derived from post-excavation recording of individual timbers, with sections on the structural elements making up the hull and the evidence for propulsion, steering, and boatbuilding techniques. Standardised description and illustration of individual timbers have been placed in an extensive appendix that presents the primary archaeological data upon which much of this section is based.

In the concluding section, the evidence is drawn together to provide a theoretical reconstruction of the vessel's original form and an assessment made of its handling characteristics including performance and cargo capacity. The method and order of its construction are discussed and its place in the previously recognised Romano-Celtic boatbuilding tradition considered. The nature of conditions in the waters of the Bristol Channel and Severn Estuary is reviewed and the boat's sphere of action and mode of operation discussed with reference to contemporary trade. Finally, the loss and possible reuse of the boat are considered along with the wider implications of the vessel's discovery.

1.2 Location and topographic and geomorphological setting

Barland's Farm was 0.8km south-west of Llandevenny, Gwent, close to the northern, 'landward' edge of the Caldicot Level (Figs 1.2 and 1.3). Streams running off the Wentwood Hills to the north join to form Poolhead

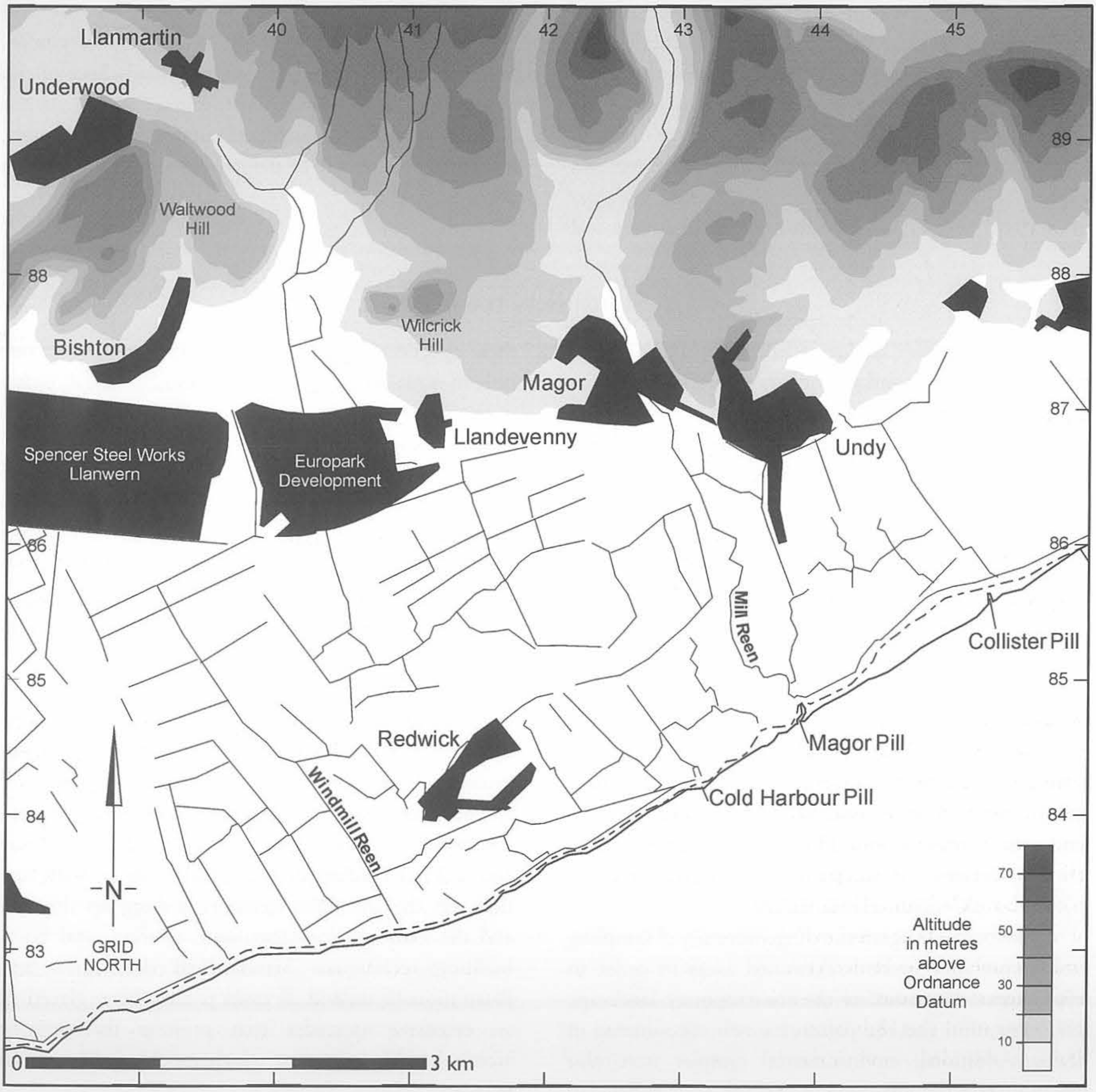


Figure 1.2 The Caldicot Level and its hinterland in the vicinity of Barland's Farm. The present sea wall is marked by a dashed line. The numbers on tick marks refer to eastings and northings of the National Grid kilometre squares. The origin at the bottom left is at ST 380 820. Derived from Ordnance Survey 1:50,000 sheet 171. Crown Copyright.

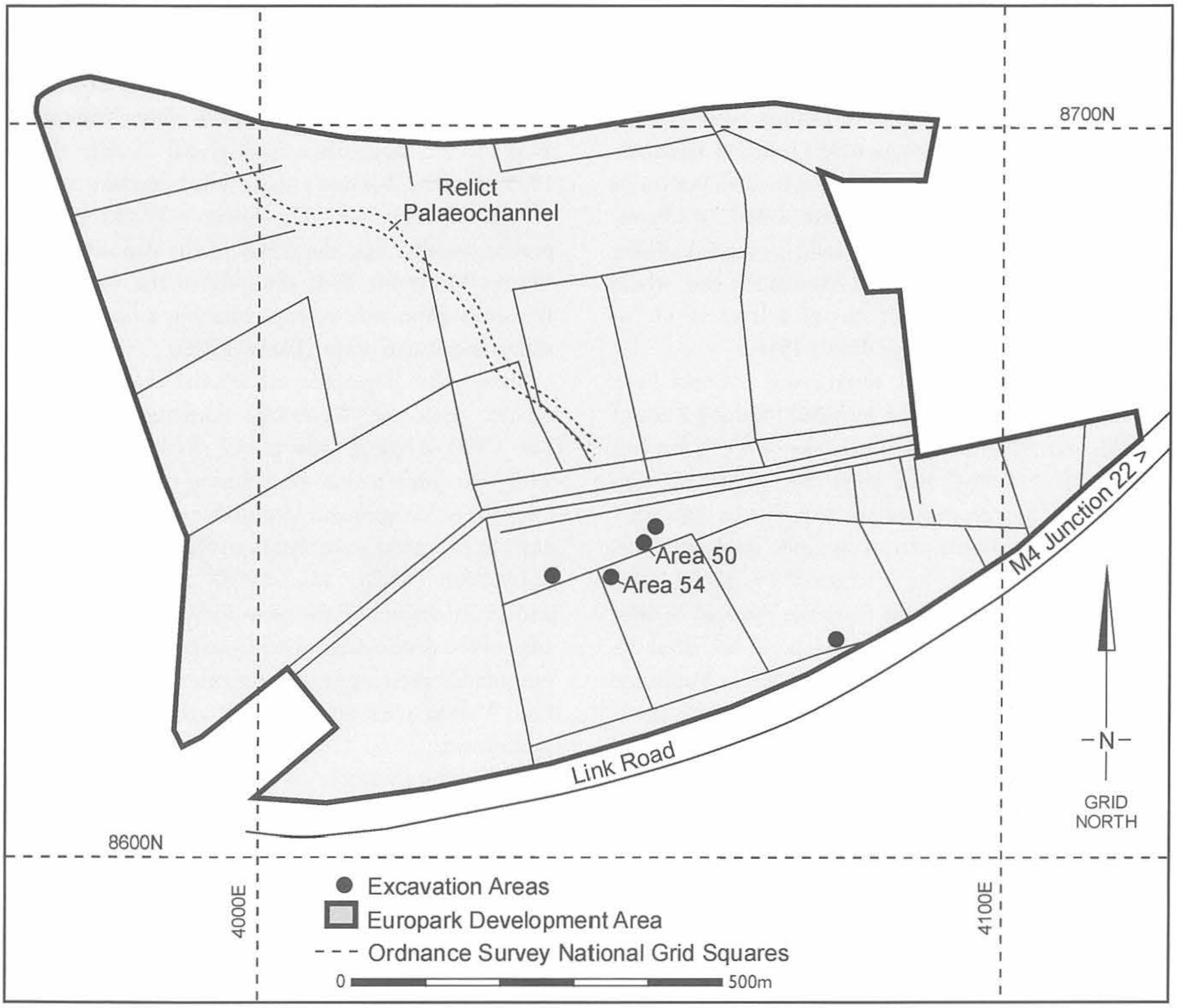


Figure 1.3 The Europark development area and the areas of excavation. Unnumbered areas were excavated within temporary coffer dams to sample Holocene environmental deposits.

Stream that flows between Waltwood and Wilcrick Hills and enters Wilcrick Moor Reen, part of the artificial, rectilinear network of drainage channels known locally as reens that has been constructed over centuries of reclamation. This 'back-fen' area, which, prior to development, was pasture with a land-surface at 5–6m above Ordnance Datum (OD), was probably one of the last parts of the Level to be enclosed. Cartographic and documentary evidence (Rippon 1996a, 76–7 and 106) suggest that substantial enclosure in the area did not occur until the 18th century. While the system of drainage recorded prior to development of the site is unlikely to have any direct bearing on the Roman drainage, freshwater run-off from the hinterland passing down the Poolhead Valley, would have been a significant factor in the hydrology of the area at this time.

The Levels themselves comprise a complex of deeply stratified beds of Flandrian alluvial clays and peats overlying periglacial head and reworked beach deposits that in turn overlie an eroded Mercia Mudstone surface. Synthesis of the results of borehole surveys carried out within the development area and data from studies in adjacent locations allows characterisation of this geological sequence.

The Mercia Mudstone (a reddish-brown silty mudstone, typical colour 7.5 YR 4/4) was reached by some twenty of the boreholes allowing the plotting of the Mercia Mudstone surface. In general, the top of the Mercia Mudstone lies between –4m and –2m OD, sloping down to the north. The heavily weathered surface of the Mercia Mudstone is interpreted as the marine erosion platform identified by Williams (1968) of the Ipswichian interglacial. The borehole profile published by Locke (1971, fig 2) along the Spencer Works east access road to the south of the Barland's Farm site shows the Mercia Mudstone shelf at –3m OD from the Spencer Works to the south of Barland's Farm; the Mercia Mudstone surface then slopes up to reach a level at +3m OD 0.5km east of Barland's Farm, which then stretches back to the solid geology. A similar profile was found at Stoop Hill 5km to the east, where the Mercia Mudstone shelf was at a level of +1.7m OD (Parkhouse and Lawler 1990, 19).

At Barland's Farm this surface was overlain by a firm reddish sandy clay that included localised areas of pebbles and gravel as well as local deposits of sand and clay, between 0.05–2.10m thick (at –1.75m OD to –3m OD).The presence of shell fragments (probably *Macoma*) in the north part of site may imply that this was a shoreline during an interglacial (Williams 1968, 334–5). A borehole section from the Spencer Works, Llanwern, 1km to the west, has been described by Andrews *et al* (1984, 968–9). The Mercia Mudstone formed a shelf at –4m OD, overlain by a sandy gravel with shells (to –2m OD); the molluscs were restricted to –3.6m to –4m OD, and included intertidal and rocky shore species (*Littorina littorea, L littoralis, Nucella lapillus, Cardium edule,* and *Macoma balthica*), leading Andrews to interpret the site as a former beach close to an intertidal lagoon. A radiocarbon date on the shells (25,450 ± 750 BP) place the beach deposit in the Pre-Flandrian Pleistocene; amino acid racemisation placed the beach deposit earlier than the Devensian (equivalent to Oxygen Isotope Stage 5e: *c*120,000–130,000 BP; Andrews *et al* 1984, 972), perhaps to the Ipswichian interglacial. It is assumed that the Llanwern and Barland's Farm beach deposits are related; the Barland's Farm shells have been reworked by periglacial activity. A beach deposit was also found at Stoop Hill (Parkhouse and Lawler 1990).

Overlying head deposits are a mixture of high- and low-energy sediments, presumably periglacial in origin. Shell fragments that continue to appear in small numbers are presumably re-deposited. A layer of basal sands and gravels is found overlying the Mercia Mudstone throughout the Caldicot Level at a depth of 1.5–3m deep (Locke 1971, 4; SSCG 1991). This is interpreted as glacial or immediately post-glacial in date (Locke 1971, 5). The Barland's Farm head deposits are part of this phenomenon. The Spencer Works borehole profile revealed that the depth of the deposits on the Mercia Mudstone shelf dropped to the west of the Barland's Farm site, perhaps marking a long-standing valley and watercourse (Locke 1971).

Subsequent deposition of alluvial clays and intercalated peats, the Wentlooge Formation (Allen and Rae 1987), relates to post-glacial relative sea-level rise, with peat growth occurring during periods when sea level was either approximately stable or falling. Detailed analysis of these deposits has been the subject of separate publication (Walker *et al* 1998). Apparent thinning and/or truncation of the peat horizons at the western edge of the development site suggests that watercourses, presumably carrying freshwater run-off from the Poolhead Valley, were active in this area during the late prehistoric.

Following a number of more recent excavations on the Caldicot Level (see below Chapter 5), it is now evident that the uppermost metre of alluvium represents post-Roman flooding and sediment accretion prior to the construction of medieval flood defences. Although no visible stabilisation horizons were observed at Barland's Farm, such as organic bands or gleyed zones seen elsewhere on the level, a similar pattern of post-Roman alluviation at the site is probable. The silted Roman watercourses encountered during the excavations may be seen as a continuance of natural drainage of fresh water from the hinterland, interacting with incursions of estuarine waters along tidal inlets. Detailed analysis of palaeoenvironmental data characterising the nature of these watercourses is presented in the environmental section, while consideration of the wider implications of their presence is addressed in the concluding chapters.

1.3 Project background

The first stage in the development of an industrial park at Gwent Europark, an area between the M4 motorway and Llanwern steelworks (Figs 1.2 and 1.3), comprised the construction by Tesco Stores Ltd of a dry goods warehouse on a site of 15ha at Barland's Farm. Preliminary field evaluation on the site was undertaken in April 1993 by the Glamorgan-Gwent Archaeological Trust (Contracts Division) to a brief prepared by Alison Borthwick (archaeological consultant to Tesco Stores Ltd) and the Curatorial Division of the Glamorgan-Gwent Archaeological Trust. The initial evaluation comprised a gridded borehole survey that characterised the broad sequence of Mercia Mudstone bedrock platform overlain by interglacial gravels and sands

(Ipswichian beach deposits) and post-glacial estuarine clays with interdigitated peat horizons. This deep sequence of deposits was investigated in greater detail in June and July at three locations where sections within coffer dams were excavated by hand to a depth of 7m below surface level. The results of selective analysis of the large number of environmental samples taken from the prehistoric deposits are published elsewhere (Walker *et al* 1998).

At a fourth location, where a geotechnical trial pit and archaeological boreholes had encountered stone 2.5m below surface level stratified within clays, an open area excavation was carried out (see section 2.1 Area 50). This required the machine removal of the overburden of estuarine clays over a large area to ensure that the edges of the excavation area were sloped at a safe angle. This revealed a number of features located within a silted palaeochannel, including a concentration of timber piles and rubble. Associated pottery indicated a late 3rd- or early 4th-century date for the structure. Following sampling of timbers and sediments, this area was backfilled in advance of construction works.

These works were periodically monitored by Trust staff and in November 1993 a further stone and timber structure was discovered after the removal of approximately 2m of overlying clays and silts, some 70m to the west of Area 50 (see section 2.2, Area 54, Fig 1.3). Associated finds again indicated a late Roman date. In the course of rapid recording and sampling of this structure, a curved timber nailed to horizontal planking was discovered and identified as part of a contemporary boat or ship. Rapid assessment, requiring the removal of a temporary construction road by machine, suggested the presence of approximately 9m of the vessel lying just outside the proposed wall line for the warehouse under construction.

While advice from consulting engineers suggested that the inorganic elements of the stone and timber structure could be preserved *in situ*, the boat remains were under immediate threat from construction operations and longer-term threat from dewatering. A costed project design drafted by the Glamorgan-Gwent Archaeological Trust (Contracts Division), following consultation with the developer, their archaeological adviser, and the site contractors (Wimpey Construction UK Ltd) identified the objectives and methods of a programme of fieldwork to last six weeks. The main academic objectives comprised: the characterisation of the precise form of the boat, its construction method, and extent of survival; the date of the boat and nature of the materials used in its construction; its relationship to the adjacent stone and wood structure and any natural features (eg silted palaeochannels); and the contemporary environmental setting. The recovery of the vessel following *in situ* recording was seen as essential to meet these objectives but also desirable to allow its long-term preservation and (preferably) display. Newport Museum, acting as the receiving museum, undertook to arrange storage of the vessel in a custom-built holding tank where the timbers could be recorded prior to conservation. Once agreement had been reached on funding and procedures, work commenced with the establishment of a safe and controlled environment within which to carry out the fieldwork.

An exclusion zone was established within the very busy construction site and a protective shelter built over an excavation area of 15m by 5m. The site contractors set up and maintained pumping of the excavations, the supply of clean, fresh water, electricity via a generator, and heating within the shelter to prevent freezing. Excavation proceeded along agreed lines, beginning with removal of the fill of the interior of the vessel. Once the vessel had been completely exposed, progress was reviewed. In addition to photographic, EDM, and traditional tape and frame drawing/survey of the vessel, a photogrammetric survey of the remains was carried out by Mike McKay for Atkins AMC. Controlled dismantling and recovery of the vessel then commenced (see section 2.4). In the meantime limited additional excavation and recording of the associated structure was completed along with a programme of environmental sampling from two main locations.

Recovery of all the boat timbers and completion of excavations was concluded the day before Christmas Eve, 1993.

Early in 1994, a post-excavation assessment was drafted by the Trust and presented to Tesco Stores Ltd, who contributed towards the funds to enable completion of the analysis and publication of the finds within this volume.

2

THE EXCAVATED EVIDENCE

2.1 Area 50

This area was excavated in order to examine a reported sandstone rubble deposit buried at a depth of 2.5m that had been located by a geotechnical trial pit. A rectangular area was opened using a machine to remove overlying alluvium and leaving battered sides for safety and ease of access. Within an excavation area of some 11.5 × 8m, spreads of stone and associated timber appeared to occupy a silted watercourse running approximately north-south (Figs 2.1 and 2.2). Selected areas were excavated below the level of the trench floor to investigate this feature, associated palaeochannel fills, and the underlying prehistoric horizons (Fig 2.3).

2.1.1 Pre-channel stratigraphy

2.1.1.1 Peats

The base of the recorded stratigraphy in Area 50 was the upper part of the main peat sequence (middle Wentlooge Formation) encountered elsewhere at Barland's Farm. A very dark brown humified peat (2307)

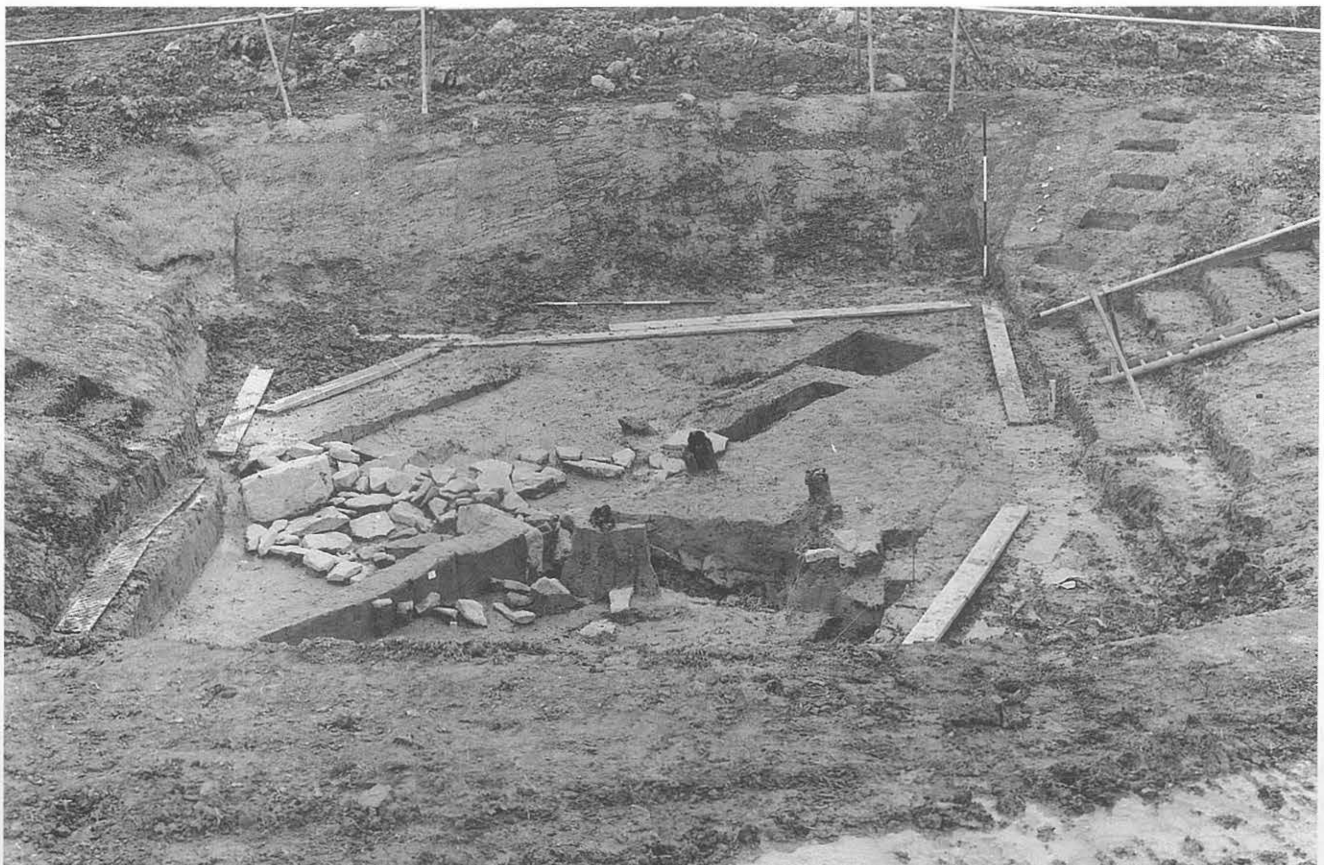


Figure 2.1 Photograph of Area 50.

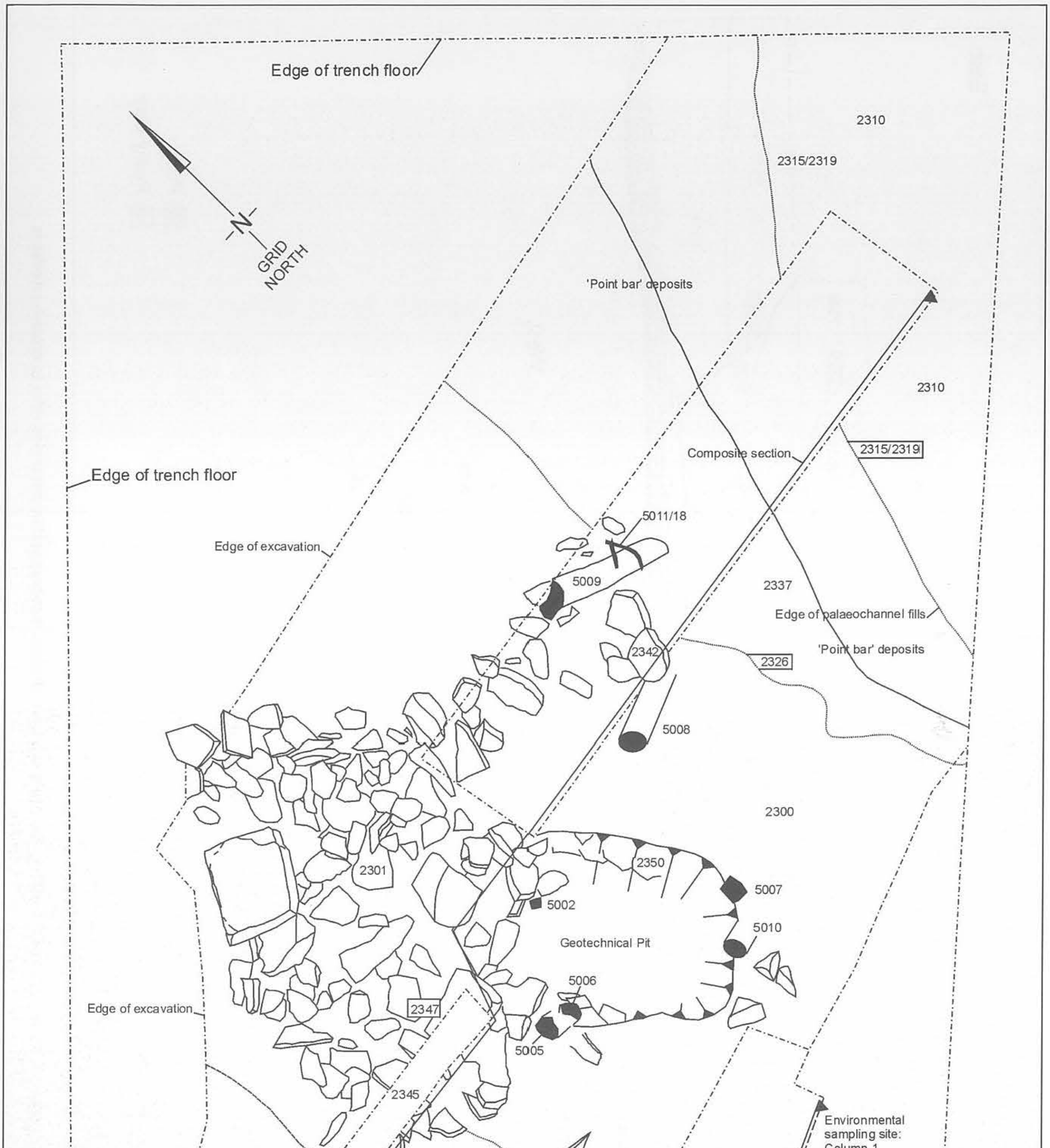


Figure 2.2 Plan of Area 50.

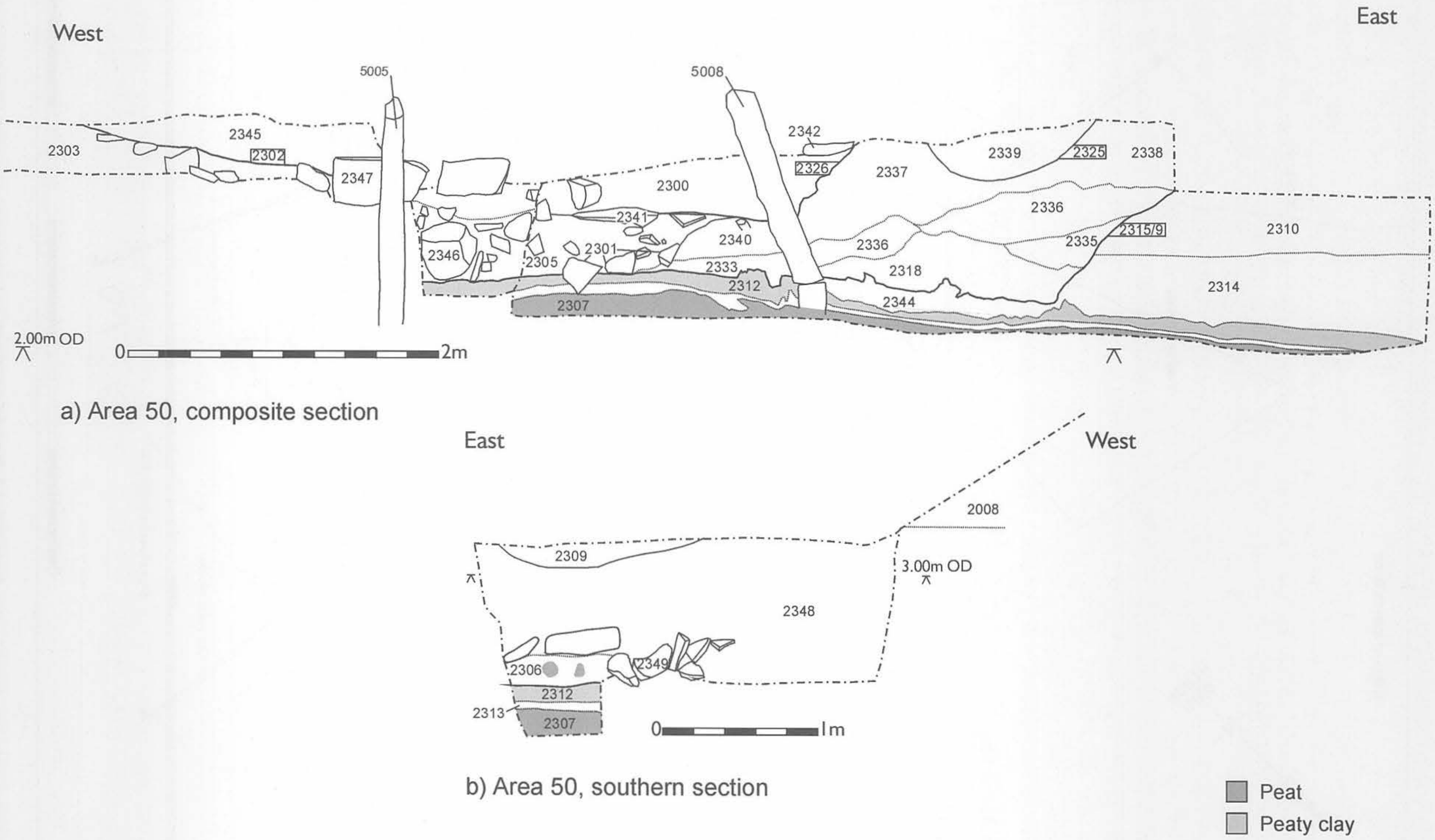


Figure 2.3 Sections, Area 50. Basal peats, peat clusters, and peaty clays are shaded. Numbers within rectangles refer to erosive interfaces.

was overlain by a thin, discontinuous, dark greenish-grey, silty clay layer (2313) about 50mm thick. Sealing the silty clay was a layer of slightly fibrous peaty clay, with interleaved fine silty clay lenses (2312). In a machine-cut trench where a length of the peat surface 5.8m long (2307) could be examined in section (Fig 2.3a), it undulated, the convoluted surface varying from *c* 2m OD in the east to 2.3m OD in the west.

2.1.1.2 Basal clays

Visible in section on the east and west edges of the excavated area were silty clays that appeared to overly the upper surface of the peats and to be conformable with them. On the east side a dark greenish-grey silty clay (2314) had a sharp contact with the underlying peaty clay surface and was overlain by a layer of dark grey/dark greenish-grey silty clay with patches of manganese flecks (2310). A layer of dark greyish-brown silty clay (2344) directly underlying the earliest palaeochannel cut may be equivalent to 2314, but could equally be a basal palaeochannel fill.

At the west edge a similar silty clay (layer 2303) was interpreted in the field as equivalent to 2310. Given the evidence for some westward migration of the palaeochannel and the limited visibility of the upper peat surface, particularly to the west, the possibility that some of these deposits were associated with fluvial sedimentation cannot be dismissed.

2.1.2 Basal palaeochannel and fills

Extending approximately north–south through the excavated area (and probably taking up most of the basal area of the excavations) was a length of watercourse that had completely silted up. Investigation was concentrated on the basal fills of this channel (the lowest 1.3m). As the horizons above this level had been removed by machining, it was only possible to examine upper fills in the battered sides of the excavations, where discriminating between pre- and post-channel estuarine deposits and upper fills proved problematic. The maximum width of the basal channel fills was some 7.5m, but it seems likely that the actual width at the time of human activity represented by artefact deposition and structural evidence was about 5m, the extra width represented by lateral silting on the east side of the channel.

The earliest cut of the channel was on its east side (2315/2319). This was visible as a fairly clean irregularly sloping edge running from c 3.0m OD down to an irregular, approximately horizontal base at *c* 2.25m OD (Fig 2.3a). Accretion appears to have occurred along this eastern edge, with the accumulation of: dark greenish-grey, silty clay (2318) characterised by well-defined darker (olive brown) organic banding; a less organic, greyish-brown deposit (2335) that filled an intrusive pocket close to the bank; and an overlying layer of brown, slightly sandy, silty clay, with nodules of dark grey silty clay (2333/2336). The latter deposit sloped down from the eastern edge (top height *c* 3.04m OD) to the centre of the channel (at *c* 2.50m OD). As no artefactual material was recovered from these basal deposits, the few fragments of immature roundwood observed, but not identified, are interpreted as naturally deposited driftwood.

In the south (Fig 2.3b), a grey, silty clay mottled with peat clasts (2306) occupied the base of the channel (2.29–2.48m OD).

2.1.3 Rubble and pile structure: primary construction

The initial construction of a rubble and pile structure would appear to have taken place after the accretion of the above deposits.

The driving of wooden piles into the contemporary channel base seems to have been the first stage of construction. Fast-grown oak and ash wood was used for the piles at least one of which (5005) was a reused structural timber (Fig 2.2). Four of the piles were ash (*Fraxinus excelsior* L), all relatively immature (18–29 years old at felling) and fast grown (average ring widths of 2.61–5.79mm). Only one (5009) showed any signs of conversion, with three sides squared off. Pile 5006 was clearly winter felled (ie felled following completion of the growing season in late summer but prior to the commencement of earlywood growth in the following spring). The outermost rings on both 5002 and 5009 were not as well preserved but winter felling is probable. The three remaining piles were all oak (*Quercus* spp). One (5008) was unconverted, immature, and relatively fast grown. The remaining two were both boxed heartwood with some sapwood surviving on their corners. Although the bark and latest sapwood rings had been removed from these timbers in their conversion, it seems likely that both were derived from trees in excess of 50 years old in contrast to the ash piles and unconverted oak. The only pile that was lifted in its entirety (5005) featured a redundant chiselled mortise containing an oak peg (5005a) that had been trimmed flat with the face of the timber. This gives unequivocal evidence of reuse for 5005 and suggests 5007 may also have been reused. These timbers probably came from a dismantled building in which the peg had supported some kind of internal fitting rather than acting as a structural element (Goodburn pers comm).

In plan (Fig 2.2), the seven piles were set fairly close together in the central part of the channel. Disturbance caused by the excavation of the geotechnical pit may have removed others. They survived to a height of approximately 3.5–3.6m OD and must have been over 2m long originally, although only 5005 was lifted in its entirety. In the vicinity of pile 5009, a concentration of immature roundwood (5011–5018) 15–30mm in diameter was possibly a remnant of wattling. With the exception of 5018 (*Quercus* spp), these were all identified as hazel (*Corylus avellana* L). This wood is unlikely to have grown in the immediate vicinity but is particularly favoured for use in hurdling and other craft activities requiring flexible straight stems.

A basal spread of fairly small, subangular sandstones (2301) up to 0.25m across was concentrated in the area cut by the geotechnical pit. This continued as an increasingly sparse spread to the east at a height of 2.7–2.8m OD, lying on the surface of 2333/6 and is associated with this phase of construction.

2.1.4 Accretion and maintenance

Following construction of the pile structure further sediment accumulated, initially as point bar deposits along the eastern edge, but also in the bed of the channel. Greyish-brown, silty clay with well-defined organic bands with fine laminations and occasional clasts of very dark brown peat (2337/8) had built up along this eastern edge, sloping down to the centre of the channel (Fig 2.3a). West of pile 5008 a similar, but slightly less organic deposit (2340) accumulated to a height of 2.8m OD. This was overlain by grey, sandy silt clay (2305) occupying the bed of the channel, into which rubble had been deposited. Overlying 2337/8, a dark greenish grey silty clay (2339) possibly occupied a localised erosive interface (2325) with a base height of 3.05m. This feature was reminiscent of deposit 2335 and interpreted as sedimentation within an intrusive pocket close to the eastern bank.

Substantial spreads of fairly flat, tabular slabs of stone up to 0.6m across (2341/2346/2349/2350/2351) were dumped to the north and around the wooden piles and along the western edge of the channel. It seems probable that their deposition was intended to reduce erosion along the western bank caused by natural processes of channel migration indicated by the organic point bar deposits accumulating along the eastern edge and to consolidate the piles. The number of contexts assigned to this event reflects stratigraphic isolation of contemporary material by the intrusion of the modern geotechnical pit. Contexts 2341 and 2346, seen in the composite section (Fig 2.3a) at between 2.4 and 2.85m OD, appeared to slope down slightly towards the south. Where it was visible in the west-facing section of the geotechnical pit, the rubble (2350/1; Fig 2.2) had been laid down in a fairly thin band (2.35–2.65m OD) of tabular, sandstone fragments with angular or subangular edges up to 0.30m across. To the south (Fig 2.3b) a basal channel fill of grey, silty clay with darker mottles of peaty material (2306) was overlain by a spread of angular slabs and cobbles (2349) lying at between 2.3 and 2.7m OD. These rubble spreads and associated sediments contained several sherds of pottery dated to the late 3rd to early 4th century (see section 4.2).

There is limited evidence for erosion in the bed of the channel (seen as cut 2302/2326 in Fig 2.3b) cutting into the organic deposit 2337 along its eastern edge down to 2.8m OD following deposition of the rubble. It would appear that deposition of the dumps of stone, concentrated in the centre and along the western edge of the channel, led through natural fluvial processes to the formation of an asymmetric channel profile sloping down from west to east. A subsequent dump of blocks and slabs of stone (2347) between 0.15m and 0.50m across running down from 3.3m OD in the west to 2.95m in the middle of the channel followed the line of this slope. Following sedimentation with dark grey, silty clay (2300/2345) containing pottery and animal bone, a further spread of flat, tabular slabs (2342) was deposited in an area approximately 2.2m (east–west) by 1.5m (north–south) on the east side between 3.4 and 3.15m OD, isolated from the earlier rubble concentrated on the other side of the channel. This material formed a well-defined mass some 0.90m in thickness, including some sub-rounded stones among the predominantly angular/subangular edged rubble. A number of larger slabs up to 0.6m across occurred on the surface of the feature. One block, measuring 0.8 × 0.7 × 0.4m had been squared, though the edges were badly abraded.

To the south (Fig 2.3b) there was no evidence for channel recuts. Rubble 2349 was overlain by greyish-brown silty clay with discrete darker mottles and silt bands (2348) and the very similar, overlying 2309 to a height of 3.2m OD.

2.1.5 Upper sedimentation

Overlying sediments largely removed by machine and recorded in the battered edges of the excavations are summarised in Table 2.1. The presence of a small

Table 2.1 Upper sedimentation, Area 50

context	*OD height (top)*	*description*
2002	5.60	topsoil: brown, stiff, slightly silty clay loam
2003	5.08	alluvium: brown slightly clayey silt
2004	4.48	alluvium: brown, slightly silty clay
2005/2330	4.33	alluvium: grey clay silt
2006/2331	4.18	alluvium?: grey silty clay
2007	4.08	alluvium?: grey silty clay
2008	3.98	alluvium?: grey silty clay

number of stones (2343) within deposit 2008 at a height of *c* 3.6m OD adjacent to the surviving top of pile 5008 is not seen as indicative of intentional deposition. In the field the extent to which these deposits reflected estuarine sedimentation predating or postdating channel incision, or upper sedimentation of the channel itself was unclear.

2.1.6 Discussion

Interpretation of the structure encountered in Area 50 is not facilitated by the damage caused by the geotechnical pit that had been excavated through it. Rubble appeared to have been concentrated on the western, eroding side of a meander bend with sediment accreting on the opposite bank. The disposition of the timber piles shows no clear pattern, as might be expected if they carried a timber superstructure associated with a bridge, and no well-defined abutment was encountered. Alternative interpretations (eg as a fish weir) are, however, no more convincing.

In the light of discoveries in Area 54, an interpretation as a river crossing of some form is favoured.

Figure 2.4 Photograph of Area 54 during the watching brief/evaluation, looking east. Scale: 0.5m.

2.2 Area 54

This excavation area was established some 70m west of Area 50 following the discovery of additional structural remains during groundworks. A palaeochannel ran roughly north – south through the excavation area, although not enough was uncovered to allow its course to be determined with any certainty. The western side of the palaeochannel was not uncovered and may have been truncated by or lain beyond a post-medieval reen now filled that marked the west side of the excavated area (Fig 2.4).

2.2.1 Pre-channel sediment

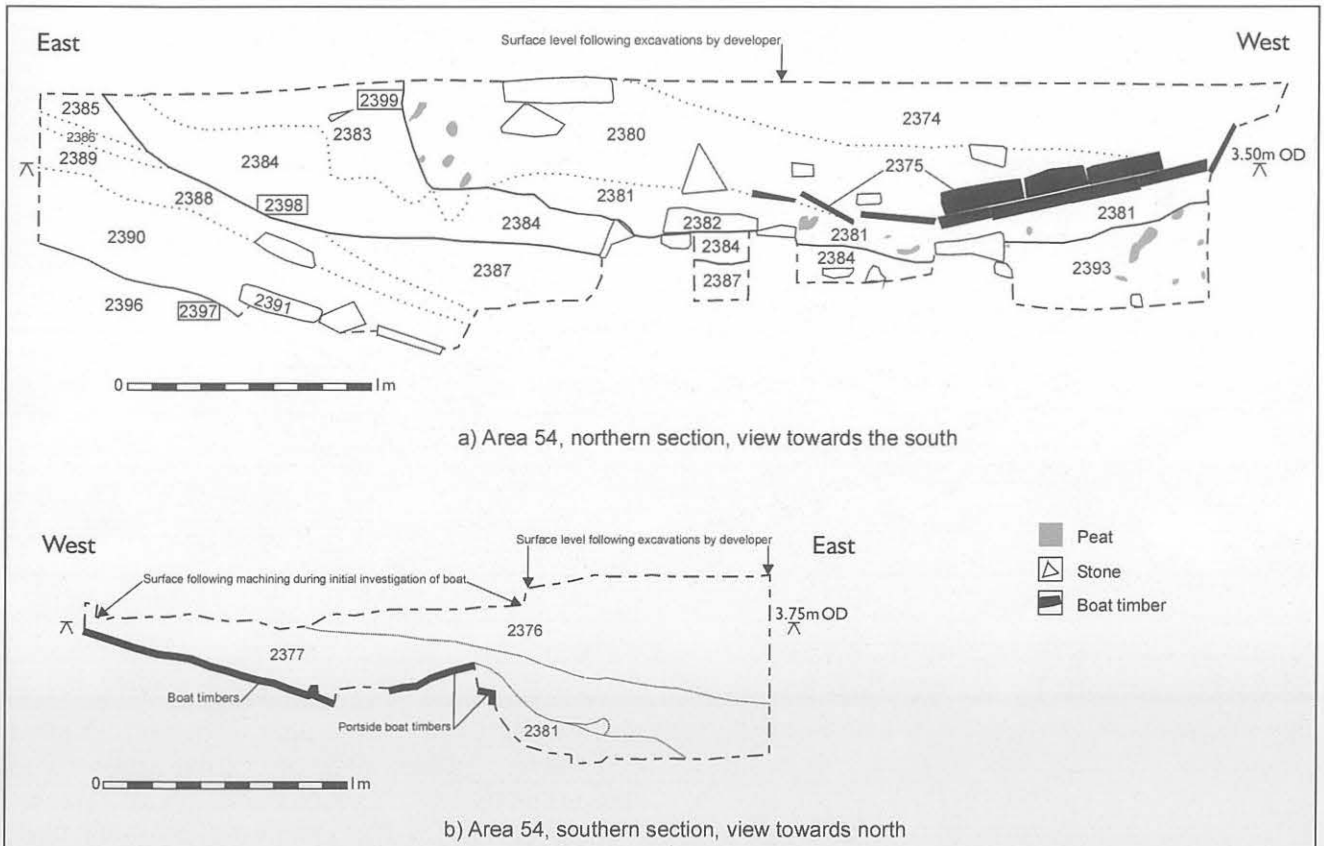
Deposits predating the palaeochannel course associated with Roman activity were encountered only in the immediate vicinity of a stone abutment that was partially excavated. A firm, bluish-grey, silty clay with manganese staining (2365/2396) was observed below and to the south of this structure, where it had been eroded by the watercourse (Fig 2.5a). Observed in section between 2.85m and 3.18m OD, the deposit appeared to continue to the machined ground level at *c* 3.75m OD (Fig 2.5a). This sediment is interpreted as upper Wentlooge Formation estuarine clay.

2.2.2 Palaeochannel 2397

The eastern side and base of the earliest palaeochannel observed (2397) indicated the presence of a channel with an estimated base height of *c* 2.5m OD, running approximately north–south. The side of the palaeochannel sloped down at approximately 45° while the small portion of the base of the channel uncovered appeared to be flat. Its width could not be determined as subsequent sedimentation and structures were only partially excavated and a post-medieval reen had truncated the sequence at the west end of the excavation area. Contemporary ground level must have been above *c* 3.75m OD.

2.2.3 Stone and timber structure 2366

A stone and timber structure had been built into the east side of this channel (Figs 2.4–2.8). The structure and adjacent driven upright timbers preceded all of the channel fills recorded in the excavation. Its full



a) Area 54, northern section, view towards the south

b) Area 54, southern section, view towards north

Figure 2.5 Area 54 – sections.

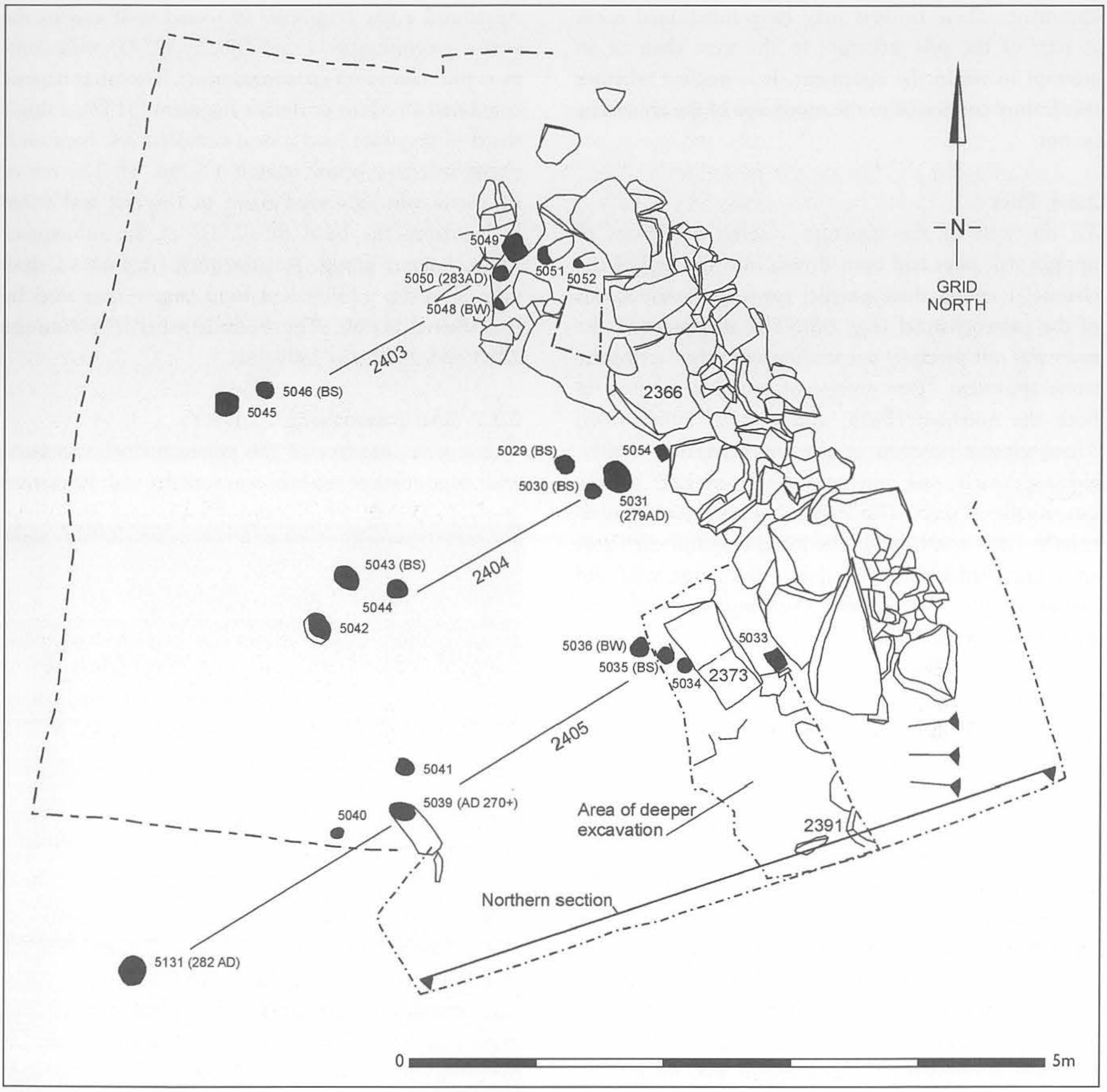


Figure 2.6 Plan of abutment 2366 and associated piles.

depth was only exposed within a trench measuring 2.5 × 1m excavated to uncover the structure's face. Here the channel edge appeared to have been cut back to allow construction of a near-vertical revetment of stone which consisted of four or five unbonded courses of large, sandstone conglomerate rubble slabs up to 1.3m high, with smaller rubble filling between the rear of the wall and the channel edge (Figs 2.6, 2.7). The interstices between the stones were filled with semi-fluid grey silty clay. From its southern exposed extent, where it appeared to be petering out, the revetment ran in a slight curve towards the north-west for approximately 5.2m. The face of the revetment was well defined along the majority of its length, although at the northern end the situation was less clear. It may be that one or more courses here had slumped forward into the channel. The surviving surface of the rubble that was not truncated by machining lay at 3.6–3.7m OD, with a width of *c* 1.7m.

A rudimentary revetment (2401) comprising two squared upright oak timbers (5033 and 5054; Figs 2.6 and 2.7) driven 1.9m apart into the base of the channel flush with the stone face retained two eroded horizontal oak boards (5133 and 5124). The scantlings of the uprights (110 × 80mm and 160 × 120mm) were insubstantial in comparison with the scale of the stone abutment. These timbers may have functioned more as part of the pile structure to the west than as an attempt to retain the abutment. It is unclear whether this feature continued to the north end of the abutment or not.

2.2.4 Piles

To the west of the structure a series of groups of upright oak piles had been driven into the bed of the channel forming three parallel rows across the width of the palaeochannel (Fig 2.6). The alignment of the rows was not precisely perpendicular to the face of the stone abutment. Two groups of uprights survived in both the northern (2403) and central (2404) rows. Three groups survived in the southern row (2405), although each row was probably truncated by the post-medieval reen. The rows of posts were approximately 1.8m apart, while the groups within each row were approximately 2.4m apart. The stone wall and driven uprights are probably contemporary and form part of the same structure.

2.2.5 Fills of palaeochannel 2397

The earliest fill of the palaeochannel was a greenish-grey silty clay (2395) containing many small peat clasts. This deposit, seen directly overlying the base of the palaeochannel adjacent to the stone abutment, was characteristic of bed sedimentation associated with a channel actively eroding out middle Wentlooge Formation peats. Overlying this was a strew of sandstone conglomerate rubble (2373/2391) with an irregular surface at *c* 2.75–3m OD, observed in the deep trench cut to examine the stone revetment (Figs 2.5 and 2.6). The stone strew probably represents consolidation of the channel bottom and was dumped after the upright timbers were driven. Where the bases of uprights were uncovered the stones were laid around them. Subsequent sedimentation comprised a series of clean grey silts and silty clays (Fig 2.5a; 2385, 2386, 2387, 2388, 2389, and 2390). The uppermost deposit (2385) had been truncated by modern machining at 3.78m OD. These deposits had a perceptibly higher silt fraction than the supervening channel fills.

2.2.6 Palaeochannel 2398

A second episode of fluvial erosion was represented by palaeochannel 2398 (Fig 2.5a). Again only the eastern side lay within the excavated area. This sloped gently down from the machined surface to a near-flat bottom at 2.9–3.1m OD. Basal channel fills comprised a grey, silty clay (2384) containing mineralised *Phragmites* stems and a few fragments of roundwood and to the west a greenish-grey, firm silty clay (2393) with common peat clasts and occasional stone. The latter deposit contained an offcut or timber fragment (5132), a single sherd of greyware, and a near-complete left boot with nailed sole (see below section 4.5, no. 4). The toe of the latter was recovered 0.6m to the east and 0.2m higher from the basal fill (2381) of the subsequent palaeochannel group. A subsequent deposit of dark grey, silty clay (2383) had been largely truncated by later fluvial action. The boundary between contexts 2383 and 2384 was indistinct.

2.2.7 Boat palaeochannel 2399

The erosive interface of the palaeochannel associated with deposition of the boat was well defined. Its eastern

Figure 2.7 Photograph of abutment 2366 looking north-west. Scale: 2m.

edge was near vertical, probably the result of undercutting and slumping of the adjacent deposits through fluvial erosion. The bed of the channel, somewhat disturbed by later dumping, had an irregular rounded profile (Fig 2.5a) with a lowest recorded level of 3.1m OD. At the west end of its exposure in the north-facing section, the bed level was rising, reaching 3.34m OD below the west edge of the boat. The contemporary channel therefore had a minimum width of 3.5m.

Where exposed in an excavated area approximately 3.5 × 2.75m south-west of the stone revetment and west of later, unexcavated stone strews, the base of the channel had been consolidated by a layer of densely packed sandstone rubble (2371/2382; Fig 2.8). This deposit was largely a single stone deep and lay at between 3.2 and 3.4m OD. The eastern edge of the strew coincided with the groups of uprights immediately west of the stone revetment in the central and southern rows. It had been truncated by a post-medieval reen and the original edge was only exposed in the far west of the excavations. The evidence suggests that the stone strew was concentrated along the bed of the contemporary channel over a width of *c* 4.5m.

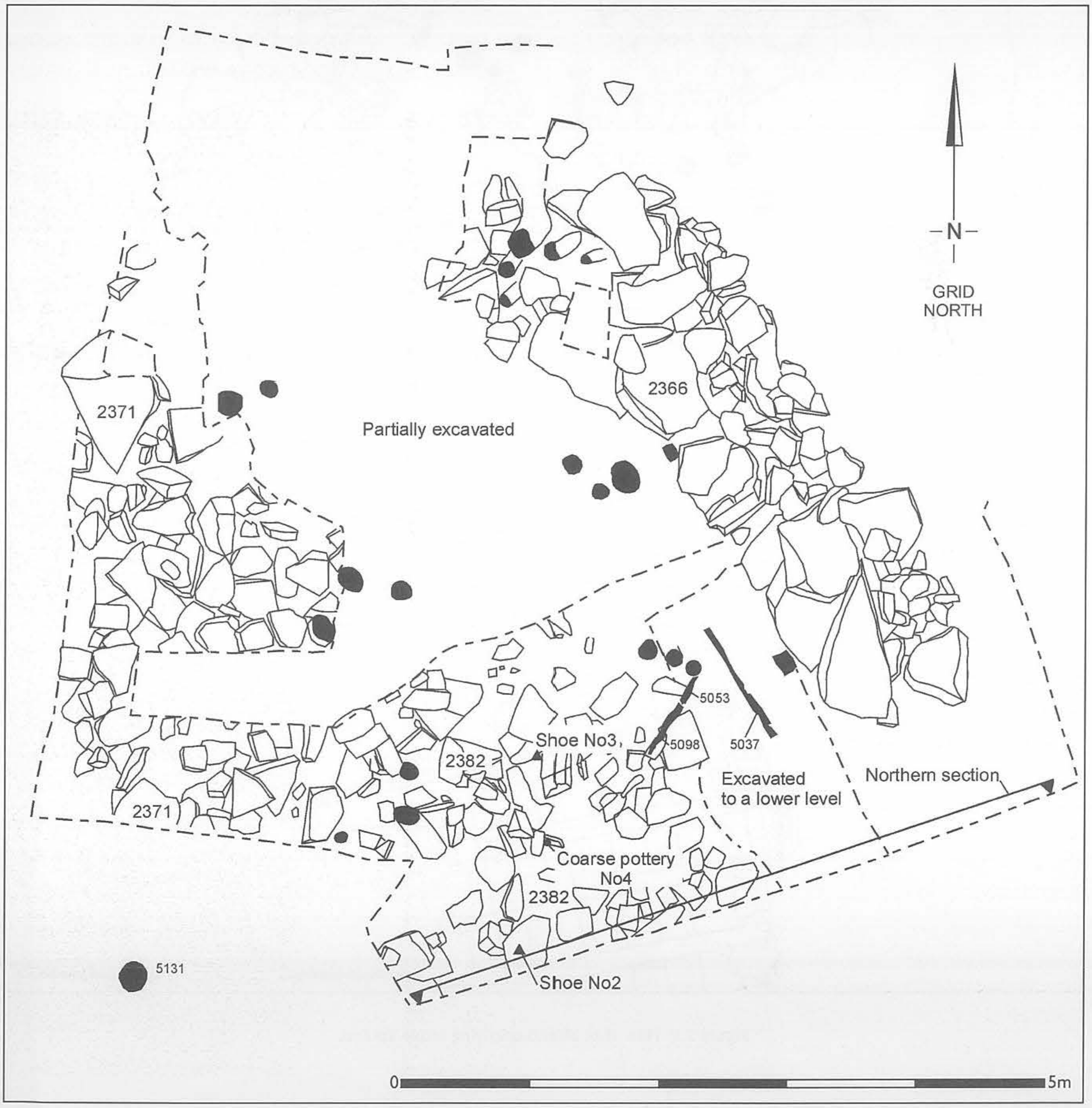


Figure 2.8 Plan of pre-boat sedimentation.

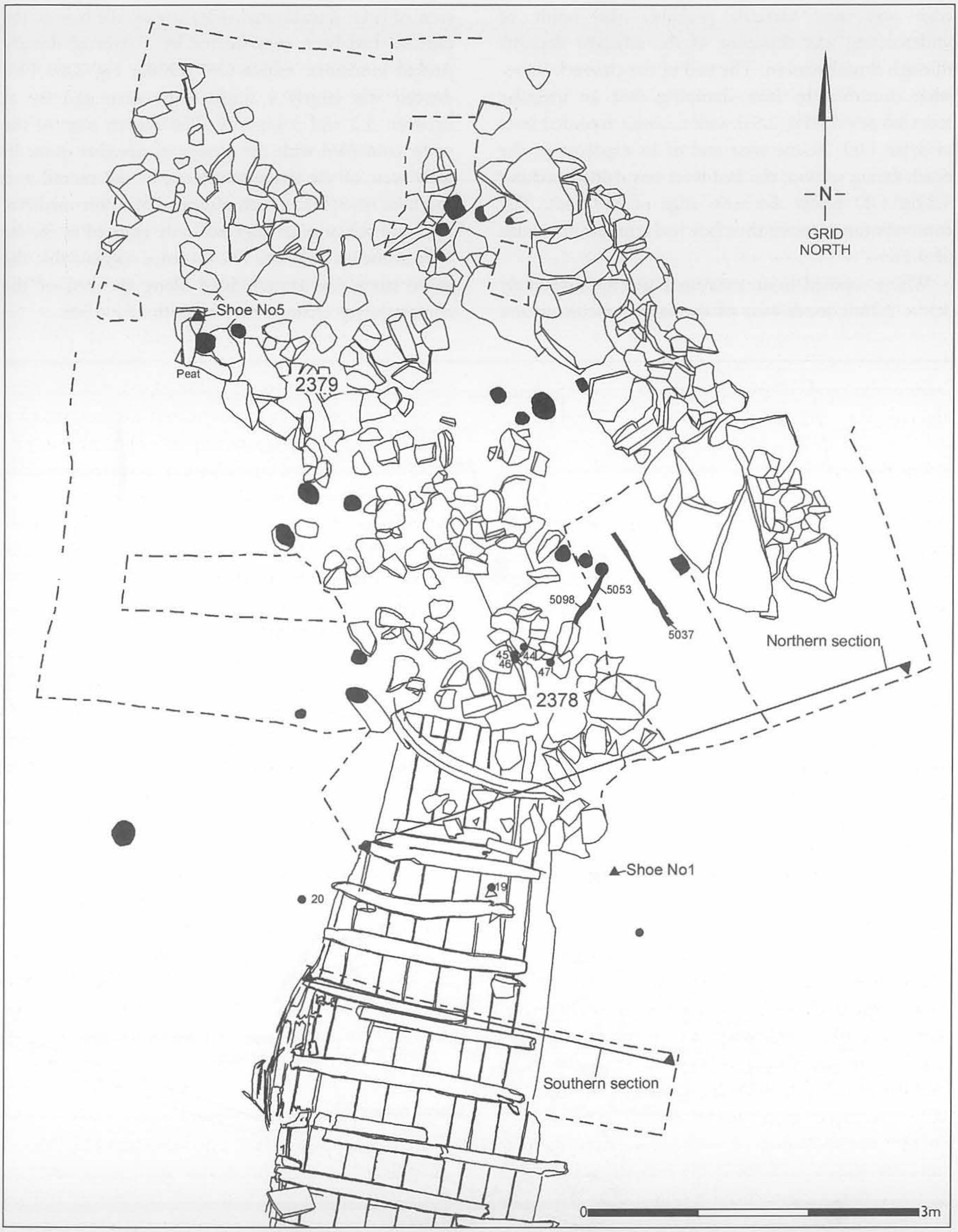


Figure 2.9 Plan of boat and overlying stone spread.

The basal stone dump lay within a matrix of organic, greenish-grey silty clay containing re-deposited peat clasts, *Phragmites* stems, and a few roundwood fragments (2367/2381) that sealed the bed of the channel, with its surface lying at 3.3–3.45m OD (Fig 2.5a). In addition to the toe of a left boot (see below section 4.5, no. 3), a further left shoe with nailed sole (see below section 4.5, no. 2; Fig 2.8) was recovered from this unit, along with a dish of black-burnished ware (see below section 4.2 no. 4), 28 pieces of animal bone including cow and lamb skulls and fish, and a single nail. As a whole, the artefactual assemblage implies intentional dumping of bone waste (see below section 4.3) and possibly other refuse. The shoes were heavily worn and had been repaired at least once. This suggests discard rather than accidental loss.

2.2.8 Boat 2375

A fragment of oak with adhering iron corrosion (5135) found within 2381 may have been derived from the boat. A more substantial boat timber fragment SFX1 (5053/5098) was partially embedded within 2381, but also within 2372. The latter deposit also contained another fragment SFX2 (5037). These timbers are interpreted as displaced framing fragments, some of which became embedded within the channel's basal fill.

The stern of the boat (2375) rested on this deposit (Figs 2.5a, 2.9). The dumped material and stone strews sloped down toward the south and the southern (bow) end of the boat was underlain by a clean, soft deposit of bluish-grey silty clay (2394). The relationship between this layer and the dumped material was not established. The disposition of the boat itself is dealt with in detail in section 2.3.

2.2.9 Later palaeochannel fills

A subsequent deposit of stone that consisted of substantial, cobble-sized sandstone conglomerate rubble (2370) ran approximately north-west to south-east, parallel with the face of the stone revetment, with a width of *c* 1.9–2.1m and overall length of *c* 8m. The irregular rubble surface generally lay at *c* 3.50m although it both petered out and sloped down slightly towards the south. Here the stone was assigned to context 2378, the matrix of mixed silty clay and re-deposited peat clasts both surrounding and overlying it which spilled into the northern end of the boat (Fig 2.9). Given the similar geologies of the stone in 2378 and that in 2370 (see below section 4.1), the two are equated. None of the stone is seen as remnants of cargo. The organic deposit around the stone strew extended to the north (as 2380) within and over 2370, but also east of it abutting the stone revetment (as 2372).

Finds from this unit comprised the decayed seat and quarter of a small sewn leather shoe (see section 4.5, no. 5; Fig 2.9), greyware (3 body sherds), red ware (three body sherds), black-burnished ware (1 handle, 1 rim, and 4 body sherds), over 150 pieces of animal bone including cow and horse skulls, and 19 corroded iron nail fragments. The majority of this assemblage is interpreted as refuse dumped intentionally along with the stone. The iron nails were probably displaced fragments of boat fastenings.

The remainder of the interior of the boat was filled with grey silty clay (2374). The lowest part of this fill (approximately 30mm) was a lighter blue-grey (2379), probably due to post-depositional changes. The same grey silty clay appeared outside the boat overlying context 2381. Here the lower part of the layer was recorded as context 2377, the upper, oxidised part as context 2376. A single black-burnished base was recovered from context 2374 (find 027).

Overlying the stone strew 2370 and the upper part of the stone structure 2366 (Fig 2.6) was a layer of oxidised silty clay (2360) containing lenses of peat and other organic material (2361, 2362 and 2363). Deposits above this in the vicinity had been machined away prior to the excavation. A further leather shoe (see section 4.5, no. 1) was recovered from fill 2360.

2.3 Description of the *in situ* boat remains

2.3.1 Orientation and codes (Figs 2.10–2.12)

The boat lay on a north–south orientation, its incomplete northern end resting on one of the spreads of dumped stone and waste (context 2381/2; Fig 2.8) apparently laid to consolidate the associated timber and stone structure. This end of the vessel was overlain by a subsequent dump of stone and waste (context 2378; Fig 2.9) deposited prior to the accumulation of fine silty clays that sealed both the boat and the structure. It lay on its hull bottom with a list of 12–15% to port (assuming the southern end is the bow – see below), such that a maximum of five side strakes survived on the port side and only three on the starboard side. The bow was highly fragmented, either

Figure 2.10 Photograph of boat *in situ* looking south (bow).

due to recent disturbance or damage from maintenance of the nearby reen. Modern machining had reduced the ground level to approximately 4m OD resulting in some damage to the uppermost surviving elements along the starboard side, but fortunately little disturbance to the more complete port side.

For the sake of clarity, throughout this description individual timbers are assigned function codes reflecting their position and purpose within the vessel in addition to individual timber numbers assigned at the time of excavation (Figs 2.11, 2.13). The majority of the hull planks are given codes P (for port) or S (for starboard) followed by a number to indicate the strake to which they belonged. Hence the four large planks forming the hull bottom are designated P1 and P2 (the two on the port side of the centreline) and S1 and S2 (the two on the starboard side). The timbers forming the frames (running at right-angles to the long axis of the vessel) are assigned a code number indicating the *station* to which they belong. The first station is numbered 1 in the south at the bow and the last surviving station in the north numbered 16. At each station timbers are described variously as floors (prefix code F), half-frames (prefix code F and suffix code Pt or St depending on which side of the vessel they were positioned) or side timbers (prefix code SF and suffix code Pt or St depending on which side of the vessel they were positioned). Floors extended from the second or third side strake on the port side to at least the first side strake to starboard. Half-frames ran across all or part of the flat bottom before extending up one or other side of the vessel. Side timbers were located on the sloping side strakes and either abutted or did not reach the hull bottom. Throughout this description it is assumed that the southern end is the bow since a small mast-step timber (a mortised timber to take a mast) was positioned towards the south end running along the centreline between stations 6 and 7. This is in keeping with other boat finds of this type that often have a mast step located approximately one-third of the overall length from the bow. Attention is concentrated on the disposition of timbers rather than detailed description of individual elements. These are considered in detail in subsequent sections (see section 6.3 and Appendix 2). Evidence for construction method and the relationships between timbers that became apparent during the dismantling and lifting of the vessel are included here (section 2.4).

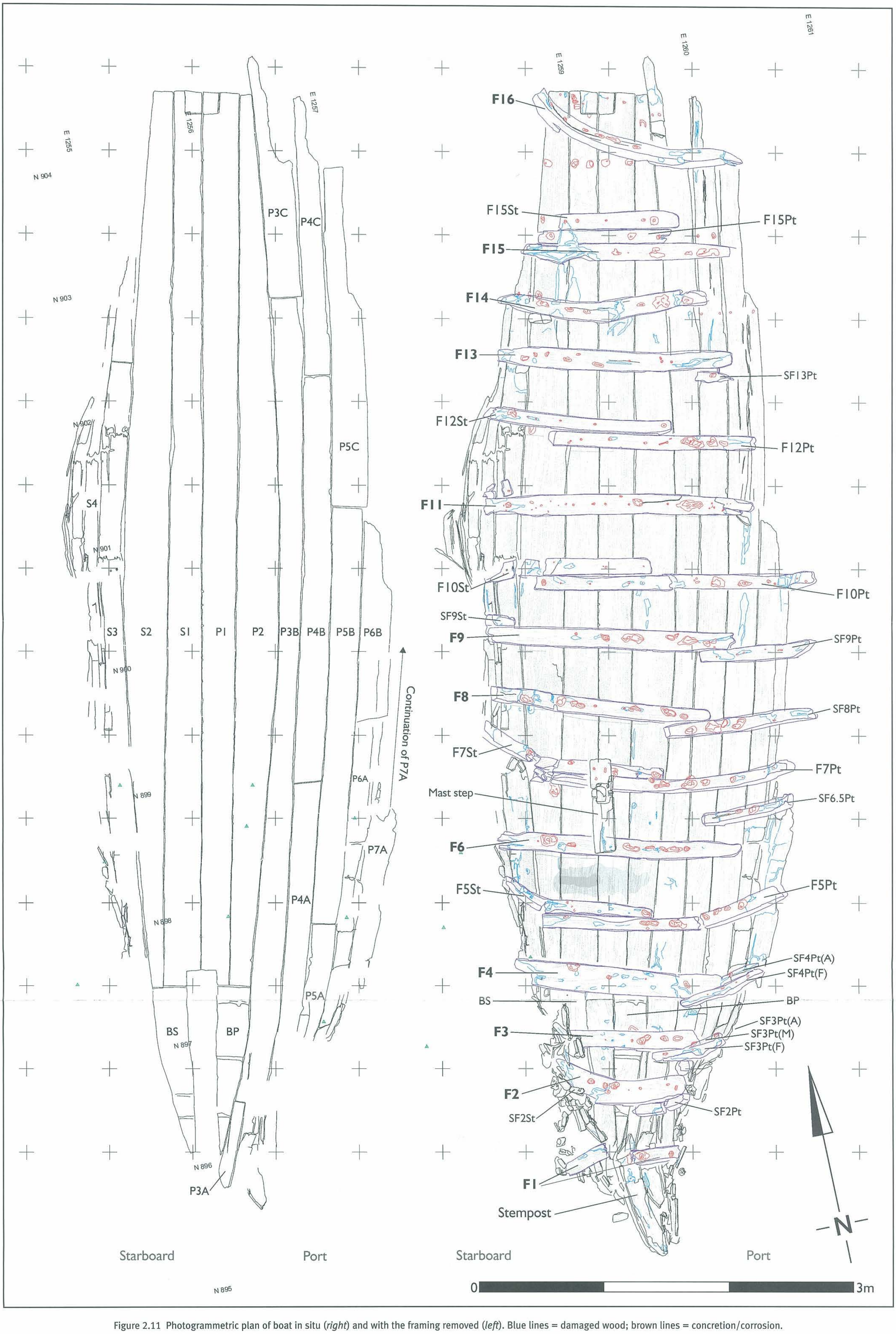


Figure 2.11 Photogrammetric plan of boat in situ (*right*) and with the framing removed (*left*). Blue lines = damaged wood; brown lines = concretion/corrosion.

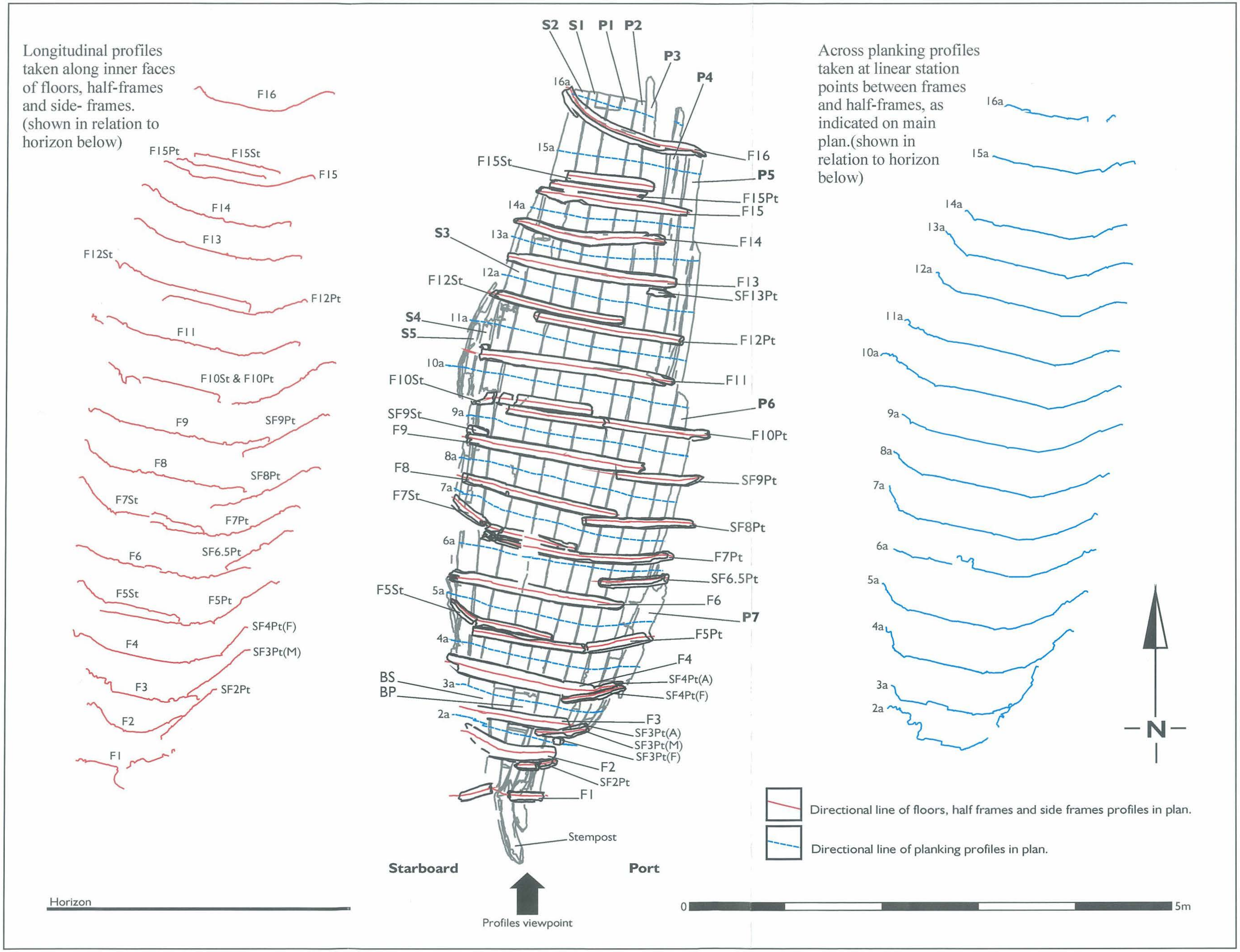


Figure 2.13
Timber codes and transverse sections through the boat *in situ*.

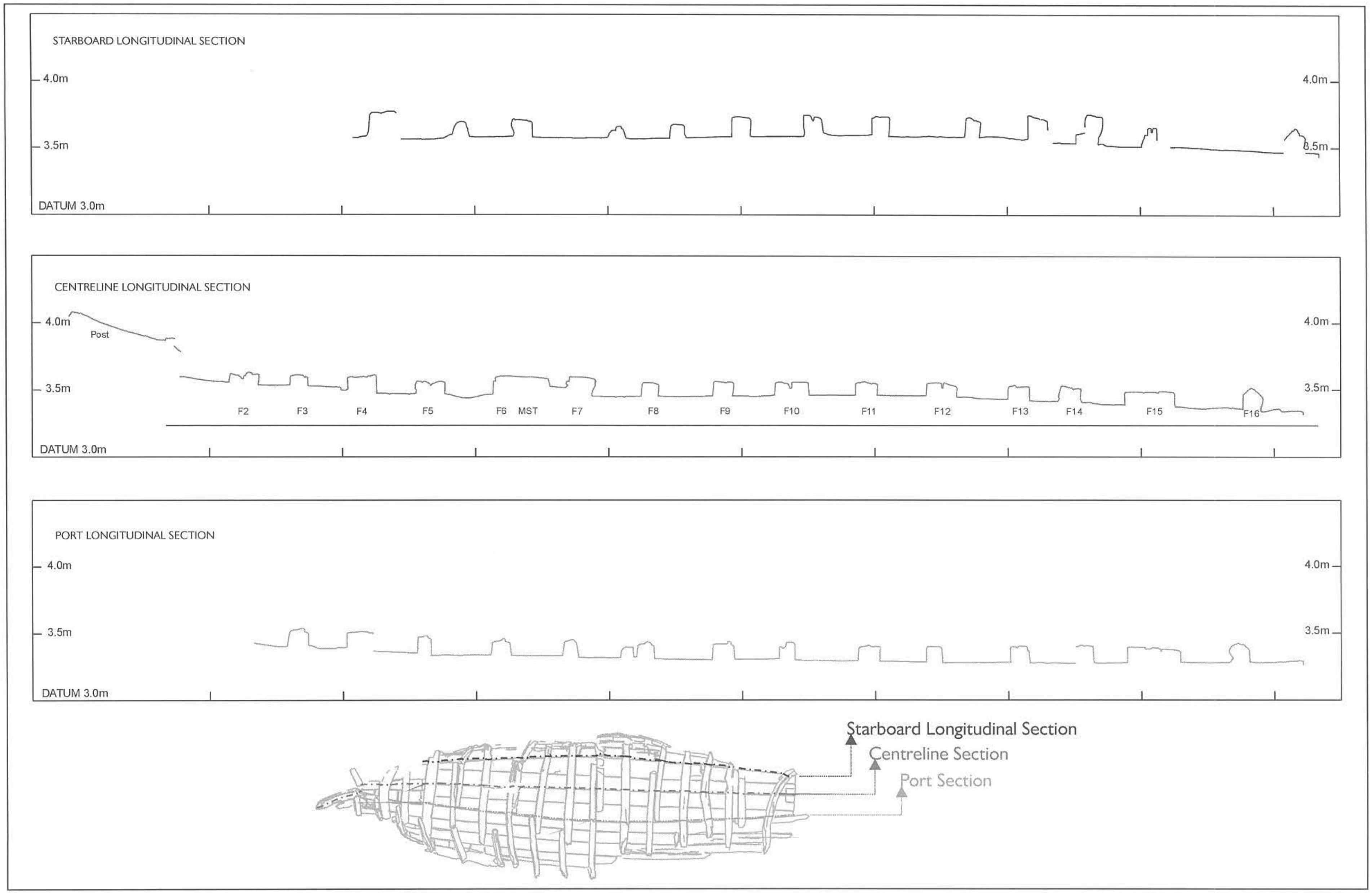


Figure 2.12 Longitudinal sections through the boat *in situ*.

2.3.2 Bow section (Fig 2.14)

The bow area from the forward end of the stem post to station 4 had undergone considerable disturbance. The stem post had snapped near station 1 and the forward fragment been displaced to the east, its upper face sloping down from 4.07m OD at its surviving forward end to 3.78m OD, while the aft section sloped less steeply from 3.55m to 3.52m OD forward of F4 (Fig 2.12). The strakes that had run into a rebate on either side of this timber were highly fragmented, particularly along the starboard side where pieces had been displaced to the east. These had partially obscured the lower hull planking and the starboard end of the frames. The frame at station 1 that had apparently consisted of a single floor timber running over the stem post attached to the adjacent planking had snapped into two separated pieces (see Figs 2.11 and 2.13) that sloped down towards the stem post.

Approximately 0.55m to the north of these (centre to centre) lay the less disturbed framing timbers at station 2. These included a substantial floor timber (F2) running from P4 over the stem post to at least S2. It had split near the centreline and the starboard section had been displaced to the east. On the port side immediately forward of F2 and butting its forward face, a small side timber ran up the side planking from P3 possibly as far as P6. While fragments of a side timber survived on the starboard side, their

Figure 2.14 Photograph of bow from F4 (foreground) to F1.

relationship to the side planking was unclear due to displacement.

At the third station, a further 0.4m aft, a floor timber (F3) ran from P5 to its damaged starboard end at S3. A displaced fragment of the starboard end was found overlying the starboard planking. An insubstantial side timber ran from just forward of the port end of F3 to P7. Butted onto the forward face of both of these, a further port-side timber ran from P3 to P7. No side timber was immediately evident on the starboard side, although a fragment (timber 5101) recovered during lifting of the highly fragmented starboard planking here may be a surviving and displaced piece of this.

Timbers at the aftmost station (4) associated with the bow section included the most substantial floor timber to survive (F4). It ran from P5 to S4. A small oak wedge (5105) appeared to have been driven between its forward face and the underlying planking at the chine between S2 and S3. No side timbers survived on the starboard side, but two were found on the port side. The less substantial of these ran from the port end of the floor to P7 while the other butted the forward face of the aforementioned elements of station 4 from P4 to P7.

Floors 2–4 in the bow section were all displaced somewhat aft, allowing a preview of the arrangement of the bottom planking in this area that became clearer once the frames had been lifted. F4 overlay the junction between the two plank-keel timbers (P1 and S1) and the two outer bottom planks (P2 and S2), the stem post, and the continuation of the bottom along both sides of the stem post made up of two planks (BS and BP) that had been rebated to accommodate floors F2 and 3. The lower edge of the lowest side strakes (P3 and S3) on each side butted the outer edges of these planks. In the port longitudinal section (Fig 2.12), the outer edge of BP is seen sloping down from 3.42m OD aft of F2 to 3.39m OD forward of F4. In the case of strake P3, the forward end of plank P3B had been half-lapped to a small plank (P3A) and a fragment (P3A*). The angled forward end of P3A originally sat in the port-side rebate of the stem post. Although the bow section was much disturbed, it provided invaluable evidence for the method of construction and form of the bow.

2.3.3 The hull bottom (Figs 2.15–2.17)

The bottom of the main hull was made up of four tangential oak planks 7.18m long.

These lay with a distinct list to port of 12–15°, but

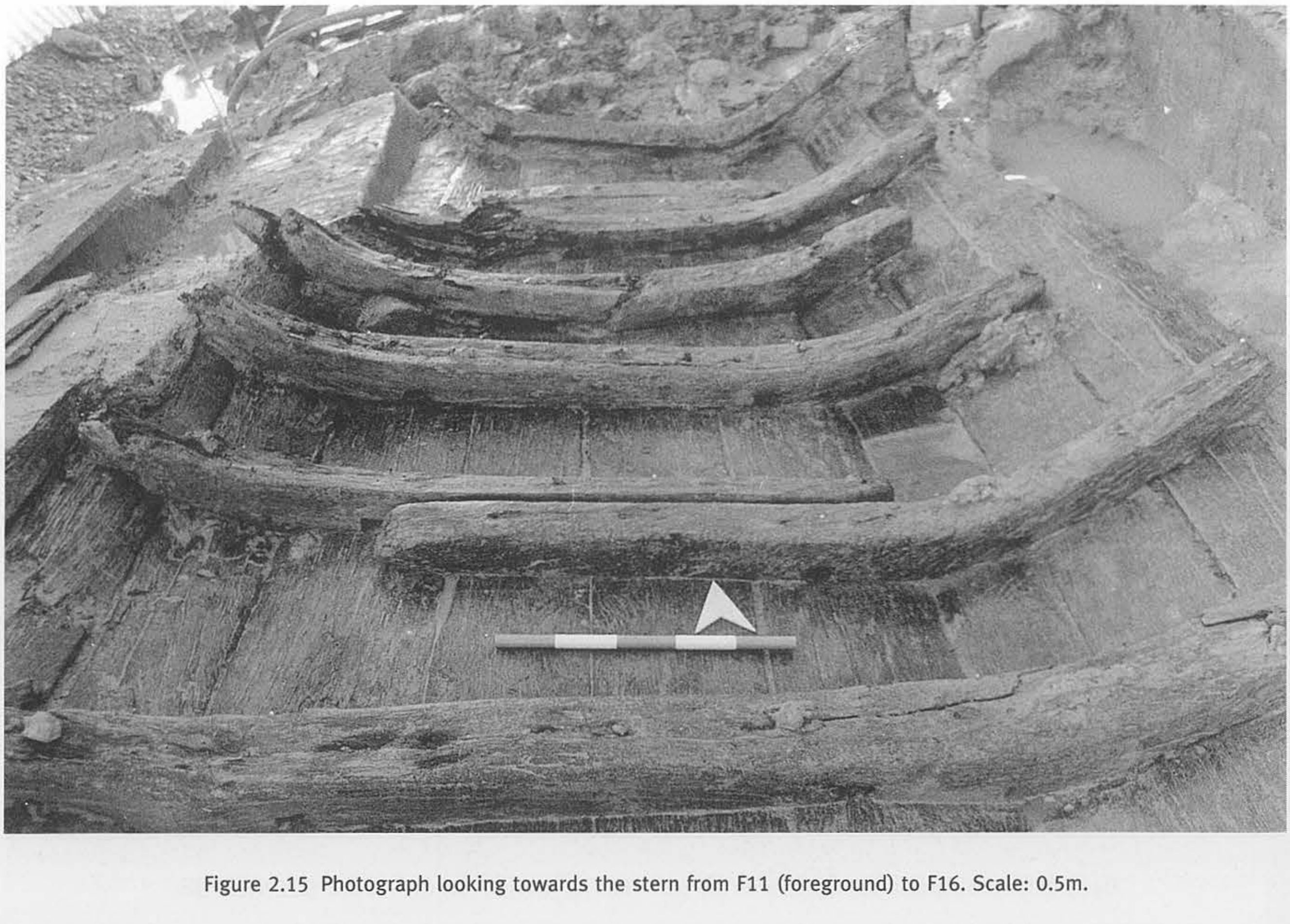


Figure 2.15 Photograph looking towards the stern from F11 (foreground) to F16. Scale: 0.5m.

Figure 2.16 Photograph looking towards the stern from F6 (right foreground) to F13. Scale: 0.5m.

Figure 2.17 Photograph looking towards the stern from F4 (foreground) to F7Pt and St. Scale: 0.5m.

were near horizontal in longitudinal section (Fig 2.12). The curving upper, outer edge of S2 rose from 3.47m OD at its aft end to a maximum height of 3.6m OD at station 11 before dipping down to 3.57m OD at station 7 where it levelled out for the rest of its length. While this rise towards the middle of the plank's length was in part due to its concavely curving outer edge, it also reflected differential settling of the hull bottom resulting from the location of a large rubble slab lying beneath the starboard hull at station 10/11. Its presence registered to a lesser extent in the projection of the centreline, which rose from 3.39m OD at the aft end of P1/S1 (where a rabbet cut to take the absent stern post reduced the level locally by *c* 20mm), to 3.45m around stations 10/11, 3.466m OD immediately forward of the mast step timber at F6, and 3.48m OD aft of F4. A distinct depression *c* 30mm deep visible in the projection between F5 and F6 reflected extensive wear in the base planks immediately forward of the mast step. The upper, outer edge of P2 sloped down very slightly from 3.28m OD at its aft end to 3.27m OD between stations 12 and 13, before rising gradually to 3.357m OD aft of F4.

The two central planks P1 and S1 were both 7.18m long and 60mm thick and butted against each other along the centreline to form a plank-keel. P1 tapered from its aft end to its forward end. Conversely S1 tapered from forward to aft. A rabbet had been cut into the aft end of these timbers. Iron corrosion within this rabbet indicated the former presence of nails used to fasten the missing stern post. A series of small, blind holes had been augered along the centreline. In some instances these cut into both central planks at the same time, indicating that these had been bored after the two planks had been butted together. P2 and S2 butted onto the outer edges of the plank-keel and were the same length. Their outer edges had a marked concave curve giving maximum widths of 0.37m at the midship position between stations 10 and 11. These were cut to an angle from the vertical to form the chine point for the commencement of the side planks. P2 tapered from its aft end to its forward end. Conversely S2 again tapered from its aft end towards its forward end. At *c* 45mm these outer planks were slightly thinner than the central planks. While originally the upper faces of the bottom planks must have been flush, some settling had occurred in the outer planks. Nonetheless the underside of the hull bottom still exhibited a slightly stepped profile during dismantling (see Fig 6.7), the central planks forming a plank-keel.

Figure 2.18 Photograph of planking on starboard quarter from F13 (left) to F16. Scale: 1m.

2.3.4 Starboard-side planking (Fig 2.18)

The side planking on the starboard side had undergone damage during modern machining, but had also clearly not survived to the extent of the port side due to its higher position within less permanently waterlogged silts and clays. The nature of the planks along the first, starboard-side strake (S3) was far from clear due to its fragmentary state forward of station 4. Strake S4 and remnants of S5 were fragmentary along their entire surviving length. They survived to the greatest height at stations 7 (3.9m OD) and 11 (3.95m OD). Possible reconstructions of these problematic planks are discussed in detail in subsequent sections.

2.3.5 Port-side planking (Figs 2.19–2.23)

Although still disturbed in the bow section, the port-side planking survived up to P7 and was far better preserved. Short plank P3A (5122) ran from the stem to station 2 where it had been half-lapped to the second plank in this strake, P3B (5110). The latter plank ran back to station 14. It was broadest at its ends and narrowest near station 9. P3C (5109) ran from the butt end of P3B to beyond the aft end of P2, where its eroded and incomplete aft end extended 0.24m beyond the hull bottom.

The second side strake was apparently more even in width and comprised three planks: P4A (5118) ran from the bow (fragmentary from stem post to stations 2/3) to station 7 where it butted P4B (5117). P4B ran to station 13 and butted P4C (5108). P4C survived to its full width as far as station 16, and for a further 0.4m beyond that frame's aft face.

The third side strake comprised P5A (5129). This had an apparent width of little more than 50mm at station 3, broadened to 0.23m at its aft end at station 5, where it butted P5B (5119) that ran to station 11 and was butted by P5C (5106). P5C survived to its full width as far as station 14, and continued partially to station 16. A small, detached fragment of plank 5107 found east of station 15 could have been part of the latter plank.

The fourth port-side strake survived from station 2 aft to just forward of station 11 and comprised two planks: P6A (5219) and P6B (5120) which butt joined at station 8. The uppermost surviving strake comprised a single plank (P7, 5121) that survived from aft of station 3 to station 9. Unlike planks of other strakes which had generally remained in close contact with the frame timbers, the section of this plank aft of inter-frame side timber SF6.5Pt had slumped away

Figure 2.19 Photograph of port planking and framing from F16 (left) to F13. Scale: 1m.

Figure 2.20 Photograph of port planking and framing from F13 (left) to F10Pt and St. Scale: 1m.

Figure 2.21 Photograph of port planking and framing from F11Pt (left) to F7Pt. Scale: 1m.

Figure 2.22 Photograph of port planking and framing from F6 (left) to F2. Scale: 1m.

Figure 2.23 Photograph of port planking and framing from F3 (left) to F1. Scale: 1m.

from the upper ends of frames 7–9 and was not visible at the time of photogrammetric recording.

2.3.6 Framing timbers (Figs 2.13–2.23)

Description of the framing timbers here concentrates on their position, condition, and completeness. Detailed information on specific timbers is given in section 6.3.3. Where redundant iron fastenings, score marks, or shadows were evident on the hull planks, indicating the original position of absent or displaced frame elements, these are also mentioned. Measurements of their position relative to one another are given centre to centre, usually along the centreline.

Frame group 5 comprised two half-frames, the forward of which (F5Pt, 5072) lay *c* 0.5m aft of floor F4. It ran from the outer edge of S2 where it had a flared end (presumably cut to face onto the angled upper face of S3) across the bottom of the hull and up the port side beyond the surviving upper edge of P7 with a top height of 4.01m OD. It had sheered apart near the seam between P4 and P5 and appeared to lean aft, although this may partly reflect post-depositional displacement. Two square limber holes had been cut into the underside to overlie S2 and P2. Unless otherwise stated, all the floors and half-frames described subsequently also had limber holes where/if they crossed P2 and S2. The aft half-frame (F5St) butted against the aft face of F5Pt and had a squared-off port end in line with the outer edge of P2. It survived to an incomplete and damaged end at S4 with a top height of 3.90m OD. Again this timber had sheered near the S2/3 join and the upper fragment appeared displaced to aft.

A single floor timber (F6, 5070) was recorded at station 6 at 0.5m aft of F5St, running from the upper surviving edge of S4 (at 3.89m OD), across the hull bottom, and up to the upper edge of P5 (at 3.57m OD). Aft of this timber on the port side, an inter-frame side timber (SF6.5Pt, 5080) ran up from the middle of P4 to its damaged upper end at 3.84m OD. Opposite this timber on the starboard side, a small fragment of timber (5082) overlying S4, obscured during photogrammetry by a first attempt at encasing timbers in fibre-glass moulds (see section 2.4), may have been a remnant of a similar side timber.

Frame group 7 comprised two half-frames. The forward, port-side timber (F7Pt, 5069) 0.51m aft of F6 ran across the full width of the hull bottom before curving up the port side to P7 with a top height of 3.81m OD. Directly aft of this, the starboard half-frame (F7St, 5068) ran from the outer edge of P2, along the aft face of F7Pt, and then up the starboard side to a damaged upper end with a top height of 4.02m OD.

A longitudinal timber some 0.75m in length, apparently slightly displaced to port at its forward end, ran along the centreline with shoulders overlying both half-frames at station 7 and floor F6. A blind mortise interpreted as a mast step cut into it measured *c* 120 × 80 × 60mm.

Framing timbers at station 8 comprised a slightly displaced floor (F8, 5067) 0.50m aft of F7St that ran from its damaged upper end on S4 (at 3.83m OD) to the middle of P4. A shadow on the hull bottom suggested that this timber had been displaced aft by up to 40mm. A side timber (SF8Pt, 5079) angled *c* 10° towards the stern ran from the bottom of P3 up to P7 with a top height of 3.87m OD. Tapering of the port end of F8 along its forward face, port of P2 where SF8Pt butted against it, suggests that this angle was in part intentional.

The floor at station 9 (F9, 5066) lay 0.55m aft of F8 and also appeared to be displaced aft by *c* 40mm. It ran from its damaged starboard end over S4 (top height 3.86m OD) to P4 (top height 3.50m OD), where a side timber (SF9Pt, 5078) butted onto its slightly tapered forward face and ran up to 3.87m OD (where it would have joined slumped P7) with an angle of 6° towards the stern. The fragmentary base of a side timber (SF9St, 5083) butted onto the aft face of F9 on S3 and S4 (top surviving height 3.89m OD).

Framing timbers at station 10 comprised two half-frames, a near-complete, forward, port-side timber (F10Pt, 5065) broken at its port end and where it ran over P4, and an aft starboard half-frame (F10St, 5064) that ran from P2 to S4. The starboard end of the latter timber had fractured twice over S2 and S3 and was incomplete, indicated by a shadow that continued to the truncated upper edge of S5.

The only substantial timber surviving at station 11 was a floor (F11, 5063) running from S4 (top height 3.87m OD) to P5 (top height 3.49m OD). A shadow on planks P2–P4, 20mm forward of F11, indicated some localised displacement. Three fragments immediately aft of the starboard end of F11 located on S3 (5105) and S4 (5103 and 5104) may have been remnants of an aft starboard-side timber.

The arrangement of frames at station 12 was similar to that at station 10, with a forward port half-frame (F12Pt, 5062) running from S2 across the hull bottom and up the port side to an incomplete end on P5 (top height 3.58m OD). Immediately aft of this timber, a starboard half-frame (F12St, 5061) ran from close to the outer edge of P2 to an incomplete end over S5 where a small fragment (5084) had become detached. Shadows forward of these timbers on P1 to S2 suggest that the framing timbers had been displaced by 50–75mm towards the stern relative to the bottom planking.

A floor (F13, 5060) running from the incomplete upper edge of S4 to P5 (top height 3.44m OD) and a fragment of side timber (SF13Pt, 5099) forward of the former's port end mirrored the timbers at station 11.

Surviving timbers associated with stations 14–16 had all undergone some damage during initial uncovering of the aft section of the vessel. In addition to damage to its starboard end, probably incurred during machining of the area to produce a formation level for construction, the floor at station 14 (F14, 5059) had been displaced forward and fractured near the centreline. A stone wedged between S2 and the forward face of this floor was probably part of the stone spread 2378 trapped by the timber's recent displacement. Nails visible in P1 to P5 forward of the position of F14 indicated the original position of the floor and a probable port-side timber that did not survive.

Framing timbers at station 15 were unique in comprising three closely butted timbers. The most forward of these (F15, 5058) ran from its damaged starboard end over S3 to P4 and is interpreted as a floor timber. Immediately aft the second timber in the group (F15Pt, 5057) that ran from the outer edge of S2 to an incomplete end over P2 is interpreted as a port half-frame with evidence for its original continuation surviving as nails in P4. The third timber in the group (F15St, 5056) ran from P2 (with a flared end facing onto P3) as far as its incomplete end on S2. Although no starboard-side planking survived this far aft, it seems probable that this timber also functioned as a half-frame.

The last surviving framing timber (F16, 5038/5055) was displaced aft, particularly towards its starboard end, and was found leaning aft. Nails visible on planks P1 to S2 indicated its original position, probably running from P5 to at least S4.

Just forward of the aft ends of the bottom planks, nails indicated the former position of a framing timber, presumably similar to that at F4.

2.4 Recovery, by N Nayling and Kate Hunter

The discovery of the Barland's Farm boat raised the issue of recovering it for detailed investigation and possible active conservation for long-term retention and display. *In situ* preservation was rejected as a feasible response, as the immediate area was subject to direct threat from the building programme – the projected wall line of the distribution centre would have passed through the vessel. Even if alterations to the building design had been possible, disruption of the boat's burial environment and anticipated lowering of the local water table through additional drainage left recovery of the boat as the only practical option.

Discussions involving Tesco Stores Ltd, Newport Museum and Art Gallery, and members of Newport Borough Council (now Newport County Borough) led to identification of an enthusiastic receiving museum that agreed to provide conservation assistance during recovery, establish a wood store for timber cleaning and recording, and ensure the eventual conservation and display of the boat find.

A start-up factory unit belonging to Newport Borough Council was identified as a storage and recording facility for the boat. Although the largest empty unit available, it was only just possible to accommodate a tank for the boat timbers and incorporate a useful working area. A scaffold tank measuring 10 × 4 × 0.5m was installed. At 0.5m high the tank was deep enough to stack two layers of timbers on pallets separated by brick stacks, but was shallow enough for easy access in and out, both to step into and work around. Safety cut-out switch electric heaters with frost protection thermostats were installed to prevent the tank from freezing up during winter months. Nine metres of benching designed to hold at maximum a complete run of planking was erected by the museum technician along one wall.

Once recording of the vessel *in situ* had been completed, the floors and side timbers were removed. Fortunately the iron nails that had secured these to the planking were highly corroded and most of these timbers were lifted by hand without the need for any support. Notes were made on each individually numbered timber during the lifting operation and samples of sediment taken for plant-macrofossil analysis of possible cargo residues. After preliminary cleaning, the timbers were placed in the back of a Luton van and transported to the Newport store where they were submerged underwater in the scaffold tank. Rubberised carpet underlay was used as temporary wrapping material during transportation to reduce evaporation and provide protection and support.

Following additional recording of the planks, now fully exposed through the removal of the frames (see Fig 6.5), the two outer bottom planks and both elements of the plank-keel were recovered. These were each tangentially converted oak timbers over 7m long. With a thickness of 40–60mm, thay were extremely cumbersome. It was decided to ease transportation, reduce the risk of inadvertent damage, and along the way take slices for dendrochronology by cutting each plank into three using a petrol-powered circular saw which gave a very clean cut with a narrow kerf. Each plank was lifted in three sections (plus a slice for dendrochronology), each section being placed in a custom-built pallet made from 50 × 25mm by 25 × 25mm timber and Correx® (corrugated plastic) held together with brass screws. Samples of organic caulking between the planks were taken as the recovery progressed. A similar approach was taken with the lifting of the best-preserved planks on the port side.

The more fragmentary upper port and starboard planking proved more problematic. Using existing breaks between the planking, thirteen individual blocks were identified, cleaned on the inboard face, and faced up with polyester and fibreglass. Aluminium foil was used as a separating layer. Three coats of polyester and two of fibreglass proved sufficient for each block. As the site was very cold and wet, the first block took three days to set fully. Thereafter quantities of catalyst in excess of the manufacturer's recommendations were used and each set promptly. Since these materials present a health and safety risk, gloves and respirators were worn throughout. Because even in such an exposed and draughty site the smell lingered, block construction was done when possible during lunch and other breaks. Once the blocks were in place the excavation team was able to cut away soil from outboard, isolate each block, and push it backwards onto the fibreglass support. In general the supports proved very successful for keeping these very fragmentary pieces together. Because the supports themselves follow the curvature of the upper planking in the ground, they will also aid reconstruction and display.

Once these lifting blocks had been transported to the wood store and placed in the water tank, the tank was covered in polystyrene sheeting and black polythene to reduce microbial activity during production of a full post-excavation assessment report.

3

Palaeoenvironmental Evidence

3.1 Introduction, by M J C Walker

Extensive sampling of Holocene deposits at Barland's Farm was undertaken in order to characterise the changing Flandrian landscape and vegetation. This formed an integral part of the archaeological field programme. Following post-excavation assessment, a subset of samples was selected for analysis. Only those samples analysed from Area 50 that have a bearing on the Roman environment associated with the timber and stone structure and its associated palaeochannel deposits are considered here. The results of the analyses of sediments that predate these sequences are described elsewhere (Walker *et al* 1998).

3.1.1 Sample locations

Within Area 50 a single column comprising two 100 × 100 × 500mm monoliths (1111 and 1116) was extracted for pollen analysis next to the structure in this trench (Fig 3.1.1 and Table 3.1.1). An adjacent column of spot samples (1117–1139) was also taken for diatom analysis along with three samples from overlying deposits exposed in the battered side of the excavations (1102, 1106, and 1110). A subset from a contiguous column of bulk samples was selected for molluscan analysis. Bulk samples taken from a number of locations in the north-facing section were selected for plant macrofossil, sediment, and additional diatom

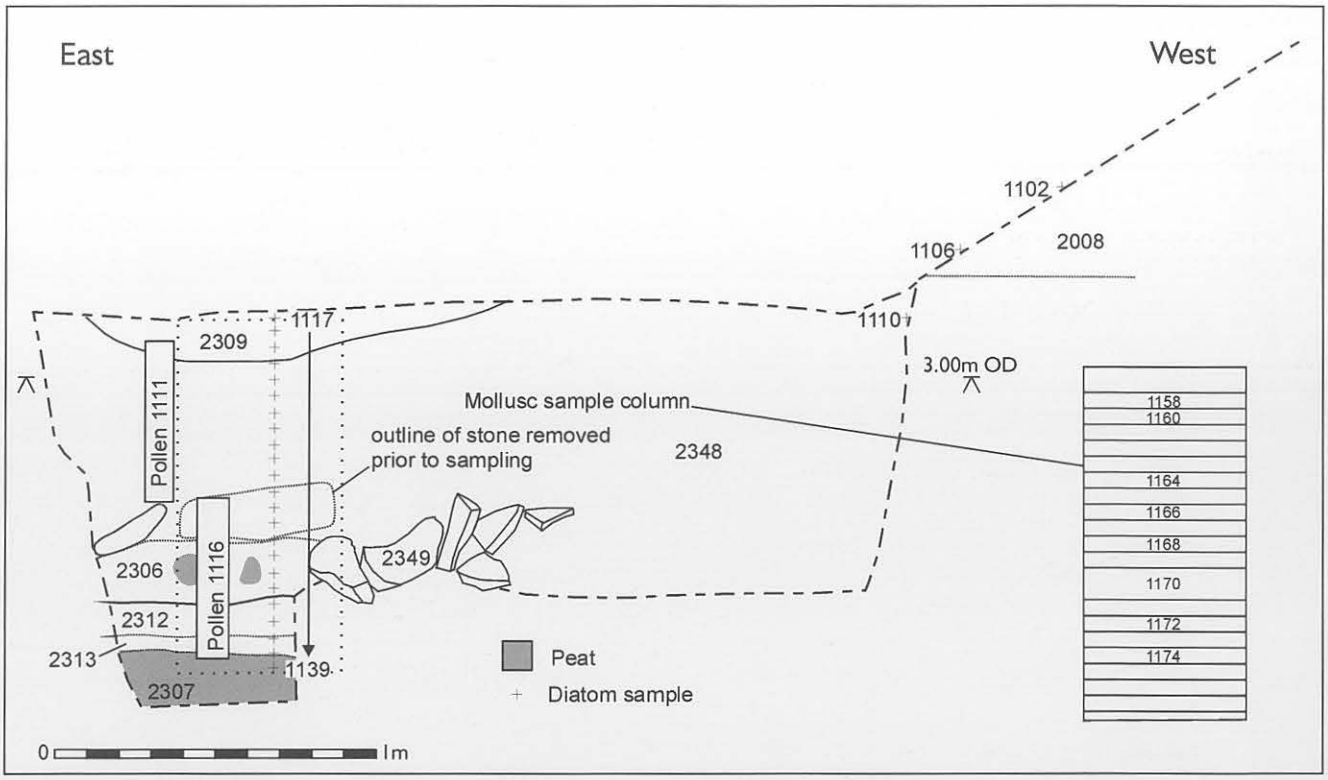


Figure 3.1.1 Area 50: sampling column 1.

Table 3.1.1 Bulk samples, Area 50 north-facing section. Samples selected for analysis are indicated by a cross.

sample	*context*	*plant macro-fossils*	*mollusca*	*diatoms*	*sediment*
1144	2318/44			+	+
1145	2318	+		+	+
1146	2336			+	+
1147	2335			+	+
1148	2318				+
1149	2336				+
1150	2312	+			+
1151	2300				+
1152	2337				+
1153	2310				+
1154	2337			+	+
1155	2337			+	+
1156	2337	+		+	+
1157	2307	+			+
1158	2309		+		
1160	2348		+		
1164	2348		+		
1166	2348		+		
1168	2348		+		
1170	2348		+		
1172	2306		+		
1174	2312		+		

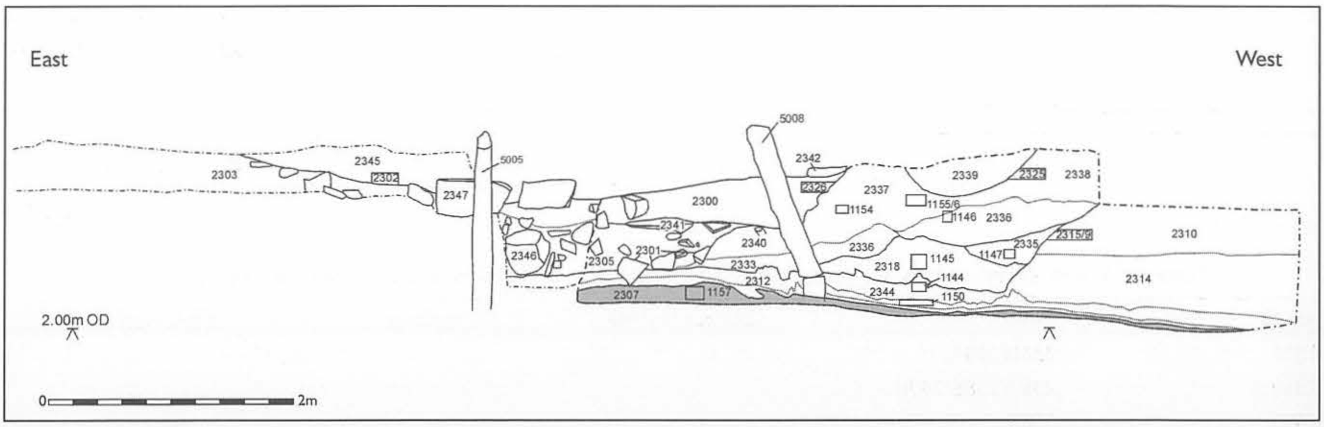


Figure 3.1.2 Area 50: north-facing composite section. Bulk samples 1144–7 and 1154–6.

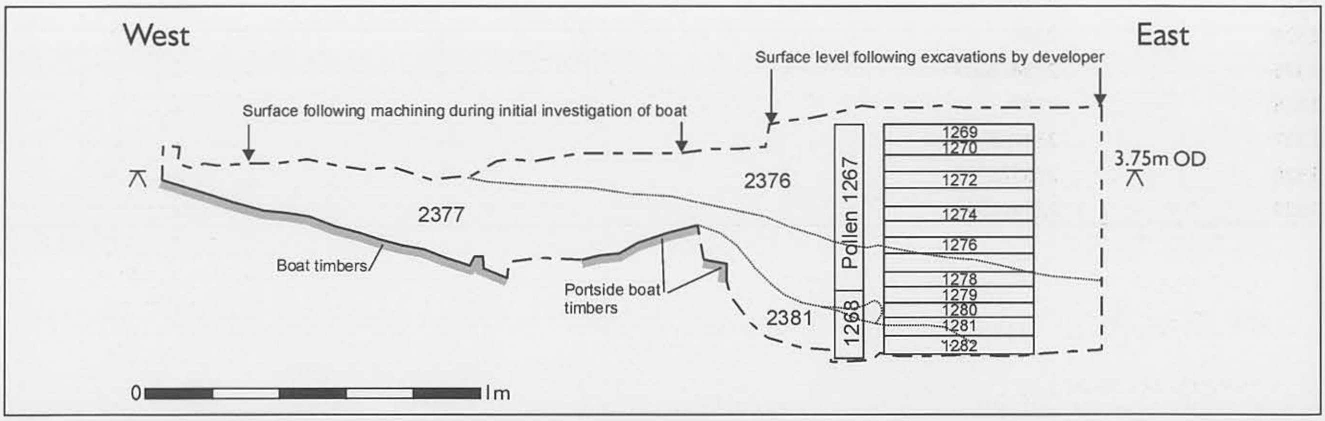


Figure 3.1.3 Area 54: south-facing section, sampling column 2.

Table 3.1.2 Area 54, south-facing section. Bulk samples. Samples selected for analysis are indicated by a cross.

sample	*contexts*	*plant macro-fossils*	*mollusca*	*sediments*
1269	2376			+
1270	2376	+	+	+
1271	2376			+
1272	2376		+	+
1273	2376			+
1274	2376	+	+	+
1275	2376			+
1276	2376/2377		+	+
1277	2376/2377			+
1278	2377	+	+	+
1279	2377		+	+
1280	2377		+	+
1281	2377/2381		+	+
1282	2377/2381	+	+	+

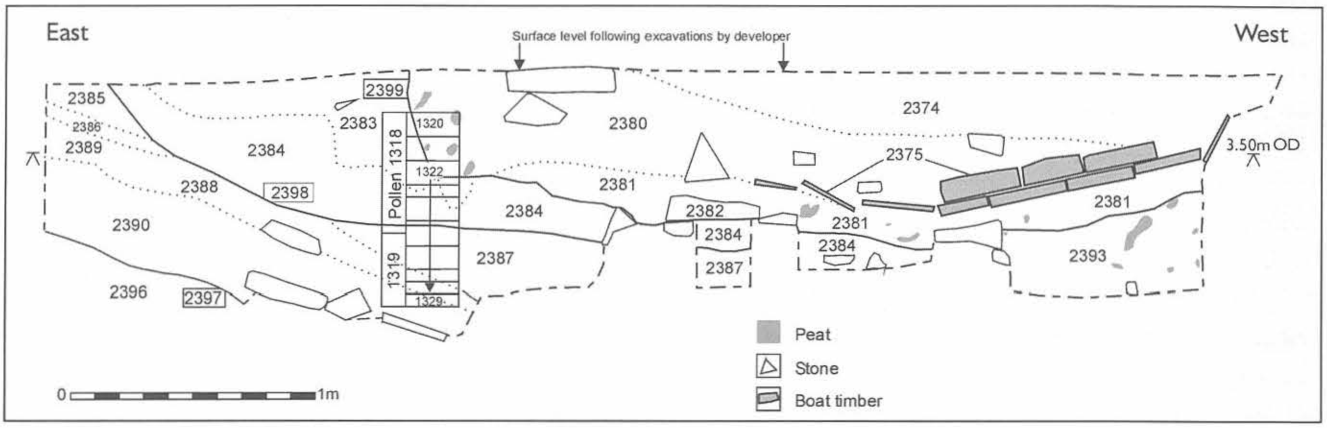


Figure 3.1.4 Area 54: north-facing section, sampling column 3.

Table 3.1.3 Bulk samples, Area 54, north-facing section. Samples selected for analysis are indicated by a cross.

sample	*contexts*	*plant macro-fossils*	*mollusca*	*sediments*
1318	2380/2384			
1319	2387/2388/2390			
1320	2380	+	+	+
1321	2380			+
1322	2380		+	+
1323	2380			+
1324	2384	+	+	+
1325	2384/2387		+	+
1326	2387	+	+	+
1327	2387/2388		+	+
1328	2387/2388		+	+
1329	2388/2390		+	+

analysis (Fig 3.1.2), including strata thought to be point bar deposits.

Following the discovery of further Roman structural remains, including the boat in Area 54, an additional project design was written identifying the need for supplementary sampling. Two main locations were chosen: the south-facing section of an area excavated immediately to the east of the boat (Fig 3.1.3 and Table 3.1.2); and a north-facing section near the surviving stern of the boat (Fig 3.1.4 and Table 3.1.3). Samples for pollen were recovered from both locations using monolith tins of galvanized steel; these comprised a column of one 500mm and one 300mm tin at the northern location (samples 1318 and 1319) and one 500mm and one 200mm tin at the southern site (samples 1267 and 1268). Contiguous columns of bulk samples for plant-macrofossil, sediment, and molluscan analysis were taken from both sections (samples 1320–1329 and 1269–1282). Again a subset of these was selected for analysis following post-excavation assessment. Numerous samples were also taken from sediment held in the limber holes of framing timbers within the boat in the hope of identifying cargo residues.

The locations of monolith tins, the spot samples taken for diatom and pollen analysis, and associated bulk samples are presented graphically in enlargements of the relevant parts of the excavation sections along with a description of the lithostratigraphy of the contexts identified in the field.

3.1.2 Contexts and lithostratigraphy

3.1.2.1 Column 1: Area 50 north-facing section (Fig 3.1.1); monoliths 1111 and 1116 (pollen), column of spot samples 1117–38 (diatoms), bulk samples 1158–74 (mollusca)

Context 2309

0–40mm monolith 1111, diatom column 400–530mm, mollusca bulk sample 1158.

Dark grey to dark greenish-grey (N4–5GY 4/) generally homogeneous silty clay with some concentrations of small manganese flecks. Well-defined, sloping, fine silt lenses. Very similar to underlying 2348.

Context 2348

40–500mm monolith 1111, 0–140mm monolith 1116, diatom sub group 270–400mm, diatom column 530–1090mm, mollusca bulk samples 1160, 1164, 1166, 1168, and 1170.

Greyish-brown (10YR 5/2) silty clay with well-defined silt lenses, occasional plant macrofossils, and dark grey (10YR 4/1) mottles.

Context 2306

140–330mm monolith 1116, diatom column 1090–1260mm, mollusca bulk sample 1172. Grey (10YR 5/1) silty clay mottled with dark grey (10YR 4/1) peaty material. Occasional peat clasts.

Context 2312

330–430mm monolith 1116, diatom column 1260–1400mm, mollusca bulk sample 1174.

Dark grey (10YR 4/1) peaty clay becoming very dark grey (10YR 3/1).

Context 2313

430–480mm monolith 1116, diatom column 1400–50mm.

Very dark grey (10YR 3/1) band of silty clay with thin lenses of dark grey (10YR 4/1) silty clay.

Context 2307

480–500mm monolith 1116.

Very dark brown (10YR 2/2) compact peat.

3.1.2.2 Area 50, part of north-facing composite section; bulk samples 1144–7 and 1154–6 (Fig 3.1.2)

Context 2300

Bulk sample 1151. Dark grey to dark greenish-grey (N4–5GY 4/1) silty clay. Fairly homogeneous, soft and malleable.

Context 2336

Bulk samples 1146 and 1149. Brown (10YR 5/3) silty clay with small nodules of very slightly sandy, silty clay.

Context 2337

Bulk samples 1152 (clay component of deposit), 1154 (clay/organic mixed component of deposit), 1155 (silt component of deposit), and 1156 (peaty clay lump within deposit). Greyish-brown (10YR 5/2) silty clay with well-defined organic bands with fine laminations. Occasional clasts of very dark brown (10YR 3/1) peat.

Context 2335

Bulk sample 1147. Greyish-brown (10YR 5/2) homogeneous, slightly sandy, silty clay. Diffuse organic bands.

Context 2310

Bulk sample 1153. Dark grey to dark greenish-grey (N4–5GY 4/1) silty clay with occasional concentrations of manganese flecks and plant macrofossil remains.

Context 2318
Bulk samples 1144–5 and 1148. Dark grey (10YR 4/1) silty clay with well-defined dark greyish-brown (10YR 4/2) banding. Concentrations of manganese flecks and small roundwood at base.

Context 2344
Bulk sample 1144. Greyish-brown (10YR 5/2) silty clay. Some diffuse organic staining.

Context 2312
Bulk sample 1150. Dark grey (10YR 4/1) peaty clay becoming very dark grey (10YR). 3/1.

Context 2307
Bulk sample 1157. Very dark brown (10YR 2/2) compact peat.

3.1.2.3 Column 2: Area 54, south-facing section. Pollen monolith and bulk samples (Fig 3.1.3)

Context 2376
0–370mm pollen monolith 1267, bulk samples 1269–77. Grey and greyish-brown (N5 and 10YR5/2), very slightly silty, sticky clay with abundant creamy pink/brown mottles and iron staining (oxidized), occasional manganese flecks, roundwood and plant macrofossils.

Context 2377
370–500mm pollen monolith 1267, 0–60mm pollen monolith 1268, bulk samples 1276–82. Dark grey to dark greenish-grey (N4 to 5GY4/1), moist, sticky clay with common manganese flecks, common/occasional iron staining, and occasional roundwood. Far less oxidized than overlying 2376.

Context 2381
60–200mm pollen monolith 1268, bulk samples 1281–82. Dark greenish-grey (5BG4/1) silty clay with common peat clasts and manganese flecks and occasional roundwood and Phragmites? roots. The upper part of the layer was fairly clean: peat clasts tended to occur in the lower part of the layer around stone strew 2382 where the sediment had a noticeable sand content.

3.1.2.4 Column 3: Area 54, north-facing section. Pollen monolith and bulk samples (Fig 3.1.4)

Context 2380
Bulk samples 1320–22. 0–300mm pollen monolith 1318. Dark grey (5Y4/1) silty clay with frequent stone, abundant peat clasts, common plant macrofossil stems/roots.

Context 2384
Bulk samples1324–5. 300–470mm pollen monolith 1318. Dark grey (N4) silty clay with common manganese flecks, moderate iron staining, and occasional plant macrofossils.

Context 2387
Bulk samples 1325–28. 470–500mm pollen monolith 1318, 0–130mm pollen monolith 1319. Grey (N6) silty clay with moderate mottles of silty clay (10YR7/2) and abundant concentrations of iron corrosion. Slightly softer and much 'cleaner' than overlying 2384. The mottles (maximum dimension 30mm) were concentrated in the top 0.05m of the layer.

Context 2388
Bulk samples 1327–9, 130–220mm pollen monolith 1319. Dark greenish-grey (5G4/1) silty clay with abundant manganese flecks, occasional iron staining, and plant macrofossils and rarely occurring stone. The top of this layer was marked by a continuous band of manganese streaks.

Context 2390
Bulk sample 1329. 220–300mm pollen monolith 1319. Bluish-grey (5B5/1) soft, silty clay with moderate manganese staining.

3.2 Pollen data by M J C Walker and J H James

3.2.1 Introduction
This report describes the pollen evidence from deposits associated with Romano-British activity at the site. Environmental reconstructions based on pollen and other fossil records from the pre-Iron Age levels in the Barland's Farm sediments are discussed in Walker *et al* (1998).

3.2.2 Sampling contexts
Samples for pollen analysis were removed from two localities during archaeological excavations at the site. In the open trench (Area 50), two 100 × 100 × 500mm monoliths (1111 and 1116) were extracted from the silts and clays overlying the peats adjacent to a wooden structure that had been exposed during excavation (Fig 3.1.1). Four monoliths were removed from the channel infill associated with the boat (Area 54), two 500mm

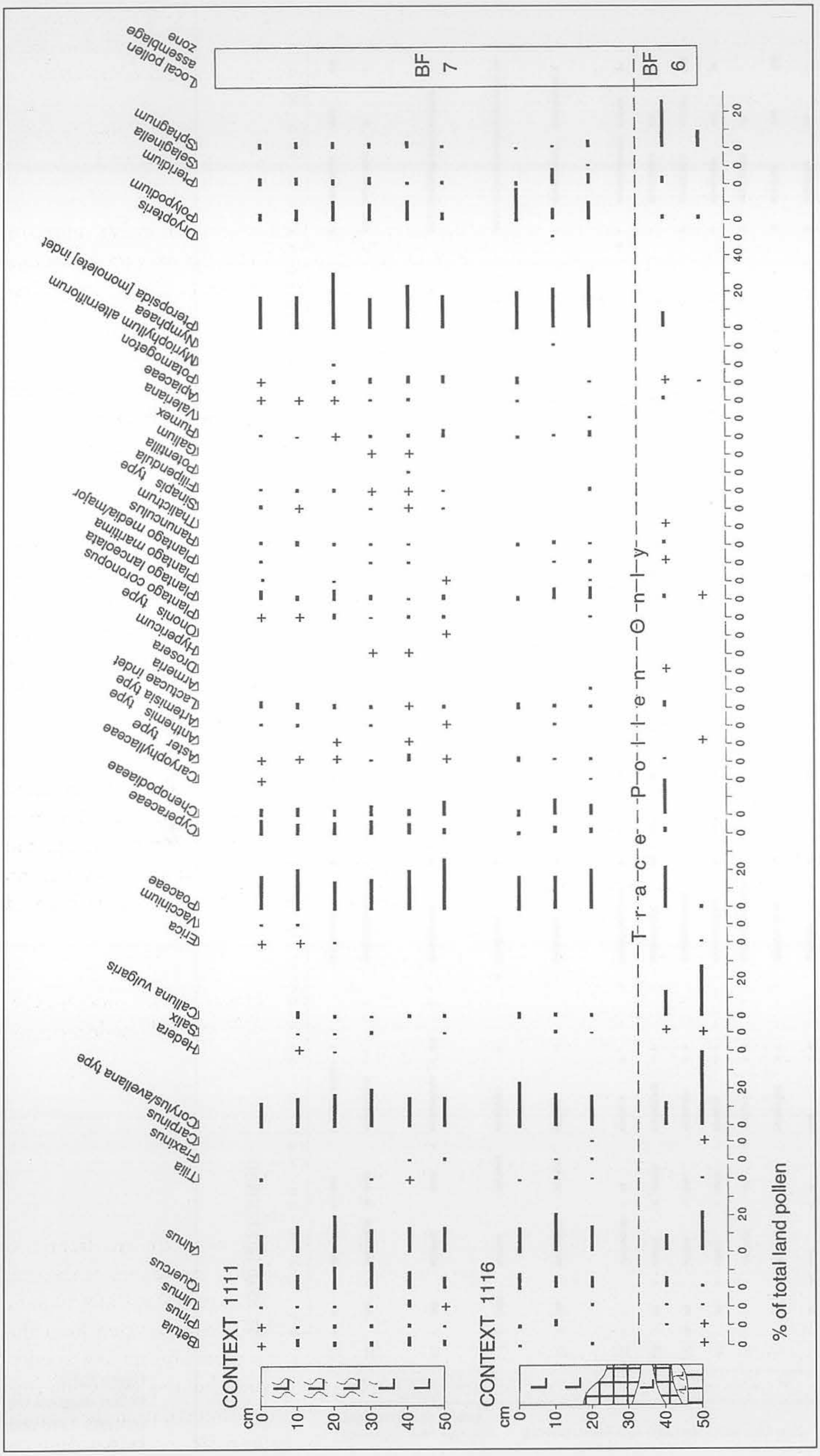


Figure 3.2.1
Pollen diagram for contexts 1111 and 1116.

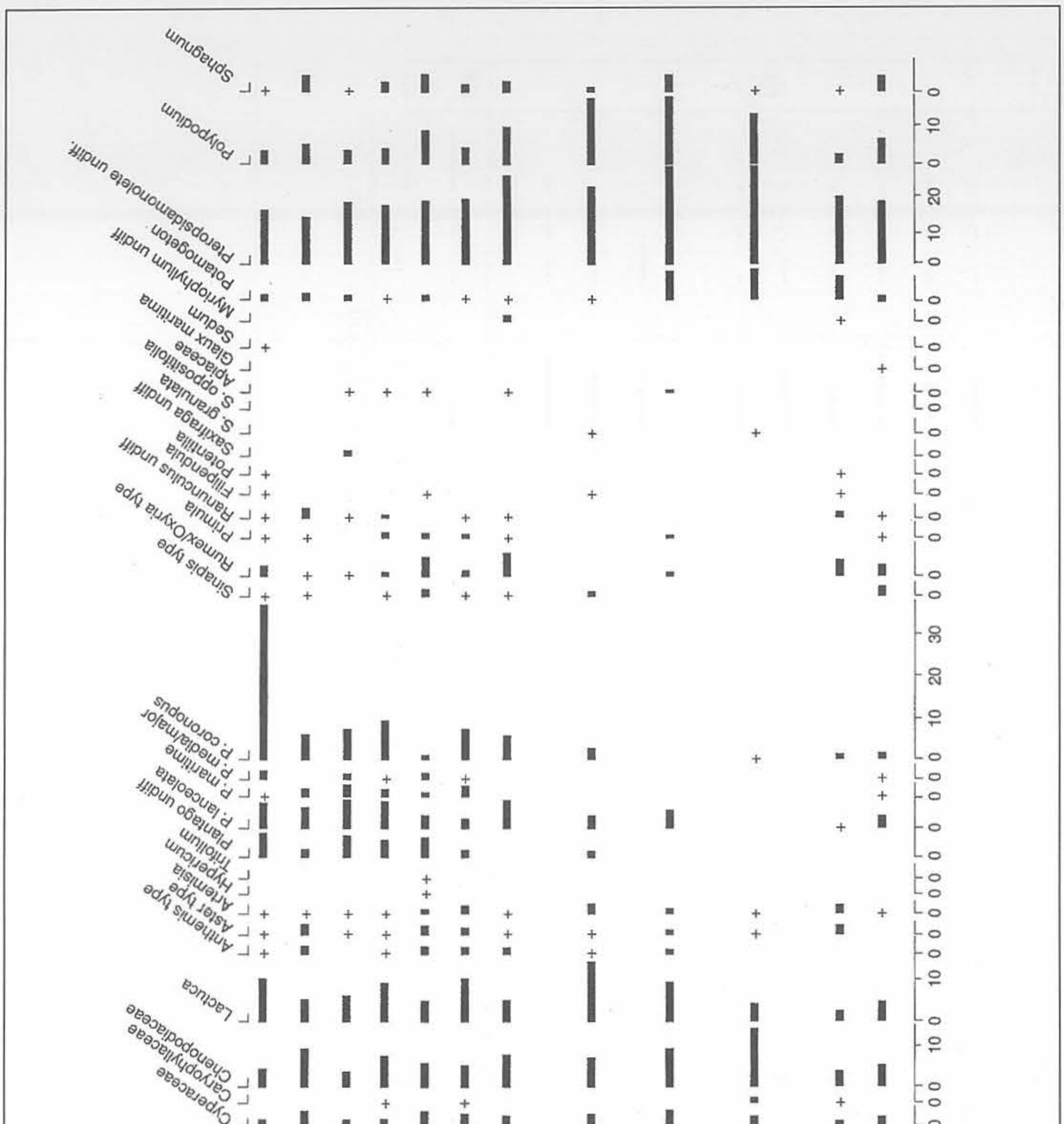


Figure 3.2.2
Pollen diagram for contexts 1318 and 1319.

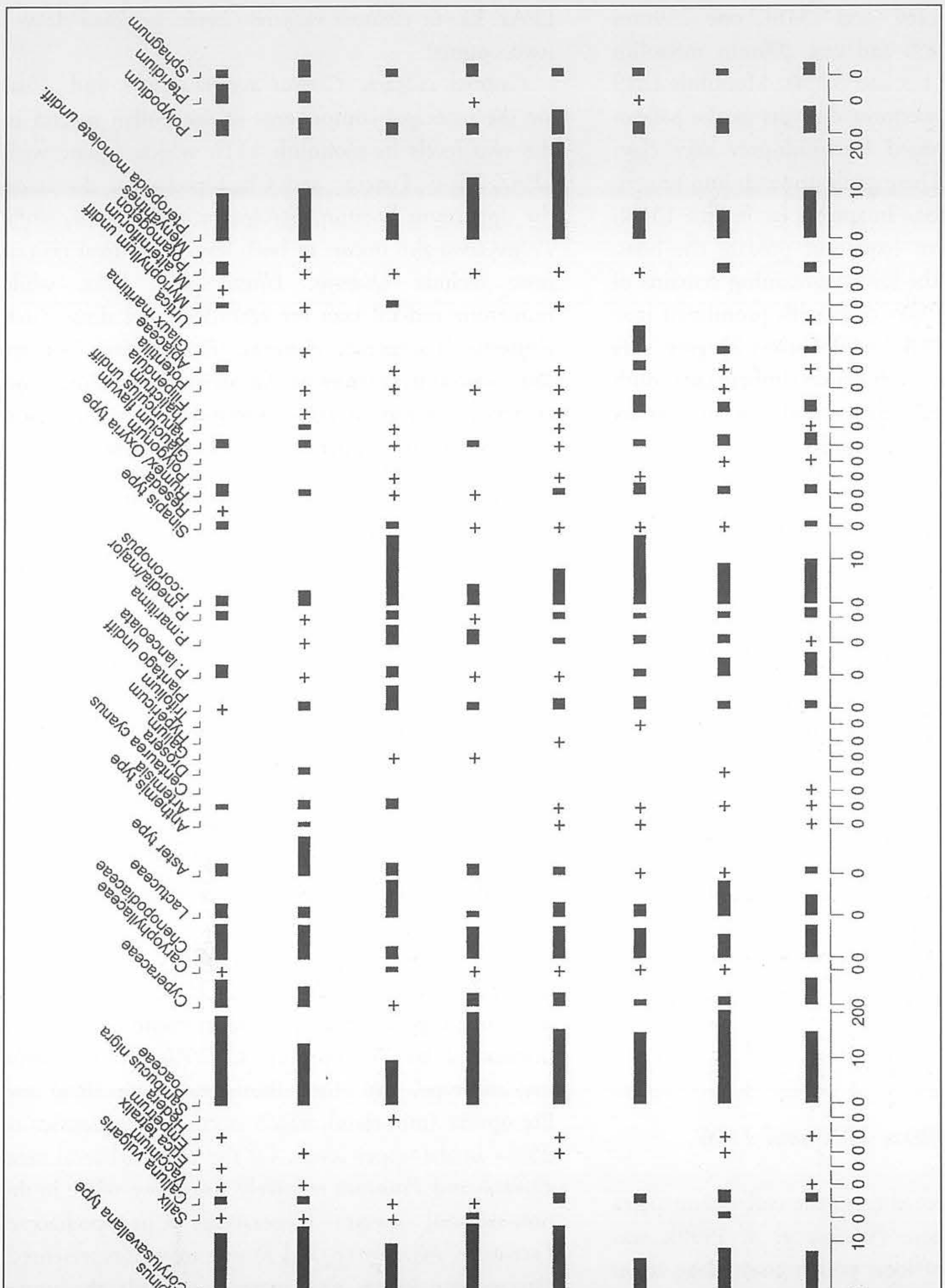


Figure 3.2.3 Pollen diagram for contexts 1267 and 1268.

monoliths (contexts 1267 and 1318), one 250mm monolith (context 1319) and one 200mm monolith (context 1268; Figs 3.1.3 and 3.1.4). Monolith 1319 was taken from the lowermost deposits in the palaeochannel, which comprised brownish-grey silty clays with dark grey lenses. These grade upwards into brown-grey silty clays with stone fragments (monolith 1318). Both of these sediment sequences predate the boat. Immediately beneath the levels containing remains of the boat are dark grey silty clays with prominent iron staining (monolith 1268), while brownish-grey silty clays form the infill above the boat timbers (monolith 1267). Pollen analyses were carried out on twenty samples from these four monoliths.

3.2.3 Laboratory methods

In the laboratory subsamples were removed from the monoliths at 50mm intervals. These were treated using conventional procedures (Moore *et al* 1991), including disaggregation in 10% KOH followed by Erdtman's acetolysis preceded where necessary by heating in 40% HF. The residues were mounted in safranin-stained glycerine jelly and counted on a Vickers Ml5C microscope at x400 magnification, with critical identifications under oil at x1000. The state of preservation of the pollen was good and a sum of 300 grains (total land pollen) was achieved for all levels, with the exception of one horizon in the monolith from 1116 where only traces of pollen were recovered. The results of the pollen analyses are shown in Figs 3.2.1, 3.2.2, and 3.2.3. Plant nomenclature follows Stace (1991).

3.2.4 Pollen data

3.2.4.1 Area 50: contexts 1111 and 1116 (Fig 3.2.1)

The long Flandrian record from the coffer dam (Area 51), published elsewhere (Walker *et al* 1998), was divided into a series of local pollen assemblage zones (LPAZs) on the basis of fluctuations in the curves for the principal pollen taxa. Seven biozones were identified and numbered BF–1 to BF–7 from the base. The shorter pollen diagram in the open trench (Area 50: contexts 1111 and 1116) equates with the upper part of the Area 51 profile. The two local pollen assemblage zones reflected in the sequence (Fig 3.2.1) are numbered (BF–6 and BF–7) in accordance with their counterparts in the master sequence. The ages are based on an age/depth curve derived from six radiocarbon dates obtained from that sequence.

LPAZ BF–6: *Calluna vulgaris-Corylus avellana-Alnus* (two counts)

Calluna vulgaris, *Corylus avellana* type, and *Alnus* are the principal components of the pollen spectra in the two levels in monolith 1116 which equate with LPAZ BF–6. Poaceae and Chenopodiaceae dominate the uppermost horizon. *Sphagnum* is abundant, while *Polypodium* also occurs in both levels. Arboreal taxa of note include *Quercus*, *Ulmus*, and *Salix*, while numerous ruderal taxa are recorded, including *Aster*, *Anthemis*, Lactuceae, *Armeria*, *Ranunculus*, *Plantago lanceolata* and *Plantago media/major*. The radiocarbon evidence suggests an age of around 2850 radiocarbon years BP for the upper boundary of the zone.

LPAZ BF–7: Poaceae-*Corylus avellana*-Chenopodiaceae (nine counts)

This biozone is dominated by Poaceae, *Corylus avellana*, and *Alnus*. *Quercus* is also well represented, while *Betula*, *Pinus*, and *Ulmus* all form components of the arboreal pollen spectra. *Tilia* also occurs sporadically. *Calluna vulgaris* values are significantly reduced by comparison with the previous zone, but Chenopodiaceae and Cyperaceae are relatively abundant. Of the other herbaceous taxa, *Plantago lanceolata*, shows a significant increase, while a range of other herbs are present. Pteropsida and *Polypodium* show higher frequencies and *Potamogeton* is also more abundant.

3.2.4.2 Area 54: monoliths 1319, 1318, 1267, and 1268 (Figs 3.2.2 and 3.2.3)

The pollen spectra (four counts) in monolith 1319 are dominated by Poaceae (up to 25% TLP), *Corylus avellana* type, and *Alnus* (both exceeding 10%) and Pteropsida (monolete) which occur in frequencies of 25%+ in the upper levels. Of the other arboreal taxa, *Quercus* and *Pinus* are relatively abundant, while in the non-arboreal spectra Cyperaceae, Chenopodiaceae, Lactuceae, *Plantago* sp, and *Rumex* are well represented. *Potamogeton* values also increase towards the upper levels of the sediment column.

The pollen spectra in 1318 are broadly similar to those in the uppermost level of the underlying monolith 1319, although there is a marked reduction in *Potamogeton*. Above 300mm, however, there is a significant change, most notably in the increase in *Plantago* pollen (*P coronopus*, *P lanceolata*, and *P maritima*), in the appearance of *Rumex*, in the expansion of Poaceae, and in the reduction in *Quercus* and *Alnus*. Frequencies of fern spores (Pteropsida and *Polypodium*) also tend to be lower. Unusually high counts for *Plantago coronopus* are recorded in the uppermost level of the profile.

The three levels that were analysed from monolith 1268 produced pollen spectra very similar to the upper part of monolith 1318. The records are dominated by Poaceae, Chenopodiaceae, Lactuceae, and *Plantago* (especially *P coronopus*), and are characterised by values for *Alnus*, *Quercus* and *Alnus* which never exceed 10%, and by relatively low counts (%) for fern and moss (*Sphagnum*) spores.

In monolith 1267, where five levels were analysed, generally higher counts are recorded for woody plant pollen (*Alnus*, *Quercus*, and *Corylus*) and also for fern spores (Pteropsida and *Polypodium*). Very high frequencies of *Plantago* (principally *P coronopus*) and Lactuceae pollen tend to distort the spectra at the 200mm level. *Pteridium* appears in the upper levels of the profile.

3.2.5 Discussion

3.2.5.1 The records from Area 50, monolith tins 1111 and 1116

These two sequences were obtained from the small palaeochannel in which the archaeological deposits were located. The lower part of 1116 comprises peats and intercalated silts which are part of the main peat bed of the Caldicot Level which dates from sometime in the third millennium BP (first millennium BC). The upper part of 1116 and all of 1111 represent infill in the palaeochannel itself. The basal rubble spread that extends across the upper half of 1116 and appears to be part of a jetty or bridge, dates from the late 3rd or early 4th century AD (Lawler and Nayling 1993). The evidence suggests that the palaeochannel rapidly silted up following the building of this structure, with the sediments of the upper part of 1116 and all of 1111 accumulating perhaps within a century or so (Lawler pers comm). This in turn implies that there is a major lack of conformity in the pollen profile between the lower and upper parts of 1116 and that this horizon is reflected in the boundary between LPAZs BF–6 and BF–7. The most significant change in the pollen spectra between these two biozones includes a reduction in heathland taxa (eg *Calluna vulgaris*) in BF–7, an increase in *Plantago* sp in BF–7, and the marked increase in fern spores (Pteropsida and *Polypodium*) in BF–7. The evidence from BF–7 suggests a coastal salt-marsh, with extensive areas of damp or wetland habitats, but also areas of grassland. Indeed the rise in the *Plantago lanceolata* curve may be indicative of grazing activity. A curious feature of this biozone, however, is the relative abundance of arboreal taxa, with *Alnus* and *Quercus* both prominent. While the former may have been associated with the expansion of alder carr, it is more difficult to account for the latter. It has been suggested from the evidence of sampled wood, however, that there may have been managed, fast-growing oakwood in the hinterland (Nayling pers comm).

3.2.5.2 The records from Area 54, monolith tins 1319, 1318, 1268, and 1267)

A major difficulty in interpreting pollen spectra from fluvial deposits such as those from the Barland's Farm boat site relates to the taphonomy of the pollen assemblages. While some of the grains will be from local plant communities, others will have been derived from regional or long-distance sources, not only by wind and animal vectors, but particularly by water transport (see Caseldine and Barrow 1997). In addition reworking of channel sediments will inevitably mean that pollen assemblages will frequently tend to be biased towards the more robust grains (eg *Lactuceae* and fern spores) and will also contain a mixture of primary and secondary grains. Such problems are commonly encountered in coastal or near-coastal sites such as this, where reworking of sediment can occur through both fluvial and tidal activity (eg Robinson 1993). Careful examination of the pollen from Barland's Farm, however, showed that, while some grains exhibited signs of exine damage (abrasion, breakage, and so on), the majority were in a surprisingly good state of preservation. Although not conclusive, this might suggest that relatively few derived or secondary grains are present in most levels. This, in turn, may reflect the relatively sluggish nature of water movement in the palaeochannel and a minimum of disturbance of previously deposited sediment. Clearly, however, it is almost impossible to determine the extent to which the assemblages have been affected by differential preservation or destruction.

Despite the interpretational problems associated with this type of pollen evidence, some tentative inferences may be made from the data sets in Figs 3.2.2 and 3.2.3. The lowermost deposits in the palaeochannel (monolith 1319; levels 200 and 250mm) appear to reflect a local environment of grassland, with some damper areas of alder carr and sedge fen. Remnant areas of raised bog may have persisted, with *Sphagnum* and *Calluna* communities. Further inland stands of hazel interspersed with oak may have been present, although the former extent of the woodland cover cannot be established on the basis of the available evidence. The occurrence of *Potamogeton* throughout the profile may indicate the existence of shallow, relatively slow-moving patches of fresh water (but see section 3.5), although the rise in the curve for Chenopodiaceae and the expansion of other halophytic elements (eg *Artemisia*) suggests the encroachment of salt-marsh vegetation and an increasing marine influence. This trend is further reflected in the overlying sequence (monolith 1318) with the expansion of *Plantago maritima* and *P coronopus*, both of which are common today in salt-marsh or short turf communities around the British coast. Some species of *Anthemis* and *Aster* (eg *Anthemis punctata* and *Aster tripolium*) are also found in contemporary coastal habitats (Stace 1991). It is also noticeable that *Potamogeton* falls to very low levels, perhaps reflecting the reduction of fresh water in the channel. The implication, therefore, is of an increasing marine influence in the vicinity of the site, with a shift to more brackish water conditions in the palaeochannel, possibly associated with a slight rise in sea level.

A further feature of the pollen record of the upper part of 1318 and of monolith 1319 that merits comment is the appearance of *Plantago lanceolata*, accompanied by an abrupt rise in the curve for Lactuceae and subsequently by an increase in pollen of Poaceae. These data appear to reflect an increase in grassland habitats and in particular of short-turf communities. *P lanceolata* in particular is often found in grazed areas and has frequently been interpreted as an indicator of pastoral activity in pollen records (eg Behre 1986). Equally *Rumex* (which expands at around 300mm in monolith 1318) along with certain species of Asteraceae (eg *Anthemis* and *Aster*) have been taken as indicators of arable practices, as they are now associated with bare and unstable ground. It remains to be established, however, whether these data are in fact indicative of late Roman farming activity in the vicinity of the palaeochannel or whether they simply reflect the increasing proximity of coastal marsh and sand dune communities (in which these taxa are also found today).

The maritime influence in the vicinity of the site is most clearly demonstrated in the spectra from monolith 1268. Here, in addition to Chenopodiaceae, *Aster*, *Plantago maritime* and a strong representation of *P coronopus*, the assemblage contains a number of grains of *Glaux maritima* (sea milkwort), a plant that is found today around the coast of the British Isles in saline, sandy, and grassy places and in a few inland salt-marshes (Stace 1991). *Plantago lanceolata* and *Rumex* are once more well represented, again reflecting the presence of extensive areas of short-turf grassland. In monolith 1267 that largely postdates the remains of the boat, the maritime influence appears to be slightly reduced. *Glaux maritima* virtually disappears from the record, while *Plantago coronopus* values are markedly lower, with the exception of the 200mm level. Freshwater taxa (*Myriophyllum* and possibly *Potamogeton*) increase slightly in the uppermost levels of the monolith, perhaps indicating a stronger fresh water and hence a reduced tidal influence at the site. Again, however, the changes are relatively subtle and such inferences must remain tentative in the absence of independent corroborative evidence.

One feature that is apparent in all of the monoliths is the relatively strong representation of woody plant taxa throughout the channel infill. Of the tree taxa, *Pinus* is almost certainly of long-distance derivation through both wind and water transport. Some of the *Alnus* grains may also have been carried some distance by water. It does seem that some wooded areas were present in the hinterland of the site, however, with stands of *Quercus*, *Alnus*, *Fraxinus*, and *Corylus avellana*. Indeed short-lived episodes of woodland expansion may be recorded in monoliths 1318 and 1267. This is especially interesting as it has been suggested on the basis of sampled wood that there may have been managed, fast-growing oak woodland in fairly close proximity to the site (Nayling pers comm). Such a suggestion would certainly accord with the pollen evidence from the palaeochannel infill.

3.3 Plant macrofossils, by A Caseldine, S Johnson, and Kathryn Hunter

3.3.1 Introduction

The aims of the plant macrofossil investigations at the Barland's Farm boat site (Area 54) were two-fold. The first was to determine the nature of the environment preceding, contemporary with, and after the deposition of the boat. To this end plant remains were recovered from selected samples from two sequences adjacent to the two pollen columns analysed (see section 3.2) to determine the environmental conditions. The same samples were also examined for molluscs (see section 3.5). The second aim was to see if there was any evidence of what had been carried on the boat. Samples from the limber holes were used for this purpose. In addition selected samples from peats and point bar deposits were examined from the previously excavated site (Area 50).

Table 3.3.1 Plant macrofossils from Area 50

sample	1157	1150	1145	1156
context	2307	2312	2318	2337
sample size ml	50	100	100	50
Ranunculus sceleratus L celery-leaved crowfoot	–	10	–	–
Urtica dioica L common nettle	–	1	–	–
Sagina type pearlwort	–	–	–	452
Atriplex sp oraches	–	1	–	–
Suaeda maritima (L) Dumort annual sea-blite	–	–	4	–
Salicornia sp L glassworts	–	3	1	–
Chenopodiaceae	–	10	–	–
Calluna vulgaris (L) Hull heather	345	–	–	–
Calluna vulgaris (L) Hull flowers	46	–	–	–
Calluna vulgaris (L) Hull shoots	2	–	–	–
Erica tetralix L cross-leaved heath	160	–	–	–
Erica tetralix L leaf frags	20	–	–	–
Glaux maritima L sea milk-wort	–	4	4	5
Potentilla anserina L silverweed	–	38	–	–
Apium nodiflorum (L) Lag fool's water-cress	–	12	–	–
Plantago major L greater plantain	–	12	–	–
Triglochin maritimum L sea arrowgrass	–	4	–	–
Potamogeton coloratus Hornem fen pondweed	–	1	–	–
Potamogeton sp pondweeds	–	1	–	–
Juncus sp rushes	2	500+	20	155
Rhynchospora alba (L) Vahl white beak-sedge	2	–	–	–
Eriophorum vaginatum L hare's-tail cottongrass	26	–	–	–
Eleocharis palustris/ uniglumis common spike-rush/slender spike-rush	–	7	–	–
Carex sp – biconvex sedges	–	2	–	–
Carex sp – trigonous	–	3	–	–
Cyperaceae	2	–	–	–
Sphagnum sp	+	–	–	–
Sphagnum sp opercula frags	9	–	–	–
Aulacomnium palustre (Hedw) Schwaegr	+	–	–	–
Amblystegium riparium (Hedw) Br Eur	–	–	–	+

3.3.2 Sample contexts

Four contexts were examined from Area 50 (Figs 3.1.1 and 3.1.2): 2307 (sample 1157); 2312 (sample 1150); 2318 (sample 1145); and 2337 (sample 1156). Several contexts were also analysed from around and also within the boat in Area 54. Sequence 1320–6 largely predates deposition of the boat. Sequence 1270–82 largely postdates the boat. Three of the samples include contexts directly associated with activity at the site. Context 2384 (sample 1324) contained stone and artefactual material and predated deposition of the boat. Context 2381 (sample 1282) was broadly contemporary with the boat. Context 2380 (sample 1320) was associated with a subsequent repair/construction phase postdating deposition of the boat. The limber hole samples are 1283–97.

3.3.3 Laboratory methods

Either 50 or 100ml samples were examined from Area 50. These samples were sieved after soaking in dilute sodium hydroxide. Subsamples weighing 250g from sequences 1320–6 and 1270–82 and initially 100g subsamples from the limber hole samples were processed and analysed. Following preliminary examination of the latter set, a further 400g (total 500g) was processed and sorted from sample 1289. All the samples were washed through a stack of sieves with 2mm, 1mm, 500micron, and 250micron meshes. Identification was by comparison with modern reference material and identification texts (eg Berggren 1969 and 1981; Schoch *et al* 1988). Nomenclature follows Stace (1991). The results are presented in Tables 3.3.1–3.3.4.

3.3.4 Results and discussion

The earliest sample 1157 (Table 3.3.1) analysed from Area 50 is from a peat (context 2307) and contains a raised bog assemblage. This is consistent with the evidence from the other trenches (see Walker *et al* 1998). It is also in agreement with the pollen evidence from the basal level in pollen monolith 1116 (see above section 3.2.5.1). Sample 1150 from peaty clay (context 2312) above the peat contains a number of taxa indicative of salt-marsh including sea arrowgrass (*Triglochin maritima*) and glassworts (*Salicornia* sp). Silverweed (*Potentilla anserina*) and greater plantain (*Plantago major*) are also species found in salt-marsh. Pondweed (*Potamogeton*) species may suggest a fresher water element. The plant macrofossil evidence is consistent with the comparable pollen evidence from level 400mm in monolith 1116 (see section 3.2.5.1).

Only a few plant remains were recovered from sample 1145 from the lower point bar deposit (context 2318) and again the assemblage suggests a salt-marsh environment. Sample 1156 from an upper point bar deposit (context 2337) contained a large quantity of a *Sagina* type (pearlwort) and sea-milkwort (*Glaux maritima*) but little else. The diatom assemblages from these contexts also suggest a brackish environment (see section 3.4).

All the samples from sequences 1320–6 and 1270–82 in Area 54 (Table 3.3.2) contain an element indicative of salt-marsh. This suggests that the channel was subject to a tidal influence throughout the period covered by the samples. Oraches (*Atriplex* sp), glassworts (*Salicornia* sp), annual sea-blite (*Suaeda maritima*), salt-marsh rush (*Juncus gerardii* included under *Juncus* sp), sea arrowgrass (*Triglochin maritima*), spiral tasselweed (*Ruppia cirrhosa*), sea aster (*Aster tripolium*), and sea club-rush (*Bolboschoenus maritimus*) are all frequently found in salt-marsh habitats (Rodwell 2000). The evidence for fresh water is slight with only the sporadic occurrence of water-starwort (*Callitriche* sp) and bulrush (*Typha* sp): the latter can occur in reedswamp where there are brackish conditions. Similarly fennel pondweed (*Potamogeon pectinatus*) and horned pondweed (*Zannichellia palustris*) can be found in either fresh or brackish water. There is comparatively little plant macrofossil evidence to suggest environmental change within the channel environment during the period represented by the samples. In contrast higher *Potamogeton* values in the pollen record (see section 3.2.5.2) from the earliest deposits (monolith 1319) could indicate fresher water conditions compared to later (monolith 1318). It is possible, however, that some of the *Potamogeton* pollen could in fact represent *Triglochin maritima*, which is known to be present from the plant macrofossil record. Similarly some *Potamogeton* species, such as *Potamogeton pectinatus* that was present at that time, can occur in both fresh or brackish water. It has also been suggested (see section 3.2) that there is evidence (in the form of *Glaux maritima* pollen) for a marine influence in the lowest levels of 1267–8, although *Glaux maritima* was first noted as a plant macrofossil in sample 1278, slightly later than in the pollen record.

Other plant macrofossil remains indicate environments away from the channel. The occasional seed of heather (*Calluna vulgaris*), leaf fragment of cross-leaved heath (*Erica tetralix*), and sclerenchymatous spindle of cotton grass (*Eriophorum vaginatum*) probably reflect reworking of raised bog deposits. Taxa such as selfheal (*Prunella vulgaris*), hawkweed oxtongue (*Picris hier-*

Table 3.3.2 The plant remains from sequences 1320–26 and 1270–82

sample number	1326	1324	1320	1282	1278	1274	1270
context	2387	2384	2380/1383	2377/2381	2377	2376	2376
height (+m OD)	3.04– 3.09	3.24– 3.34	3.59 3.69	3.19– 3.24	3.39– 3.44	3.59– 3.64	3.79– 3.84
sample size	250g	250g	250g	250g	250g	250g	250g
Ranunculus repens type buttercup	–	–	1	–	–	–	–
Ranunculus sardous Crantz hairy buttercup	–	–	–	–	–	1	–
Ranunculus sceleratus L celery-leaved buttercup	1	–	1	–	–	–	1
Ranunculus Subgenus *Batrachium* crowfoots	–	–	–	–	3	–	1
Urtica dioica L common nettle	–	–	–	1	1	–	–
Betula sp birch	–	–	–	3	1	2	–
Chenopodium rubrum L red goosefoot	–	–	–	–	–	–	2
Atriplex sp oraches	3	–	2	4	–	–	2
Salicornia sp glassworts	3	–	–	5	–	–	–
Suaeda maritima (L) Dumort annual sea-blite	5	–	–	2	–	1	–
Chenopodiaceae	–	–	–	–	–	1	–
Cerastium sp mouse-ears				2	–	–	–
Sagina type pearlworts	1	–	3	5	4	–	3
Spergularia sp spurreys	17	8	12	6	6	7	3
Caryophyllaceae	–	–	–	–	–	1	–
Polygonum aviculare L knotgrass	–	–	1	–	–	–	–
Rumex acetosella L sheep's sorrel	1	–	–	–	–	–	–
Rumex conglomeratus Murray clustered dock with perianth	–	–	–	1	–	–	–
Rumex sp dock	1	–	–	–	–	–	–
Calluna vulgaris (L) Hull heather	1	–	1	–	–	1	–
Erica tetralix L leaf frags	1	–	–	–	–	–	–
Anagallis type pimpernels	–	–	–	1	–	–	–
Glaux maritima L sea-milkwort	–	–	–	–	1	–	–
Rubus fruticosus agg bramble	–	–	–	1	–	–	–
Potentilla anserina L silverweed	–	–	1	1	–	–	1
Potentilla sp cinquefoil	–	–	1	–	–	–	–
Linum catharticum L fairy flax	–	–	–	1	–	–	–
Apium graveolens L wild celery	–	–	1	–	–	–	–
Apium nodiflorum (L) Lag fool's water-cress	–	–	1	–	1	–	–
Torilis nodosa (L) Gaertner	–	–	–	1	–	–	–

knotted hedge-parsley							
cf *Stachys* sp woundworts	–	–	–	1	–	–	–
Prunella vulgaris L selfheal	–	–	1	1	1	–	–
Lycopus europaeus L gypsywort	–	–	–	1	–	–	–
Callitriche sp water starworts	–	–	1	–	–	–	–
Plantago major L greater plantain	–	2	2	2	1	–	2
Euphrasia sp L/ *Odontites vernus* (Bellardi) Dumort eyebright/red bartsia	–	18	1	1	–	–	–
Cirsium sp thistles	–	–	–	2	–	–	1
Leontodon sp hawkbits	–	1	2	–	–	–	–
Picris hieracioides L hawkweed oxtongue	1	–	–	–	–	–	–
Sonchus asper (L) Hill prickly sow-thistle	–	1	–	3	–	–	–
Aster tripolium L sea aster	–	–	1	–	–	–	–
Asteraceae	–	–	1	–	–	–	–
Alisma sp water-plantains	–	–	1	–	–	1	–
Triglochin maritimum L sea arrowgrass	1	3	3	1	8	–	–
Potamogeton pectinatus L fennel pondweed	1	–	–	–	–	–	–
Ruppia cirrhosa (Petagna) grande spiral tasselweed	1	–	–	1	–	–	–
Juncus sp rushes	73	70	349	212	188	142	198
Juncus bufonius L toad rush	3	1	7	7	8	4	–
Zannichellia palustris L horned pondweed	1	–	2	–	2	1	–
Eriophorum vaginatum L hare's-tail cottongrass	1	–	–	–	–	–	–
Eleocharis palustris/ *uniglumis* common spike-rush, slender spike-rush	–	–	–	2	–	–	–
Bolboschoenus maritimus (L) Palla sea club-rush	13	1	–	7	3	–	–
Carex pseudocyperus L cyperus sedge	1	–	–	–	–	–	–
Carex sp -biconvex	–	1	2	–	–	–	–
Carex sp -trigonous	–	1	–	–	–	1	–
Cyperaceae	1	–	–	–	–	–	–
Bromus sp brome	–	–	–	–	1	–	–
Poaceae large >2.0mm grasses	2	–	–	–	2	2	–
Poaceae small <2.0mm	11	57	10	15	17	8	5
Typha sp bulrushes	1	–	–	–	–	–	–
flower calyces	5	–	–	–	2	–	–
Pteridium aquilinum (L) Kuhn bracken	–	–	–	9	8	–	–
Sphagnum sp leaves	18	2	2	8	5	1	–
Chara sp stoneworts	–	–	–	–	–	1	–

acioides), and fairy flax (*Linum catharticum*) support the pollen evidence for grassland habitats (see above 3.2.5.2). Similar interpretive problems to those encountered with pollen also occur with plant macrofossils. As well as those taxa that are assignable to a specific habitat, certain families include species representative of a range of environments: a number of individual species found in salt-marshes are not confined solely to that environment. Hence grasses (Poaceae) include species both of grassland, reed swamp, and salt-marsh, as do hawkbits (*Leontodon* sp) and species such as silverweed (*Potentilla anserina*). The latter also frequently occurs in disturbed ground. Eyebright/red bartsia (*Euphrasia* sp/*Odontites vernus*) include species and subspecies which live in salt-marshes, by rivers, in pasture and turf, particularly by the sea, and in arable and waste ground. The occurrence of knotted hedge-parsley (*Torilis nodosa*) could be attributable to arable activity in the area or the presence of bare ground. It is another species that favours close proximity to the sea, while prickly sow-thistle (*Sonchus asper*) could also be indicative of cultivation or disturbed ground.

Samples 1282, 1320, and 1324 from contexts directly associated with activity at the site show comparatively little difference from those from other contexts. In general, there is less evidence for disturbance and trampled ground than is the case with the Bronze Age palaeochannels at Caldicot (Caseldine and Barrow 1997).

The samples from the limber-hole samples (Table 3.3.3) provide evidence both for the contemporary depositional environment and for activity associated with the boat. A similar range of taxa to those in the previous samples are present, particularly in 1282, including species indicative of salt-marsh. These confirm that the channel was subject to a marine influence at the time the boat was submerged. A number of weed seeds indicative of arable cultivation are present, however, as well as some wheat chaff, cereal caryopses fragments, and brome (*Bromus*). The latter may have been present as a weed or have been cultivated. Stinking chamomile (*Anthemis cotula*), scentless mayweed (*Tripleurospermum inodorum*), parsley piert (*Aphanes inexspecta*), radish (*Raphanus raphanistrum*), fat hen (*Chenopodium album*), and poppy (*Papaver rhoeas/dubium*) are typical cornfield weeds. As in the previous samples fairy flax and selfheal indicate grassland and grass seeds are frequent. A number of taxa, namely knotgrass (*Polygonum aviculare*), dock (*Rumex* sp), and orache (*Atriplex* sp), could represent several environments, including disturbed ground, cultivated areas, or grassland. Gorse spines (*Ulex* sp) and bracken fragments (*Pteridium aquilinum*) are also present. Although it is possible that the cornfield remains could be from arable cultivation taking place nearby which had become trapped in the limber holes, it is perhaps more likely they represent plant material which had actually been carried on the boat. The 'dryland' plant remains could simply represent material that had been brought onto the boat accidentally on human or animal feet, but they may represent material deliberately brought onto the boat. One possible interpretation is that they are the remnants of either fodder or bedding for animals, which would suggest the boat was used to carry livestock. Alternatively the boat could have been used to carry a cargo of cereal at some stage or perhaps cereal straw had been used as dunnage. The evidence suggests that the boat may have been used for a variety of purposes during its lifetime.

In contrast to the plant macrofossil evidence from Barland's Farm, plant macrofossils of a similar date from Rumney Great Wharf (Robinson 1994) suggest an environment that is primarily non-brackish. The pollen (Keith-Lucas 1994) and plant macrofossil evidence from Rumney suggests a damp grassland environment, although some cereal-type pollen is recorded which suggests arable activity in the area and a seed of *Linum usitatissimium* indicates flax was being cultivated. Other plant macrofossil evidence for Roman agriculture in the wider area, although of 1st-century AD date, includes that from two wells at Caerleon where the occurrence of cereal remains suggest arable activity. The presence of salt-marsh taxa may be derived from dung and reflect the exploitation of 'local' salt-marsh environments for grazing or haymaking (Caseldine and Busby 1993).

In addition to the analysis of samples to ascertain the contemporary environmental conditions, samples of caulking were examined to determine the material used for that particular purpose. Eight samples of caulking were examined. All the samples were carefully washed over a 500micron sieve and all proved to be wood. Identification was difficult (although not impossible) because of the twisted nature of the material. The results are presented in Table 3.3.4. Three were of hazel (*Corylus avellana*), four were of willow (*Salix* sp), and one consisted of both hazel and willow. Hazel and willow are both suitable woods to use as caulking because of their flexibility.

Table 3.3.3 Limber-hole samples

sample number	1283	1285	1289	1293	1295	1297
limber-hole	F12 Pt	F13	F10 St	Mast Step	F5 St	F4
sample size	100g	100g	500g	100g	100g	100g
Ranunculus repens type	–	–	–	1	–	–
buttercup						
Papaver rhoeas/dubium	–	–	3	–	–	–
common poppy/long-headed poppy						
Chelidonium majus L	–	–	1	–	–	–
greater celandine						
Urtica dioica	3	–	4	1	2	–
common nettle						
Alnus glutinosa (L) Gaertner	–	–	–	–	2	–
alder						
Chenopodium album L	3	–	1	1	–	–
fat-hen						
Atriplex sp	2	3	22	2	4	4
oraches						
Salicornia sp	1	–	5	–	1	1
glassworts						
Suaeda maritima (L) Dumort	3	7	35	4	1	7
annual sea-blite						
Chenopodiaceae	1	2	–	–	–	–
Stellaria media (L) Villlars	2	–	9	–	–	–
common chickweed						
Cerastium sp	–	1	1	3	–	–
mouse-ears						
Sagina type	4	3	1	–	2	1
pearlworts						
Spergularia	3	1	1	1	–	2
spurreys						
Caryophyllaceae	1	–	–	–	–	–
Polygonum aviculare L	2	–	2	1	1	5
knotgrass						
Rumex conglomeratus Murray	5	1	13	–	3	1
clustered dock incl perianth						
Rumex sp	2	1	23	12	1	2
docks						
Rumex sp	–	–	3	–	–	3
perianth frags						
Rumex sp	1	3	11	14	1	–
tubercles						
Hypericum sp	1	–	1	–	1	–
St John's wort						
Raphanus raphanistrum L	5	–	–	–	–	–
wild radish frags						
Raphanus raphanistrum L	–	–	1	–	–	–
fruit segments						
Brassicaceae	1	–	2	–	–	–
Calluna vulgaris (L) Hull	–	–	1	–	1	1
heather						
Anagallis cf *arvensis* L	–	–	2	–	–	–
scarlet pimpernel						
Rubus fruticosus agg	–	–	1	–	1	1
bramble						
Potentilla anserina L	2	3	1	1	–	–
silverweed						
Aphanes inexpectata Lippert	–	–	1	–	–	–

slender parsley-piert						
Ulex sp	6	–	9	1	1	–
gorse spines						
Epilobium hirsutum type	3	–	5	3	–	–
great willowherb type						
Linum catharticum L	–	–	1	–	–	1
fairy flax						
Myosotis sp	–	–	2	–	–	–
forget-me-not						
Apium graveolens L	–	–	1	–	–	–
wild celery						
Apium nodiflorum (L) Lag	–	1	6	1	–	–
fool's water-cress						
Torilis nodosa (L) Gaertner	–	1	–	–	–	–
knotted hedge-parsley						
Prunella vulgaris L	–	1	3	3	2	–
selfheal						
Lycopus europaeus L	–	–	–	–	–	–
gypsywort						
Mentha sp	–	–	2	–	–	–
mint						
Plantago major L	2	1	10	7	4	1
greater plantain						
Plantago lanceolata L	–	–	–	1	–	–
ribwort plantain						
Euphrasia sp L/ *Odontites vernus* (Bellardi) Dumort	–	4	21	12	5	2
eyebright/red bartsia						
Sambucus nigra L	–	–	1	–	–	–
elder						
Cirsium sp	–	–	1	–	1	1
thistles						
Hypochaeris radicata L	1	–	–	–	–	–
cat's-ear						
Leontodon sp	4	3	13	3	–	1
hawkbits						
Picris echioides L	1	–	1	–	–	–
bristly oxtongue						
Picris hieracioides L	–	–	1	1	–	–
hawkweed oxtongue						
Sonchus arvensis L	–	–	–	1	–	–
perennial sow-thistle						
Sonchus cf *oleraceus* L	–	–	1	–	–	–
smooth sow-thistle						
Sonchus asper (L) Hill	2	–	3	–	–	–
prickly sow-thistle						
Aster tripolium L	–	–	–	–	–	–
sea aster						
Anthemis cotula L	2	–	21	2	–	1
stinking chamomile						
Tripleurospermum inodorum (L) Schultze-Bip	3	–	7	–	–	–
scentless mayweed						
Senecio aquaticus Hill	2	–	–	–	–	–
marsh ragwort						
Asteraceae	1	–	–	–	1	–
amall Asteraceae	2	–	3	3	3	2
Alisma sp	–	–	–	–	–	1
water plantains						
Triglochin maritimum L	1	1	17	8	5	1
sea arrowgrass						
Juncus sp	396	39	294	103	216	36

rush						
Juncus bufonius L	12	2	1	5	26	–
toad rush						
Juncus sp	1	–	–	1	–	–
capsule						
Eriophorum vaginatum L	–	–	–	1	–	–
hare's-tail cottongrass						
sclerenchymatous spindles						
Eleocharis palustris/ *uniglumis*	1	–	–	–	–	–
common spike-rush/slender spike-rush						
Carex sp – biconvex	2	2	2	1	1	–
sedge						
Carex sp trigonous	–	–	2	–	–	–
Cyperaceae	–	–	1	–	–	–
Triticum dicoccum	–	1	2	–	–	–
emmer wheat glume bases						
T cf *dicoccum*	–	–	–	1	–	–
emmer wheat spikelet fork						
T dicoccum/ *T spelta*	–	–	3	–	–	–
emmer/spelt spikelet forks						
T dicoccum/ *T spelta*	3	2	24	–	–	–
glume bases						
T spelta	–	–	2	–	–	–
spelt wheat glume bases with rachis						
T spelta	1	–	12	–	–	–
spelt wheat glume bases						
T cf *spelta*	–	–	7	–	–	–
glume bases						
Hordeum sp	–	–	2	–	–	–
barley rachis frags.						
cf *Avena* sp	–	–	1	–	–	–
oat pedicel						
Avena/large Poaceae	–	–	1	–	–	–
oat/grass lemm base						
cereal	–	–	2	–	–	–
cereal/large Poaceae	–	–	4	–	–	–
nodes						
cereal/large Poaceae	–	5	16	4	2	3
chaff n f i						
large Poaceae	–	1	–	–	–	–
with chaff						
Bromus sp	2	–	–	–	–	–
brome						
Poaceae large >2.0mm	5	–	18	7	2	2
Poaceae small <2.0mm	50	14	98	46	37	17
flower calyces	–	–	5	1	1	–
Pteridium aquilinum (L) Kuhn	1	1	52	5	–	1
bracken						
Sphagnum sp leaves	–	–	1	–	1	1

Table 3.3.4 Caulking samples

sample no	*identification*
1229	*Corylus avellana* L
1300	*Salix* sp
1303	*Corylus avellana* L
1305	*Corylus avellana* L
1309	*Salix* sp
	Corylus avellana L
1313	*Salix* sp
1317	*Salix* sp
1337	*Salix* sp

3.4 Diatoms, by N Cameron

3.4.1 Introduction

A diatom assessment was carried out on selected samples from Area 50, including a sample from a point bar formation in the palaeochannel. Its aim was to determine the potential of diatom analysis in the investigations of these sediments and in particular the value of diatom analysis in reconstructing the salinity conditions under which the sediments formed. The relatively good preservation of diatoms in the samples assessed indicated that diatom analysis would be a valuable tool in characterising the environment of deposition. A programme of diatom analyses was, therefore, implemented and this is described in this report

3.4.2 Laboratory methods

Diatom preparation and analysis followed standard techniques (Battarbee 1986). For assessment and counting, slides were examined at a magnification of x1250 under phase contrast illumination. A total of 100 to 150 valves were counted from the sample: the counting sums for these contexts were considered adequate, given the relatively low species diversity and usefulness of counting a larger number of samples at closer intervals in the time available. Where necessary diatom identifications were confirmed using diatom floras and taxonomic publications held in the collection of the Environmental Change Research Centre (ECRC), UCL, and in the author's own collection. The floras most commonly consulted were: Cleve-Euler (1951–5), Hendey (1964), Hustedt (1930–66), and Werff and Huls (1957–74). A number of taxa were of uncertain identity, usually being close in morphology to one or more taxa of known ecology. In a few cases it was possible to assign the taxon to the halobian group appropriate for the taxon or taxa that the diatom closely matches. Otherwise these taxa were assigned to the 'unknown' halobian category. The principal source of data on species ecology used was Denys (1992).

Data were entered into the AMPHORA diatom database at the ECRC, where these data, slides, and cleaned valve suspensions are available for examination. The program TRAN (Juggins 1992) was used for data manipulation. Diatom species' salinity preferences were classified using the halobian groups of Hustedt (1953 and 1957, 199) summarised thus:

polyhalobian: $30gl^{-1}$;

mesohalobian: $0.2–30gl^{-1}$;

oligohalobian–halophilous: optimum in slightly brackish water;

oligohalobian–indifferent: optimum in fresh water but tolerant of slightly brackish water;

halophobous: exclusively freshwater;

unknown: taxa of unknown salinity preference.

3.4.3 Results

3.4.3.1 Area 50, column 1 (Table 3.4.1)

Detailed diatom analysis confirmed the results of the preliminary assessment in that assemblages between +2.28m and +3.58m OD (Fig 3.2.1, contexts 2306, 2348, 2309, and 2008) are dominated by polyhalobous taxa, which have abundances from *c* 60–80% in this section of the profile. The dominant species are planktonic or tychoplanktonic (Round 1981), such as *Paralia sulcata*, *Cymatosira belgica*, and *Rhaphoneis minutissima*. These diatom assemblages are presently associated with

Table 3.4.1 Diatom data (percentages) from Area 050

halobian group and taxon									
depth (mm)	0	200	400	410	450	500	550	600	650
height OD (m)	3.58	3.38	3.18	3.17	3.13	3.08	3.03	2.98	2.93
context	2008	2008	2348	2309	2309	2309	2348	2348	2348
sample	1102	1106	1110	1117	1118	1119	1120	1121	1122
polyhalobous									
Actinoptychus undulatus	0.9	1.8	4.5	0.9	3.4	–	2.7	2.6	–
Biddulphia sp	0.9	–	–	–	–	–	0.9	–	–
Campylosira cymbelliformis	1.9	4.5	1.8	1.9	0.8	1.7	2.7	1.7	2.6
Coscinodiscus sp	0.9	–	–	–	–	–	–	–	–
Cymatosira belgica	28.7	19.1	16.1	28.7	9.3	28.4	35.7	27.0	26.1
Dimeregramma minor var *nanum*	–	–	–	0.9	–	0.9	0.9	–	–
Navicula palpebralis var *palpebralis*	–	1.8	–	1.9	–	–	–	0.9	1.7
Nitzschia panduriformis	–	–	–	0.9	–	0.9	–	–	–
Paralia sulcata f *sulcata*	27.8	22.7	33.0	19.4	26.3	11.2	8.0	18.3	17.4
Plagiogramma van-heurckii	–	0.9	1.8	1.9	–	3.4	1.8	1.7	1.7
Podosira stelligera	–	0.9	1.8	0.9	–	0.9	0.9	0.9	–
Rhaphoneis amphiceros	0.9	0.9	1.8	–	–	–	–	–	0.9
Rhaphoneis minutissima	21.3	19.1	8.9	16.7	14.4	26.7	33.0	14.8	20.9
Rhaphoneis sp	1.9	1.8	3.6	2.8	1.7	0.9	–	1.7	0.9
Rhaphoneis surirella	1.9	4.5	1.8	0.9	0.8	1.7	0.9	3.5	2.6
temporary sp 14	–	–	–	–	–	–	–	–	–
temporary sp 17	–	–	–	–	–	–	–	–	–
temporary sp 21	–	–	–	–	0.8	–	–	–	–
temporary sp 23	–	–	–	–	–	–	–	–	–
temporary sp 25	–	–	–	–	–	–	–	–	–
temporary sp 3	–	–	–	0.9	0.8	–	–	–	–
Thalassionema nitzschioides	0.9	1.8	0.9	0.9	–	0.9	1.0	–	1.7
polyhalobous to mesohalobous									
Cocconeis scutellum var *scutellum*	–	–	–	–	–	–	–	–	–
Diploneis smithii var *smithii*	–	–	0.9	–	–	–	–	–	–
Navicula flanatica var *flanatica*	–	0.9	–	–	9.3	–	0.9	0.9	0.9
Pseudopodosira westii	–	–	0.9	0.9	–	–	–	–	0.9
temporary sp 18	–	–	–	0.8	–	–	–	–	–
temporary sp 6	–	0.9	–	0.9	0.8	1.7	–	–	0.9
Thalassiosira decipiens	–	–	–	6.5	5.1	–	–	–	–
Thalassiosira sp	1.9	1.8	5.4	–	–	3.4	1.8	4.3	4.3
mesohalobous									
Achnanthes brevipes var *brevipes*	–	–	–	–	–	–	–	–	–
Achnanthes hauckiana	–	1.8	–	–	0.8	1.7	–	–	–
Amphora coffeaeformis var *coffeaeformis*	–	–	–	–	–	–	–	–	–
Bacillaria paradoxa	–	–	–	–	–	–	–	–	–
Caloneis westii	–	–	–	–	–	–	–	–	–
Cyclotella striata var *striata*	–	–	–	–	–	–	–	1.7	2.6
Diploneis aestuari	–	2.7	1.8	–	0.8	0.9	–	1.7	–
Diploneis didyma	–	–	–	–	–	–	–	–	–
Diploneis interrupta var *interrupta*	–	–	–	–	–	–	–	–	–
Navicula crucicula var *crucicula*	–	–	–	–	–	–	–	–	–
Navicula digitoradiata	0.9	–	–	–	–	–	–	–	–
Navicula gregaria	–	–	–	0.9	0.8	–	–	–	–
Navicula peregrina var *peregrina*	–	–	1.8	–	–	–	–	–	–

Navicula perminuta	–	–	–	0.9	1.7	–	–	–	–
Navicula phyllepta	–	–	–	–	–	–	–	–	–
Nitzschia apiculata	0.9	–	–	0.9	0.8	0.9	–	–	–
Nitzschia granulata	–	–	–	–	–	–	–	–	–
Nitzschia hungarica	–	–	–	–	–	–	–	–	–
Nitzschia navicularis	–	1.8	1.8	–	1.7	–	–	–	0.9
Nitzschia obtusa var *obtusa*	–	–	–	–	–	–	–	–	–
Nitzschia punctata var *punctata*	–	–	–	–	–	–	–	–	–
Nitzschia sigma var *sigma*	–	0.9	0.9	–	0.8	0.9	0.9	–	0.9
Rhopalodia musculus	–	–	–	–	–	–	–	–	–
Surirella gemma	–	–	–	–	–	–	–	–	–
temporary sp 11	–	–	–	–	–	–	–	–	–
temporary sp 13	–	1.8	–	0.9	5.1	2.6	–	7.8	2.6
temporary sp 16	–	–	0.9	–	–	–	–	–	–
temporary sp 19	–	–	–	–	2.5	–	0.9	–	–
temporary sp 2	2.8	–	–	–	–	–	–	–	–
temporary sp 20	–	–	–	–	–	–	–	–	–
temporary sp 22	–	–	–	–	–	1.7	–	–	–
temporary sp 26	–	–	–	–	–	–	–	–	–
temporary sp 27	–	–	–	–	–	–	–	–	–
mesohalobous to halophilous									
Navicula lanceolata	–	–	–	–	–	–	–	–	–
Navicula veneta	–	–	–	–	–	–	0.9	–	–
Nitzschia tryblionella var *tryblionella*	–	–	–	–	0.8	–	–	–	–
halophilous									
Navicula cincta	–	–	–	–	–	–	–	–	–
Temporary sp 9	–	–	–	–	–	–	–	–	–
halophilous to oligohalobous indifferent									
Rhoicosphenia curvata	–	–	–	–	–	–	–	–	–
Surirella ovata var *ovata*	–	–	–	–	–	–	–	–	–
oligohalobous indifferent									
Achnanthes minutissima var *minutissima*	1.9	–	0.9	0.9	1.7	0.9	–	–	1.7
Amphora pediculus	–	–	–	–	–	–	–	–	–
Cocconeis disculus	–	–	–	–	–	–	–	–	–
Cocconeis placentula var *euglypta*	0.9	–	–	–	–	–	0.9	0.9	–
Cocconeis placentula var *placentula*	–	–	0.9	–	–	–	–	–	–
Cymbella sinuata f *sinuata*	–	–	–	–	–	–	–	0.9	–
Diploneis oblongella var *oblongella*	–	–	–	–	–	–	–	–	–
Fragilaria brevistriata var *brevistriata*	–	–	–	–	–	–	–	0.9	–
Fragilaria construens var *venter*	–	–	–	–	–	–	–	–	–
Fragilaria pinnata var *pinnata*	0.9	–	–	–	–	–	–	–	0.9
Hantzschia amphioxys var *amphioxys*	–	–	–	–	–	–	–	–	–
Nitzschia amphibia var *amphibia*	–	–	–	–	–	–	–	–	–
Nitzschia fonticola	–	–	–	–	–	–	–	–	–
Synedra ulna var *ulna*	–	–	–	–	–	–	–	0.9	–
oligohalobous indifferent to halophobous									
Cocconeis pediculus	–	–	–	–	–	–	–	–	0.9
unknown salinity group									
Achnanthes sp	–	–	–	–	–	–	–	–	–
Amphipleura rutilans	–	–	–	–	–	–	–	–	–

Amphora sp	–	–	–	0.9	0.8	–	–	1.7	0.9
Cymbella sp	–	–	–	–	–	–	–	–	–
Cymbellonitzschia diluviana	–	–	–	–	–	–	–	–	–
Denticula sp	–	–	–	–	–	–	–	–	–
Diploneis sp	–	–	0.9	0.9	–	–	–	0.9	–
Gyrosigma sp	–	0.9	–	–	–	2.7	–	–	–
Navicula mediocris	–	–	–	–	–	–	–	–	–
Navicula sp	1.9	2.7	0.9	0.9	3.4	1.7	2.7	0.9	0.9
Navicula tantula	–	–	–	–	–	–	–	–	–
Nitzschia acula	–	–	–	–	–	0.9	–	1.7	–
Nitzschia sp	–	2.7	4.5	2.8	0.8	–	–	–	0.9
Plagiogramma sp	–	–	–	–	–	–	–	–	–
Pleurosigma sp	–	–	–	–	–	–	–	–	–
Stauroneis sp	–	–	–	–	–	–	–	–	–
temporary sp 12	–	–	–	–	–	–	–	–	–
unknown	–	0.9	–	–	–	4.3	–	1.7	2.6
unknown Naviculaceae	–	1.8	–	1.9	1.7	0.9	–	–	–

	depth (mm)	700	750	800	850	900	950	1000	1050	1100
	height OD (m)	2.88	2.83	2.78	2.73	2.68	2.63	2.58	2.53	2.48
halobian group	*context*	2348	2348	2348	2348	2348	2348	2348	2348	2306
and taxon	*sample*	1123	1124	1125	1126	1127	1128	1129	1130	1131
polyhalobous										
Actinoptychus undulatus		–	–	–	–	–	–	–	–	1.6
Biddulphia sp		–	–	–	–	–	–	–	–	–
Campylosira cymbelliformis		1.8	0.9	1.8	0.9	1.7	5.2	2.8	1.8	1.6
Coscinodiscus sp		–	–	–	–	–	–	–	–	–
Cymatosira belgica		33.0	31.5	9.2	28.3	30.2	30.4	26.6	28.8	20.8
Dimeregramma minor var *nanum*		–	–	–	0.9	1.7	1.7	–	–	0.8
Navicula palpebralis var *palpebralis*		–	0.9	1.8	1.9	–	–	–	–	–
Nitzschia panduriformis		–	–	–	0.9	–	0.9	–	–	0.8
Paralia sulcata f *sulcata*		18.8	13.9	9.2	18.6	14.7	17.4	18.3	18.9	29.6
Plagiogramma van-heurckii		0.9	–	–	0.9	–	–	0.9	–	0.8
Podosira stelligera		–	1.9	–	–	0.9	1.7	1.8	0.9	0.8
Rhaphoneis amphiceros		–	1.9	–	1.8	–	–	–	–	–
Rhaphoneis minutissima		15.2	23.1	41.3	19.5	29.3	20.0	22.0	28.8	12.8
Rhaphoneis sp		3.6	–	–	1.8	0.9	0.9	–	–	1.6
Rhaphoneis surirella		–	2.8	0.9	0.9	0.9	1.7	0.9	0.9	2.4
temporary sp 14		–	–	–	–	–	3.5	1.8	2.7	6.4
temporary sp 17		–	–	–	–	–	–	0.9	–	–
temporary sp 21		–	–	–	–	–	–	–	–	–
temporary sp 23		–	–	–	–	–	–	0.9	–	–
temporary sp 25		–	–	–	–	–	–	–	–	–
temporary sp 3		–	–	–	–	–	–	–	–	–
Thalassionema nitzschioides		1.8	1.9	–	0.9	–	1.7	0.9	–	–
polyhalobous to mesohalobous										
Cocconeis scutellum var *scutellum*		–	–	–	–	–	2.6	–	–	–
Diploneis smithii var *smithii*		–	–	–	0.9	0.9	–	–	–	–
Navicula flanatica var *flanatica*		0.9	1.9	1.8	0.9	0.9	–	–	–	0.8
Pseudopodosira westii		–	0.9	–	–	–	0.9	0.9	0.9	1.6
temporary sp 18		–	–	–	–	–	–	–	–	–

temporary sp 6	–	–	–	–	–	–	0.9	–	–
Thalassiosira decipiens	–	–	–	–	–	–	–	–	–
Thalassiosira sp	2.7	4.6	4.6	2.7	6.0	–	–	–	–
mesohalobous									
Achnanthes brevipes var *brevipes*	–	–	–	0.9	–	–	–	–	–
Achnanthes hauckiana	1.8	0.9	2.8	0.9	1.7	0.9	1.8	–	–
Amphora coffeaeformis var *coffeaeformis*	–	–	–	–	–	–	–	–	0.8
Bacillaria paradoxa	–	–	–	–	–	–	–	–	–
Caloneis westii	–	–	–	–	–	–	–	–	–
Cyclotella striata var *striata*	2.7	–	–	–	0.9	–	0.9	–	0.8
Diploneis aestuari	1.8	1.9	–	2.7	2.6	–	–	1.8	–
Diploneis didyma	–	–	0.9	0.9	–	–	–	–	–
Diploneis interrupta var *interrupta*	–	–	–	–	–	–	–	–	–
Navicula crucicula var *crucicula*	–	–	–	–	–	–	–	–	–
Navicula digitoradiata	–	0.9	–	–	–	–	–	–	–
Navicula gregaria	–	–	–	–	–	–	–	–	–
Navicula peregrina var *peregrina*	–	–	–	–	–	–	–	–	–
Navicula perminuta	–	–	1.8	1.8	1.7	1.7	–	–	–
Navicula phyllepta	–	–	–	–	–	–	–	–	–
Nitzschia apiculata	–	–	1.8	1.8	–	–	0.9	0.9	0.8
Nitzschia granulata	–	–	–	–	–	–	–	–	–
Nitzschia hungarica	–	–	–	–	–	–	–	–	–
Nitzschia navicularis	0.9	–	–	–	–	–	–	–	3.2
Nitzschia obtusa var *obtusa*	–	–	–	–	–	–	–	–	0.8
Nitzschia punctata var *punctata*	–	–	–	–	–	–	–	0.9	0.8
Nitzschia sigma var *sigma*	–	–	–	–	0.8	0.9	0.9	–	0.9
Rhopalodia musculus	–	–	–	–	–	–	–	–	–
Surirella gemma	–	–	–	–	–	0.9	–	–	–
temporary sp 11	–	–	–	–	–	–	–	–	–
temporary sp 13	5.4	4.6	3.7	1.8	0.9	1.7	–	0.9	1.6
temporary sp 16	–	–	–	–	–	–	0.9	–	–
temporary sp 19	–	–	1.8	0.9	–	0.9	0.9	–	0.8
temporary sp 2	–	–	–	–	–	–	–	–	–
temporary sp 20	–	–	–	–	–	–	–	–	–
temporary sp 22	–	–	–	–	–	–	–	–	–
temporary sp 26	–	–	–	–	–	–	–	–	–
temporary sp. 27	–	–	–	–	–	–	–	–	–
mesohalobous to halophilous									
Navicula lanceolata	–	–	–	–	–	–	–	–	0.8
Navicula veneta	–	–	–	–	–	–	–	–	–
Nitzschia tryblionella var *tryblionella*	–	–	–	–	–	–	–	–	–
halophilous									
Navicula cincta	0.9	–	0.9	–	–	0.9	0.9	1.8	2.4
temporary sp 9	–	–	–	–	–	–	–	–	–
halophilous to oligohalobous indifferent									
Rhoicosphenia curvata	–	–	–	–	0.9	–	–	–	–
Surirella ovata var *ovata*	–	–	–	–	–	–	–	–	–
oligohalobous indifferent									
Achnanthes minutissima var. *minutissima*	–	–	0.9	–	–	–	–	–	–
Amphora pediculus	–	–	0.9	–	–	–	–	–	–

Cocconeis disculus	–	–	–	–	–	–	1.8	1.9	–
Cocconeis placentula var *euglypta*	–	–	–	–	–	–	–	–	–
Cocconeis placentula var *placentula*	–	–	–	–	–	–	–	–	–
Cymbella sinuata f *sinuata*	–	–	–	–	–	–	–	–	–
Diploneis oblongella var *oblongella*	–	–	–	–	–	–	–	–	–
Fragilaria brevistria var *brevistriata*	–	–	–	–	–	–	–	–	0.8
Fragilaria construens var *venter*	–	–	–	–	–		–	2.7	–
Fragilaria pinnata var *pinnata*	–	–	–	–	–	–	–	–	0.8
Hantzschia amphioxys var *amphioxys*	–	–	–	–	–	–	–	–	–
Nitzschia amphibia var *amphibia*	–	–	–	–	0.9	–	–	–	–
Nitzschia fonticola	–	–	–	–	–	–	–	–	–
Synedra ulna var *ulna*	–	–	–	–	–	–	–	–	–
oligohalobous indifferent to halophobous									
Cocconeis pediculus	–	–	–	–	–	–	–	0.9	–
unknown salinity group									
Achnanthes sp	–	0.9	–	–	–	–	0.9	–	–
Amphipleura rutilans	–	–	–	–	–	–	–	–	–
Amphora sp	–	0.9	0.9	1.8	0.9	0.9	1.8	–	0.9
Cymbella sp	–	0.9	–	–	–	–	–	–	–
Cymbellonitzschia diluviana	–	–	–	–	–	–	–	–	–
Denticula sp	–	–	–	–	–	–	–	–	–
Diploneis sp	–	–	–	0.9	–	–	1.8	–	–
Gyrosigma sp	0.9	–	0.9	–	–	1.7	0.9	1.8	0.8
Navicula mediocris	–	–	–	–	–	–	–	–	–
Navicula sp	1.8	0.9	4.6	4.4	2.6	–	–	2.7	0.8
Navicula tantula	–	–	–	–	–	–	–	–	–
Nitzschia acula	–	–	–	–	–	–	–	–	–
Nitzschia sp	3.6	0.9	2.8	–	–	0.9	0.9	–	0.8
Plagiogramma sp	–	–	–	–	–	–	1.8	–	–
Pleurosigma sp	–	–	–	0.9	–	0.9	–	–	–
Stauroneis sp	–	–	0.9	–	–	–	0.9	–	–
temporary sp 12	–	–	–	–	–	–	–	–	–
unknown	0.9	–	3.7	0.9	–	–	0.9	0.9	–
unknown Naviculaceae	–	0.9	0.9	–	–	–	1.8	–	–

halobian group and taxon							
depth (mm)	1150	1200	1250	1300	1350	1400	1450
height OD (m)	2.43	2.38	2.33	2.28	2.23	2.18	2.13
context	2306	2306	2306	2312	2312	2312	2313
sample	1132	1133	1134	1135	1136	1137	1138
polyhalobous							
Actinoptychus undulatus	1.7	–	0.8	3.9	–	–	–
Biddulphia sp	–	–	–	–	–	–	–
Campylosira cymbelliformis	5.1	1.8	2.4	2.3	0.7	2.0	1.2
Coscinodiscus sp	–	–	–	–	–	–	–
Cymatosira belgica	21.4	31.8	29.0	29.5	3.7	5.9	5.4
Dimeregramma minor var *nanum*	–	0.9	–	0.8	–	1.0	–
Navicula palpebralis var *palpebralis*	–	1.8	1.8	1.9	–	–	0.6
Nitzschia panduriformis	–	–	–	0.8	–	–	0.6
Paralia sulcata f *sulcata*	17.9	136.4	15.3	20.2	5.9	14.7	6.0
Plagiogramma van-heurckii	0.9	–	–	0.8	0.7	–	–

Podosira stelligera	–	0.9	1.6	0.8	–	2.9	–
Rhaphoneis amphiceros	–	–	–	–	0.7	–	–
Rhaphoneis minutissima	20.5	20.0	16.1	7.0	1.5	–	0.6
Rhaphoneis sp	1.7	–	0.8	1.8	–	2.0	1.2
Rhaphoneis surirella	2.6	2.7	4.0	0.9	–	–	0.6
temporary sp 14	8.5	4.5	3.2	1.6	1.5	–	1.2
temporary sp 17	–	–	0.8	–	–	–	–
temporary sp 21	–	–	–	–	–	–	–
temporary sp 23	–	–	–	–	–	–	–
temporary sp 25	–	–	0.8	–	–	–	–
Thalassionema nitzschioides	–	–	2.4	0.8	–	–	–
polyhalobous to mesohalobous							
Cocconeis scutellum var *scutellum*	0.9	–	0.8	–	–	–	–
Diploneis smithii var *smithii*	–	–	–	–	–	2.0	–
Navicula flanatica var *flanatica*	0.9	–	1.6	–	–	–	–
Pseudopodosira westii	0.9	1.8	–	–	0.7	1.0	–
temporary sp 18	–	–	–	–	–	–	–
temporary sp 6	0.9	–	–	–	6.7	2.0	2.4
Thalassiosira decipiens	–	–	–	–	–	–	–
Thalassiosira sp	–	–	–	–	–	–	–
mesohalobous							
Achnanthes brevipes var *brevipes*	–	–	–	–	–	–	–
Achnanthes hauckiana	–	–	–	–	0.7	0.9	–
Amphora coffeaeformis var. *coffeaeformis*	–	–	0.8	–	0.7	–	–
Bacillaria paradoxa	–	–	0.8	–	–	–	–
Caloneis westii	–	–	–	1.6	0.7	3.9	2.4
Cyclotella striata var *striata*	0.9	–	1.6	–	–	–	0.6
Diploneis aestuari	1.7	–	2.4	–	–	–	0.6
Diploneis didyma	–	–	0.9	0.9	–	–	–
Diploneis interrupta var *interrupta*	–	–	–	–	–	1.5	4.2
Navicula crucicula var *crucicula*	–	–	–	–	–	0.7	–
Navicula digitoradiata	0.9	–	–	2.3	3.0	–	–
Navicula gregaria	–	–	–	–	–	–	–
Navicula peregrina var *peregrina*	–	0.9	0.8	–	2.2	5.9	3.6
Navicula perminuta	0.9	–	–	–	–	–	–
Navicula phyllepta	–	–	–	–	–	–	1.2
Nitzschia apiculata	0.9	–	0.8	1.6	–	–	–
Nitzschia granulata	–	–	–	0.8	–	–	–
Nitzschia hungarica	–	–	–	–	0.7	–	–
Nitzschia navicularis	–	0.9	–	1.6	–	–	–
Nitzschia obtusa var *obtusa*	–	–	–	–	2.2	2.0	–
Nitzschia punctata var *punctata*	–	–	–	–	0.7	–	–
Nitzschia sigma var *sigma*	–	–	–	0.8	–	0.9	–
Rhopalodia musculus	–	–	–	–	–	0.6	–
Surirella gemma	–	–	0.8	–	–	–	–
temporary sp 11	–	–	–	–	3.7	–	–
temporary sp 13	0.9	–	–	9.3	8.1	–	4.2
temporary sp 16	–	–	–	–	0.7	19.6	7.2
temporary sp 19	–	1.8	2.4	–	5.2	1.0	–
temporary sp 2	–	–	–	–	0.7	2.9	0.6
temporary sp 20	–	2.7	–	1.6	4.4	2.0	2.4
temporary sp 22	–	–	–	–	–	–	–

temporary sp 27	–	–	–	–	0.8	0.7	0.6
mesohalobous to halophilous							
Navicula lanceolata	–	–	0.8	–	–	–	–
Navicula veneta	–	–	–	–	–	–	1.8
Nitzschia tryblionella var *tryblionella*	–	–	–	–	–	–	0.6
halophilous							
Navicula cincta	1.7	0.9	–	1.6	17.8	8.8	14.5
temporary sp 9	–	–	–	–	–	1.0	–
halophilous to oligohalobous indifferent							
Rhoicosphenia curvata	–	–	0.8	–	–	–	–
Surirella ovata var *ovata*	–	–	0.8	–	–	–	–
oligohalobous indifferent							
Achnanthes minutissima var *minutissima*	–	–	–	–	–	–	–
Amphora pediculus	–	–	0.9	–	–	–	–
Cocconeis disculus	0.9	–	–	–	–	–	–
Cocconeis placentula var *euglypta*	0.9	1.8	0.8	–	–	–	–
Cocconeis placentula var *placentula*	–	–	–	–	–	–	–
Cymbella sinuata f *sinuata*	–	–	–	–	–	–	–
Diploneis oblongella var *oblongella*	–	–	–	–	3.0	–	3.6
Fragilaria brevistria	–	0.8	–	–	–	–	–
Fragilaria construens var *venter*	–	–	–	–	3.0	–	–
Fragilaria pinnata var *pinnata*	–	–	–	–	–	–	–
Hantzschia amphioxys var *amphioxys*	–	–	–	–	–	1.0	–
Nitzschia amphibia var *amphibia*	–	–	–	–	0.9	–	–
Nitzschia fonticola	–	–	–	0.8	–	–	–
Synedra ulna var *ulna*	–	–	–	–	–	–	–
oligohalobous indifferent to halophobous							
Cocconeis pediculus	–	–	–	–	–	–	–
unknown salinity group							
Achnanthes sp	–	–	–	–	–	–	–
Amphipleura rutilans	–	–	–	–	0.7	–	–
Amphora sp	–	–	–	–	–	–	–
Cymbella sp	–	–	–	–	–	–	–
Cymbellonitzschia diluviana	0.9	–	–	–	–	–	–
Denticula sp	–	–	–	–	–	1.0	–
Diploneis sp	–	–	–	–	–	0.6	–
Gyrosigma sp	–	–	–	5.4	0.7	–	5.4
Navicula mediocris	–	1.8	–	–	–	–	–
Navicula tantula	–	–	0.8	–	–	–	–
Navicula sp	1.7	1.8	2.4	–	12.6	5.9	1.8
Nitzschia sp	3.6	0.9	2.8	–	–	0.9	13.9
Plagiogramma sp	–	0.8	–	–	–	–	–
Pleurosigma sp	0.9	–	0.8	–	–	–	–
Stauroneis sp	–	–	–	0.8	0.7	–	–
temporary sp 12	–	–	–	–	–	–	6.6
unknown	–	–	–	–	–	–	0.6
unknown Naviculaceae	–	1.8	0.8	–	0.7	6.9	2.4

tidal mudflats and creeks in the Severn Estuary (Underwood 1994). A number of polyhalobous species were also found in the basal part of the sequence (1.45 to 1.35m and +2.13 to +2.23 m OD, contexts 2312 and 2313; Fig 3.1.1), but the diatom assemblages from these levels are dominated by mesohalobous and halophilous taxa. These brackish water taxa are entirely of benthic origin and include diatoms such as *Navicula cincta, Navicula cincta/digitoradiata, Stauroneis* cf *amphoxys, Diplonei interupta, Navicula peregrina,* and *Caloneis westii.* It is reasonable to interpret these diatom assemblages as representing a predominantly brackish water regime, with a tidal input of planktonic estuarine (polyhalobous) taxa. Despite repreparation of the slide made from the basal sample from the vertical section (1139), diatom counting was not possible as diatom valves were found only in very low concentrations. Those valves present were poorly preserved, but appear to be a mixed assemblage of freshwater to marine taxa.

3.4.3.2 Point bar formation (Table 3.4.2)

A single sample (1155) was initially examined from the point bar formation on the east side of the palaeochannel. Although diatom valves were in low concentrations, an assemblage dominated by marine taxa with some brackish water diatoms was apparent. Hence more detailed diatom analysis was undertaken on four further samples (1144, 1147, 1146, and 1154; Fig 3.1.2). Systematic counting showed polyhalobous taxa to be dominant and to comprise *c* 75–90% of the diatom assemblages. The polyhalobous taxa are tychoplanktonic diatoms and include *Paralia sulcata, Cymatosira belgica,* and *Rhaphoneis* sp, including *Rhaphoneis minutissima.* The upper three samples (1155, 1156, and 1145) also have relatively high percentages of polyhalobous taxa (*c* 25–60%), but with larger numbers of brackish water taxa mainly from benthic habitats. The top two samples were taken from virtually the same horizon (+3.02m OD, corresponding with 0.00–0.01m in the section) in order to cross-check the assemblages. The brackish water species include *Navicula peregrina, Navicula cincta,* and *Nitzschia navicularis.* These are non-planktonic species and their increased abundances in these samples suggest that the environment of deposition was essentially a brackish one. The marine tychoplanktonic diatom component in the same samples is more likely to be allochthonous, as these species are easily transported by tidal currents.

Table 3.4.2 Diatom data (percentages) from 'point bar' deposit, Area 50

halobian group and taxon *depth (mm)*	0	10	80	100	360	430	680
polyhalobous							
Actinoptychus undulatus	–	0.5	2.6	0.6	2.6	0.8	–
Campylosira cymbelliformis	0.5	–	1.8	1.8	0.8	–	2.4
Cymatosira belgica	8.4	8.8	30.5	10.5	28.5	11.3	30.1
Dimeregramma minor var *nanum*	–	–	–	0.9	–	–	–
Paralia sulcata f *sulcata*	10.3	38.6	20.7	50.0	26.9	28.6	18.7
Plagiogramma van-heurckii	1.0	–	0.6	–	0.8	–	0.8
Podosira stelligera	1.0	2.6	0.6	2.6	1.7	1.5	–
Rhaphoneis amphiceros	–	–	0.6	0.9	–	–	–
Rhaphoneis minutissima	2.0	–	14.6	5.3	18.5	–	21.1
Rhaphoneis sp	–	3.5	2.4	8.8	2.5	3.0	0.8
Rhaphoneis surirella	0.5	0.9	0.6	3.5	2.5	0.8	1.6
temporary sp 14	–	0.9	6.1	1.8	6.7	–	–
Thalassionema nitzschioides	0.5	0.9	0.6	–	1.7	0.8	0.8
polyhalobous to mesohalobous							
Navicula flanatica var *flanatica*	–	–	1.2	–	–	–	0.8
Pseudopodosira westii	–	4.4	–	0.9	0.8	0.8	–
Temporary sp. 6	–	–	–	–	–	0.8	–
Thalassiosira decipiens	2.0	–	–	–	–	–	–
Thalassiosira sp	–	–	–	–	–	1.5	3.3
mesohalobous							
Amphora coffeaeformis var *coffeaeformis*	–	–	–	–	–	–	0.8

Bacillaria paradoxa	–	–	–	–	0.8	–	–
Caloneis westii	1.5	0.9	–	0.9	–	–	–
Cyclotella striata var *striata*	1.0	0.8	0.9	1.2	0.8	1.5	0.8
Diploneis aestuari	–	0.9	–	–	0.9	0.8	2.3
Diploneis didyma	–	–	–	–	–	0.8	–
Diploneis interrupta var *interrupta*	2.5	0.9	0.6	–	–	–	–
Navicula digitoradiata	1.0	–	–	–	–	–	–
Navicula peregrina var *peregrina*	16.7	14.9	4.9	–	–	15.0	–
Nitzschia granulata	–	–	–	–	–	8.0	–
Nitzschia navicularis	0.5	1.8	–	1.8	0.8	4.5	–
Nitzschia punctata	0.5	–	–	–	–	–	–
Rhopalodia musculus	–	–	–	0.9	–	–	–
Surirella gemma	–	–	0.6	–	–	–	–
temporary sp 13	1.0–	–	0.6	–	–	3.8	0.8
temporary sp 19	–	–	–	–	–	–	2.4
temporary sp 2	–	–	–	2.6	–	–	–
temporary sp 20	–	–	–	0.8	–	–	–
mesohalobous to halophilous							
Navicula lanceolata	–	–	0.9	–	–	–	–
Navicula veneta	0.5	–	–	–	–	–	–
halophilous							
Navicula cincta	36.5	7.0	1.8	–	2.5	12.8	–
oligohalobous halophilous to indifferent							
Rhoicosphenia curvata	–	–	–	–	–	–	0.8
Surirella ovata var *ovata*	–	–	–	–	–	–	0.8
oligohalobous indifferent							
Achnanthes lanceolata	–	–	0.6	–	–	–	–
Achnanthes minutissima var *minutissima*	–	–	–	–	1.7	–	0.8
Amphora pediculus	–	–	–	–	–	–	0.8
Cocconeis placentula var *placentula*	–	0.9	1.2	–	–	–	–
Fragilaria brevistriata var *brevistriata*	–	–	0.6	–	–	–	–
Fragilaria construens var *venter*	–	–	0.9	0.9	–	–	–
Fragilaria pinnata var *pinnata*	–	–	0.6	–	–	–	–
Gomphonema sp	–	–	0.6	–	0.8	–	–
Navicula rhyncocephala var *rhyncocephala*	–	–	–	–	–	–	2.4
unknown salinity group							
Amphora sp	–	–	1.2	–	0.8	–	0.8
Diploneis sp	1.0	0.9	–	1.8	–	0.8	–
Fragilaria sp	0.5	–	–	–	–	–	–
Gyrosigma sp	–	–	0.6	–	1.7	–	1.6
Navicula sp	3.0	1.8	1.2	0.9	2.5	1.5	4.1
Nitzschia sp	6.9	1.8	1.2	–	–	4.5	–
Surirella sp	–	0.9	–	–	–	–	–
unknown	–	–	1.2	–	2.5	–	2.4
unknown Naviculaceae	0.5	1.8	–	–	0.8	0.8	–

3.4.4 Discussion

A small but significant polyhalobous diatom component indicates the periodic influence of tides or alternatively the effects of sediment mixing processes (bioturbation and physical mixing) introducing marine diatom taxa from overlying, underlying, or adjacent sediments. In the levels at +2.28m OD and above, the polyhalobous diatom component becomes dominant, oligohalobous indifferent taxa decline to low percentages, and brackish water (mesohalobous) taxa generally decrease to values of approximately 10% or lower. Exceptionally maxima in the percentages of freshwater and brackish water diatom species are found at 3.02m OD in sample 0mm from the point bar formation. Sample 10mm from virtually the same elevation and the same feature has increased abundances of brackish water taxa compared with other samples from high elevations, but relatively low percentages of freshwater species compared with sample 0mm. Both these samples from the point bar feature appear to indicate an environment with relatively low salinity compared with other samples from similar elevations in other features. The location of the point bar formation makes the transport of alluvium and diatoms from freshwater and brackish water environments upstream a more probable explanation of these species occurrences.

The taphonomic complexity of estuarine diatom assemblages with particular reference to the Severn has been discussed elsewhere (Cameron 1993a and 1993b). It seems probable that the hypertidal nature of the estuary and resulting transport of marine or estuarine taxa into periodically inundated freshwater or brackish habitats results in a particularly large marine allochthonous component in assemblages deposited under essentially brackish to freshwater conditions (Vos and de Wolf 1988, 1993; Sherrod *et al* 1989). This factor has been taken into account in the interpretation of the Barland's Farm diatom assemblages. The study of contemporary diatom surface sediment assemblages in relation to environmental gradients such as salinity, site elevation, substrate, and habitat may be a means of improving the information available from diatom-based environmental reconstructions in the Severn and other coastal environments. Analogue matching to compare fossil assemblages from archaeological contexts directly with present-day diatom death assemblages constitutes a promising approach. Studies of contemporary diatom communities are important in this area (eg Oppenheim 1991; Underwood 1994).

3.5 Mollusca, by S Johnson and M Bell

3.5.1 Introduction

One sequence of samples was analysed from the Romano-British deposits excavated in Area 50 in the first assessment stage of the project. Subsequently two further columns of samples were analysed from Area 54 in the vicinity of the Romano-British boat. The results are described in the following report.

3.5.2 Laboratory methods

Samples of 1kg weight were removed from the monoliths from Area 50. All samples from the boat site were of 0.5kg except those also used for plant macrofossil analysis (specified on Tables 3.5.1–3.5.3) which were of 0.25kg. These were soaked in water to break down the sediment, flots were removed, and the samples soaked further with the addition of hydrogen peroxide where necessary for clay samples and sodium hydroxide for organic/peat samples (particularly from Area 50) before the final sieving of the residues. The smallest mesh size used was 250μm.

3.5.3 Results

3.5.3.1 Area 50 (Table 3.5.1)

Eleven samples were examined in a column from Area 50. Molluscs were absent in the basal peat (2307) and overlying peaty clay (2313), but they were present in the peaty clays of contexts 2312 and 2306 and in the fill of the palaeochannel (2348; Fig 3.1.1). The maximum number of shells in a sample was 46, however, and hence only a limited palaeoenvironmental interpretation is possible from these sediments.

3.5.3.2 Area 54

Seventeen samples from two columns from Area 54 were analysed, nine from contexts 1270–82 near the centre of the boat and eight from contexts 1320–9 at the north end. During sorting of the 250μm fraction of these sediments for seeds, shell apices of some aquatic molluscs were noted, particularly *Hydrobia ulvae*. Hence all fractions were subsequently examined for molluscan content. The 250μm fraction of some samples produced small numbers of tiny juvenile

Table 3.5.1 Mollusca in Area 50

sample	*context*	*OD height*	*Hydrobia ventrosa*	*Hydrobia ulvae*	*Leucophytia bidentata*	*Lymnaea peregra*	*Macoma balthica*	*Total molluscs*	*Other*
1158	2309	3.1–3.05			1			1	
1160	2348	3.05–3	1					1	
1164	2348	2.85–2.8	3				½	3.5	
1166	2348	2.75–2.7	19	4			2/2	24	
1168	2348	2.65–2.6	13	4	1			18	cf crab frag
1170	2348	2.53–2.43	37	7	1		½	45.5	
1172	2306	2.38–2.33	41	4	1			46	cf crab frag
1174	2312	2.28–2.23	7					7	

Table 3.5.2 Sample column 1320–29, north end of boat

sample	1320	1322	1324	1325	1326	1327	1328	1329
context	2380	2380	2384	2384/2387	2387	2387/2388	2387/2388	2388/2390
height (m OD)	3.69–3.59	3.49–3.39	3.34–3.24	3.24–3.14	3.14–3.09	3.09–3.04	3.04–2.94	2.94–2.89
sample weight (g)	250	500	250	500	250	500	500	500
aquatic								
Hydrobia ventrosa	9	11		80	146	5	7	23
Hydrobia ulvae	1	4	1	10	9		1	2
Leucophytia bidentata								
Leucophytia/Ovatella	1	3	1	4	9	2	1	
Lymnaea truncatula		1						
Lymnaea peregra						1		
Gyraulus laevis	1							
cf *Pisidium* sp				1.5	1.5	0.5	1	9.5
cf Unionidae*						0.5		
Total aquatic	12	19	2	95.5	165.5	9	10	34.5
land								
Succinea/Oxyloma	1							
Cochlicopa lubrica	1							
Vertigo sp		1						
Pupilla muscorum	+				1	1		
cf *Cepaea* sp					+			
Total land	2	1	0	0	1	1	0	0
Total mollusca	14	20	2	95.5	166.5	10	10	34.5
marine								
Macoma balthica								0.5
cf *Macoma balthica**				1		1		19
unident bivalve*				1			0.5	5

Notes
* shells <0.5mm
bivalves = no of valves divided by 2.

bivalves, including cf *Pisidium* sp, cf *Macoma balthica*, and one cf Unionidae.

3.5.3.3 Northern sample column 1320–9 (Table 3.5.2)

Only samples 1325 and 1326 (Fig 3.1.4), which are from contexts that predate the boat, produced good numbers of shells. The dominant species is *Hydrobia ventrosa* (80–90%) in both cases. Context 1326 contained equal numbers of *Hydrobia ulvae* and *Leucophytia bidentata* (around 5%), while 1326 contained *c* 10% *Hydrobia ulvae* and 5% *Leucophytia bidentata*. The only other aquatic molluscs present in both samples were small cf *Pisidium* sp. Land molluscs present were *Pupilla muscorum* and a single *Cepaea fragment* in 1326. The other samples from this column produced much smaller assemblages, but they seem to be similar in character to 1325 and 1326. The bottom sample (1329) contained nineteen cf *Macoma balthica* in the 250mm fraction. Overall the range of species is very limited and only those found in brackish water occur in any numbers. Land molluscs are very poorly represented: only five shells were recovered from the entire column.

3.5.3.4 Centre sample column 1270–82 (Table 3.5.3)

The lowermost four samples from this column all produced good numbers of shells and the lowest two are from contexts associated with the boat. A wider range of species was present than in the northern column, although the overall taxon composition is similar. In each of the samples the most common species was *Hydrobia ventrosa*. This accounted for around 68–75% of each sample, with around 10–20% *Hydrobia ulvae* and 5–10% *Leucophytia bidentata*. Small numbers of other aquatic species were present, including *Lymnaea truncatula, Anisus leucostoma, Aplexa hypnorum*, and *Lymnaea peregra*. The tiny bivalves that occurred regularly in the northern sample column were almost absent from this column. Sample 1282 also included a *Bithynia* operculum and a single shell of *Hippeutis complanatus*.

Overall the number of land molluscs from this column was small, although there were two or three more species than in the northern column. Even in sample 1281, however, which had the largest numbers, land mollusca accounted for less than 10% of the total assemblage. Several small crab fragments were recovered from 1281, while a single fragment of barnacle was found in 1282.

3.5.4 Discussion

All the samples from Areas 50 and 54 that had good numbers of shells were dominated by *Hydrobia ventrosa*, with lesser numbers of *Hydrobia ulvae*. The two *Hydrobia* species are both estuarine. *Hydrobia ventrosa* occurs at salinities of 6–25 parts per thousand and prefers locations without tidal movement (Graham 1988, 190), although it does occur in tidal situations such as sheltered salt-marshes (Cherill and James 1985). *Hydrobia ulvae* occurs at salinities of 5–40 parts per thousand and prefers estuarine conditions with tidal movement (Graham 1988, 188). The distribution of the two species is apparently more dependent on tidal movement than on salinity, but it is not uncommon to find both at the same location (Barnes 1991, 61). *Leucophytia bidentata* is present in some samples and is a species of brackish conditions. The occasional occurrence of crab and barnacle fragments indicates direct marine influence. The assemblages are of limited diversity and appear to derive from a specialised habit with brackish conditions. Although the samples from Area 50 came from what was interpreted as a palaeochannel, there is no molluscan evidence of freshwater inputs for instance. The total number of shells is, however, very small.

The samples from Area 54 are a little more diverse than those from Area 50, with some freshwater and land molluscs. The relatively small number of freshwater molluscs do not on their own provide clear evidence of a major freshwater input to this channel. Those freshwater species which are present are mostly members of Sparkes's (1961) 'slum' group, rather than those indicative of moving water. It may be hypothesised, however, that a palaeochannel edge site fairly high in the tidal range would accumulate marine sediment at high tide and that there would perhaps be only a limited representation of molluscs washed down by freshwater outputs at low tide. The molluscs clearly indicate that marine influence extended this far inland during the Romano-British period, when the stone and wood structure in Area 50 was in use and the boat became submerged. These Roman palaeochannel assemblages are in sharp contrast to the Bronze Age palaeochannel assemblage 8km to the east at Caldicot. These are predominantly freshwater species, although of restricted diversity, with only occasional species reflective of brackish conditions (Bell and Johnson 1997).

Table 3.5.3 Sample column 1270–82, centre of boat 2375

sample	1270	1272	1274	1276	1278	1279	1280	1281	1282
context	2376	2376	2376	2376/ 2377	2376/ 2377	2377	2377	2377/ 2381	2377/ 2381
height (m OD)	3.84–3.79	3.79–3.74	3.69–3.64	3.59–3.54	3.49–3.44	3.44–3.39	3.39–3.34	3.34–3.29	3.29–3.24
sample weight (g)	250	500	250	500	250	500	500	500	250
aquatic									
Hydrobia ventrosa	2	3	5	17	11	65	86	104	82
Hydrobia ulvae		2		4	3	13	25	13	14
Bithynia tentaculata									1†
Leucophytia bidentata									11
Leucophytia/Ovatella		2		2	2	7	8	6	
Aplexa hypnorum							1		
Lymnaea truncatula						1	2	2	1
Lymnaea peregra		1	1					4	2
Anisus leucostoma						1	2	4	1
Hippeutis complanatus									1
Unident gastropod								+	
cf *Pisidium* sp*		1				0.5			
Total aquatic	2	9	6	23	16	87.5	124	133	113
land									
Succinea putris								1	2
Cochlicopa sp								1	
Vertigo pygmaea			1			1			
Vertigo sp						1		1	
Pupilla muscorum							3	3	3
Vallonia pulchella								3	
Vallonia sp	1								
Limacidae								1	
Cepaea sp								1	
Total land	1	0	1	0	0	2	3	11	5
Total mollusca	3	9	7	23	16	89.5	127	144	118
marine									
cf *Macoma balthica**				1.5					
indet frag.								+	+
cf crab								+	
cf barnacle									+

Notes
* shells <0.5mm
† operculum
bivalves = no. of valves divided by 2.

3.6 Dendrochronology and wood identification, by N Nayling

3.6.1 Introduction

This report integrates wood records, dendrochronological dating, tree-ring counts, and wood identifications of timber and wood utilised in the boat, the associated wood and stone structure excavated in Area 54, and a further structure from Area 50.

3.6.2 The samples

The samples may be conveniently divided into those from the two timber and stone structures, the boat timbers, and the treenails used in conjunction with iron nails to fix the planking to the boat's framing timbers.

A total of 23 samples from individually numbered pieces of wood and 34 samples from wood collected by context were examined from the excavations in Area 50. Species/genus identification of all these was attempted. In addition 8 samples were analysed for tree-age, average ring-width and season of felling, and 1 sample measured for dendrochronology.

Twenty-four wood samples from the stone and timber structure in Area 54 were either examined on site and discarded (if there was no dating potential) or retained for assessment of dating potential. Of these, 15 had sufficient rings for measurement and 4 of these dated.

A total of 64 timbers (of which four were duplicates) from the boat were assessed for conversion, ring count, and average ring width during detailed timber recording. Of these, 13 had sufficient rings for measurement and 2 dated.

Sixteen treenail samples were examined microscopically to determine species, conversion if any, and indications of woodworking.

3.6.3 Methods

Oak timbers were identified to genus by eye, as the ring-porous nature of the annual rings and the presence of very wide multi-seriate rays are diagnostic and clearly visible. In the case of the non-oak treenail samples, thin sections of samples were mounted in glycerol and anatomical features visible under magnifications of x40–x400 compared with a reference collection of wood slides derived from authenticated material held by the Jodrell Laboratory, Royal Botanic Gardens, Kew, and descriptions and photomicrographs in Schweingruber 1982. The species or genus of the sample was identified where possible.

Either in the field or during detailed timber recording, oak timbers were examined with the aid of a hand magnifier to determine the number of tree-rings, the average growth rate, and where preservation permitted, the season of felling.

The samples selected for measurement were prepared by freezing them for at least 48 hours and then cleaning their cross sections with a Surform plane. The ring widths were measured to an accuracy of 0.01mm on a travelling stage connected to an Atari microcomputer, using a suite of dendrochronology programs written by Ian Tyers (1993 pers comm). The measured ring sequences were drawn by hand on log scale paper. Crossmatching was carried out first visually by comparing the graphs on a light box and then using a computer program to measure the amount of correlation between two ring sequences. The crossmatching routines are based on the Belfast CROS program (Baillie and Pilcher 1973; Munro 1984) and all the *t* values quoted in this report are identical to those produced by the first CROS program (Baillie and Pilcher 1973). Generally *t* values of 3.5 or above indicate a match provided that the visual match between the tree-ring graphs is acceptable (Baillie 1982, 82–5). For oak samples, a *t* value greater than 10 is taken to indicate an origin in the same tree. Comparisons of sequences from different trees rarely produce *t* values above 10, although ring sequences from the same tree sometimes give values less than 10.

Dating is achieved by averaging the data from the matching sequences to produce a site master curve and then testing that master for similarity against dated reference chronologies. A site master is used for dating whenever possible, because it enhances the general climatic signal at the expense of the background noise from the growth characteristics of the individual samples. Any unmatched sequences are tested individually against the reference chronologies. All potential tree-ring dates are then checked by examining the quality of the visual match between the graphs.

If a sample has bark or bark edge, the date of the last measured ring is the year in which the tree was felled. If the outer ring is complete, the tree was felled during the period from late autumn to early spring. This is termed 'winter felled' for convenience. Where the ring is incomplete, the tree was felled during late spring to early autumn; this is known as 'summer felled'. It is often not possible to distinguish between winter- and summer-felled trees, particularly where rings are narrow.

In the absence of bark edge, felling dates of oak timbers are calculated using the sapwood estimate of 10–55 rings. This is the range of the 95% confidence limits for the number of sapwood rings in British oak trees over 30 years old (Hillam *et al* 1987). Where sapwood is absent, oak felling dates are given as *termini post quem* by adding 10 years, the minimum number of missing sapwood rings, to the date of the last measured heartwood ring. In the absence of bark edge, the *terminus post quem* for the felling of the ash timbers is the date of the outer ring since sapwood rings on ash are not identifiable. The actual felling of timbers could be much later than the *terminus post quem* depending on how many heartwood rings have been lost.

3.6.4 Results

3.6.4.1 Structure in Area 50

The majority of the wood from Area 50 comprises a group of driven piles (5002 and 5005–10, see Table 3.6.1) and a group of immature roundwood (5011–18) associated with pile 5009 (Table 3.6.2). Four of the piles are ash (*Fraxinus excelsior* L), all relatively immature (18–29 years old at felling) and fast grown (average ring width of 2.61–5.79mm). Only one (5009) showed any signs of conversion, since three sides had been squared off. Pile 5006 was clearly winter felled (ie felled following completion of the growing season in late summer but prior to the commencement of earlywood growth in the following spring). The outermost rings on both 5002 and 5009 are not as well preserved but winter felling is probable. The three other piles were all oak (*Quercus* sp). One (5008) was unconverted, immature, and relatively fast grown. The remaining two were both boxed heartwood with some sapwood surviving on corners. Although the bark and latest sapwood rings had been removed from these timbers in their conversion, it seems likely that both were derived from trees in excess of 50 years old, in contrast to the ash piles and unconverted oak. The only pile which was lifted in its entirety (5005) featured a redundant chiselled mortise containing an oak peg (5005a) that had been trimmed flat with the face of the timber. This gives unequivocal evidence of reuse for 5005 and suggests 5007 may also have been reused. These timbers probably came from a dismantled building, in which the peg supported some kind of internal

Table 3.6.1 Tree-ring analysis and wood identification of piles from Area 50, context 2300.

wood number	*genus/species*	*conversion*	*total ring count*	*sap/bark*	*dimensions (mm)*	*average ring width (mm)*
5002	*Fraxinus excelsior* L	none	18	+Bw?	119 × 96	2.61
5005	*Quercus* spp	boxed heart	51	13+B	240 × 165	3.11
5006	*Fraxinus excelsior* L	none	23	+Bw	172 × 160	3.70
5007	*Quercus* sp	boxed heart	46	10	230 × 172	3.26
5008	*Quercus* sp	none	29	7+B?	193 × 180	3.28
5009	*Fraxinus excelsior* L	squared on 3 sides	29	+Bw?	205 × 200	5.79
5010	*Fraxinus excelsior* L	none	23	+B?	205 × 170	4.35

Table 3.6.2 Wood identification of roundwood from Area 50.

wood number	*context*	*genus/species*	*comments*
5000	2311/2327	bark	
5001	2001	*Alnus* sp	mature and slow grown
5003	2300	unidentified	
5004	2300	*Prunus spinosa* L	
5005a	2300	*Quercus* sp	peg within 5005
5011	2327	*Corylus avellana* L	
5012	2327	*Corylus avellana* L	
5013	2327	*Corylus avellana* L	
5014	2327	*Corylus avellana* L	
5015	2327	*Corylus avellana* L	
5016	2327	*Corylus avellana* L	
5018	2327	*Quercus* sp	

Notes
B = bark
Bw = bark wood

fitting rather than acting as a structural element (Goodburn pers comm).

The evidence for the driven structural wood suggests the use of relatively immature and fast-grown trees implying the management of woodland to optimise yields. This accords with the limited data from later Roman London, where similar assemblages have been excavated. In some cases (eg Goodburn 1992) clear evidence for the reuse of building timbers for piling has been forthcoming.

The other main group from Area 50 comprised immature roundwood (5011–18) 15–30mm in diameter associated with pile 5009, possibly a remnant of hurdlework. With the exception of 5018 (*Quercus* sp) these were all identified as hazel (*Corylus avellana* L). This wood is unlikely to have grown in the immediate vicinity, but is particularly favoured for use in hurdling and other craft activities requiring flexible straight stems. Their presence is suggestive of contemporary coppicing of hazel perhaps on drier ground to the north.

The identification of 5001 (from the geotechnical pit in Area 50) as alder (*Alnus* sp) suggests that the test pit had cut through prehistoric peat horizons and that this fragment is derived from those levels rather than Roman deposits. The single identification of blackthorn (*Prunus spinosa* L) may reflect the contemporary Roman environment directly adjacent to the site with blackthorn present either as a waterside tree or hedgerow species.

3.6.4.2 Structure in Area 54

All the samples examined were identified as oak (*Quercus* sp). Details of conversion, ring count, average ring width, and felling season are given in Table 3.6.3 and average ring width plotted against ring count in Fig 3.6.1. With the exception of timbers used in the revetting to the stone abutment (ie contexts 2401 and 2402), all the timbers comprise oak piles in the round. These vary in age from 13 to 89 years, suggesting wood was chosen on the basis of size (diameter) rather than age. It proved possible to determine the season of felling

Table 3.6.3 Tree-ring analysis and dating of samples from the stone and timber structure in Area 54. All timbers were oak (*Quercus* sp).

wood number	*context*	*conversion*	*pith*	*total ring count*	*sap/bark*	*average ring width (mm)*	*dated*
5033	2401	boxed heart		20		5.4	
5054	2401	boxed heart					
5133	2402	tangential		39		2.3	
5134	2402	radial?		28	20	2.1	
5045	2403	none	centre	73	6	1.4	
5046	2403	none	centre	48	18+Bs	1.3	
5048	2403	none	centre	21	10+Bw	3.09	
5049	2403	none		16	16	4.06	
5050	2403	none	centre	89	23+B	1.3	AD 283
5051	2403	none	centre	30	11		
5052	2403	none					
5029	2404	none	centre	16	11+Bs	5.1	
5030	2404	none	centre	30	14+Bs	2.7	
5031	2404	none	centre	74	12+B	2	AD 279
5042	2404	none	centre	61	25+B	1.5	
5043	2404	none	centre	35	14+Bs	2.03	
5044	2404	none	centre	55	–	1.8	
5034	2405	none	centre				
5035	2405	none	centre	31	15+Bs	2.3	
5036	2405	none	centre	13	9+Bw	9.64	
5039	2405	none	centre	73	17	1.5	AD 270
5040	2405	none	centre				
5041	2405	none	centre	34	16	2.2	
5131	2405	none	centre	69	28+B	1.2	AD 282

Notes
B = bark edge
Bw = bark edge, winter-felled
Bs = bark edge, summer-felled

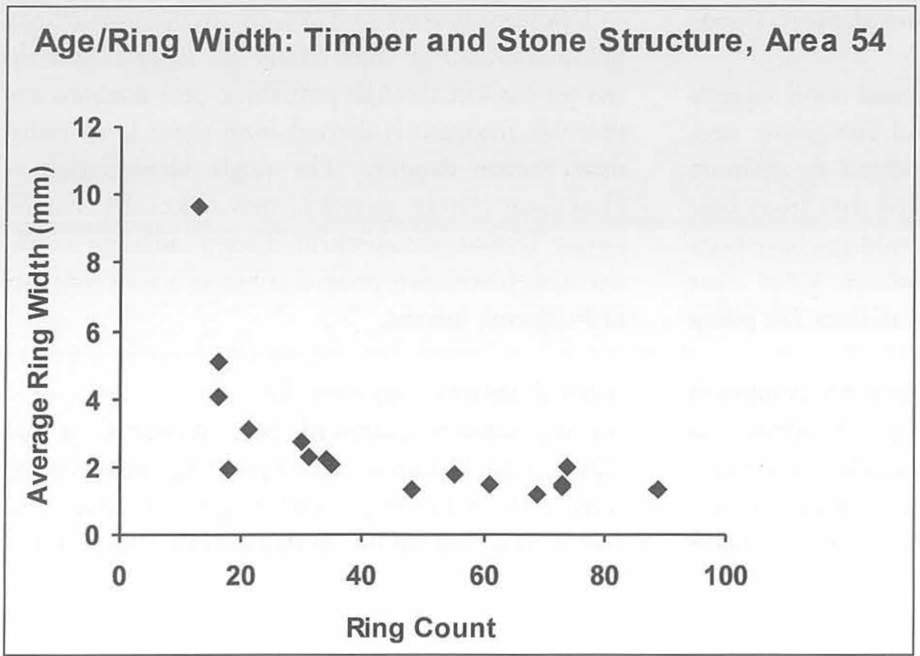


Figure 3.6.1 Ring widths plotted against ring count for samples from the timber and stone structure in Area 54 (all oak).

Table 3.6.4 Tree-ring analysis and dating of boat samples ordered by function code and wood number indicating total ring count, sapwood count, presence of bark, average ring width, and absolute dating. All timbers were oak (*Quercus* sp).

wood number	*function*	*ring count*	*sap/bark*	*average ring width (mm)*	*dated*
5080	SF6.5 Pt	26	15	1.8	
5082	SF6.5 St	30	4	2.2	
5089	SF2.5 Pt	14		1.78	
5123	BP1	13		3.8	
5122	BP2	45		2.3	
5125	BS1	55		2.3	
5076	F1	24		2.9	
5075	F2	25		4.2	
5090	SF2 Pt	17	12	3.17	
5092	SF2 St	27	19	1.8	
5074	F3	33	12	2.1	
5087	SF3 Pt	10		1.3	
5088	SF3 Pt	34		2.47	
5101	SF3 St	42	9	1.9	
5073	F4	17		5.35	
5085	SF4 Pt	23	11	1.65	
5086	SF4 Pt	18		2.05	
5072	F5 Pt	30	7	3.7	
5071	F5 St	29	10	2.69	
5070	F6	25		3.56	
5069	F7 Pt	34	13	3.15	
5068	F7 St	29	8	5.5	
5067	F8	25		4	
5079	SF8 Pt	27		4.5	
5066	F9	16		2.24	
5078	SF9 Pt	28	12	2.5	
5083	SF9 St	17		4.6	
5065	F10 Pt	34	7	5.9	
5064	F10 St	30		5.9	
5063	F11	22		3.68	
5062	F12 Pt	26		6.8	

wood number	*function*	*ring count*	*sap/bark*	*average ring width (mm)*	*dated*
5061	F12 St	22		3.41	
5084	F12 St	11		3.73	
5060	F13	25		4.3	
5099	SF13 Pt	11		3.73	
5059	F14	37		3.3	
5058	F15	37		1.81	
5057	F15 Pt	30		7	
5056	F15 St	20-30			
5055	F16	22		3.05	
5093	MST	15		3.47	
5112	P1	52	5	3	
5111	P2	52	9	2.6	AD 282
5109	P3	71		2.4	
5110	P3	67		2.3	
5108	P4	25		4.6	
5117	P4	93	H/S?	1.7	
5118	P4	27		3.8	
5129	P4	59		2.1	
5106	P5	72	5	1.6	AD 276
5119	P5	53		3.5	
5120	P6	40		4.6	
5130	P6	37		4.33	
5121	P7	27		3.07	
5113	S1	31			
5114	S2	50	5		
5126	S3	45		2.88	
5127	S3	54		1.6	
5137	S4	20		4.5	
5128	S5	43		2.33	
5091	stem post	30		6.8	
5124	stem post	30		6.8	

in six cases – two are 'winter felled' and four are 'summer felled'. This apparent lack of contemporaneity is confirmed by the absolute dating of four of the piles. Although rings were not sufficiently well preserved to allow production of a felling date for pile 5039, the felling dates for piles 5031, 5050, and 5131 of AD 279, AD 282, and AD 283 point to repair/maintenance of the structure over a relatively brief period (Fig 2.6).

3.6.4.3 Boat samples

All the samples examined were identified as oak (*Quercus* sp). Details of function, ring count, average ring width, and sapwood for analysed samples are given in Table 3.6.4. The average ring widths of samples are shown graphically in Fig 3.6.2. All the planks were sawn tangentials in which the centres of the parent tree were rarely visible and only partial if any sapwood survived. The majority of timbers had insufficient rings for dating purposes. Two samples dated – both port-side planks gave dates for their last surviving rings of AD 276 and AD 282. Using widely accepted sapwood estimates for British material (Hillam *et al* 1987) these give estimated felling ranges of AD 281–326 and AD 283–328 respectively.

3.6.4.4 Treenails

The treenail samples (Table 3.6.5) were in poor condition since they had been contaminated with iron salts from the nails that had been driven through them. Many were also fragmentary. The majority appeared to be in the round, taken from immature stems with diameters of 10–15mm and lengths of up to 60mm. While the majority exhibited anatomical characteristics (uniseriate rays, non-ring-porous annual rings) compatible with identification as hazel/alder or willow/poplar, only four samples could be confidently identified through the clear presence of perforation plates. Two were hazel (*Corylus avellana* L) and three

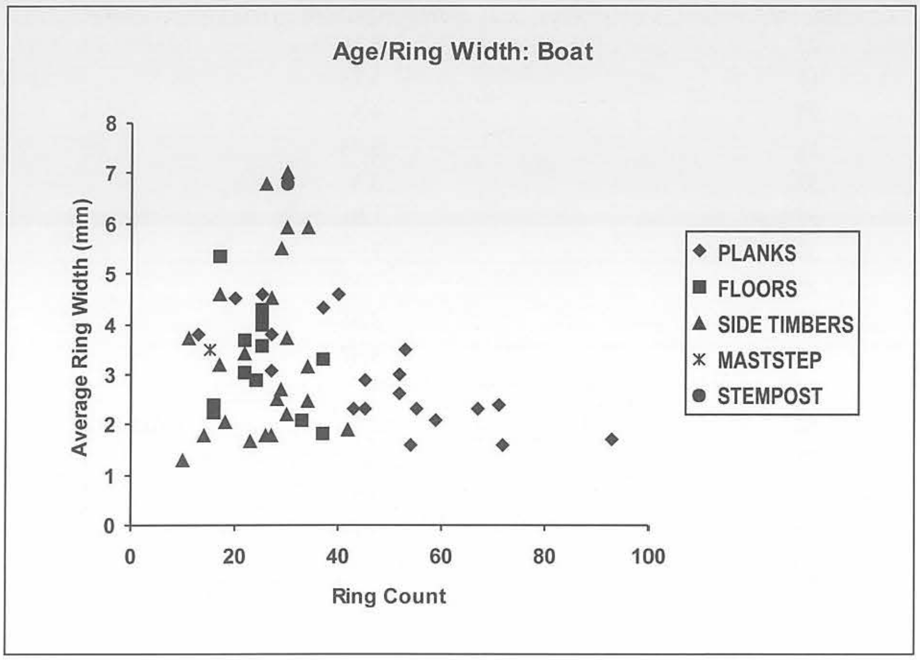


Figure 3.6.2
Average ring widths plotted against ring count for samples from selected boat timbers.

Table 3.6.5 Find number, timber code, parent wood number, and identification for treenail samples

find no	*timber code*	*wood no*	*comments*
123	plank P6A	5130	*Quercus* sp – possible wooden peg found with iron fittings. 37mm L by 13–15mm D; cut down from the round
158	floor F14	5059	*Corylus avellana* L – roundwood 42mm L by 13–17mm D
159	floor F13	5060	unidentifiable fragment, 60mm L by 10mm W by 5mm T
165	floor F13	5060	fragment of unidentifiable roundwood
167	half-frame F12 Pt	5062	compressed fragment of roundwood
168	half-frame F12 St	5061	fragment of roundwood; fluted appearance suggests trimming
176	side timber SF9 Pt	5078	compressed fragments and iron concretions
181	side timber SF6.5 Pt	5080	fragment of unidentifiable roundwood. 60mm L by 13mm D
184	half-frame F7 Pt	5069	*Corylus avellana* L; fragment 72mm L by 14mm D
185	side timber SF3 Pt(M)	5088	fragment of unidentifiable roundwood with heavy iron concretions; diameter 14mm
188	floor F4	5073	*Salix/Populus* – roundwood with square section (6–7mm) nail in good condition
191	half-frame F10 St	5064	heavy iron concretions
192	side timber SF4 Pt	5086	unidentifiable fragments
196	plank P4C	5108	*Salix/Populus* – fragment with very clean, almost polished appearance; iron stained
215	side timber SFX2	5037	unidentifiable fragments
216	side timber SFX2	5037	*Salix/Populus* – fragment of roundwood 48mm L

were willow/poplar type (*Salix/Populus*). One sample was an oak (*Quercus* sp) peg 13–15mm diameter and 37mm long. It had been cut down from a more substantial piece of wood rather than being in the round.

3.6.5 Discussion

The data generated by the tree-ring analysis and species identification of samples from the Romano-Celtic boat and the associated timber structure have implications in three main areas: dating, exploitation of available woodland products, and the nature of contemporary woodland.

Crossmatching of the measured ring width sequences by computer correlation (Table 3.6.6) and subsequent visual confirmation produced a six-timber mean comprising two samples from port-side planks and four piles from the associated timber and stone structure in

Table 3.6.6 *t*-value matrix showing the level of agreement between matching ring sequences from dated samples from both the boat (5106 and 5111) and the piles from area 54. Values less than 3 are not shown.

	5111	*5031*	*5039*	*5050*	*5131*
5106	4.7			4.7	
5111		3.1	3.5	5.6	3.3
5031			5.5	5.1	3.8
5039				7.0	5.0
5050					4.7

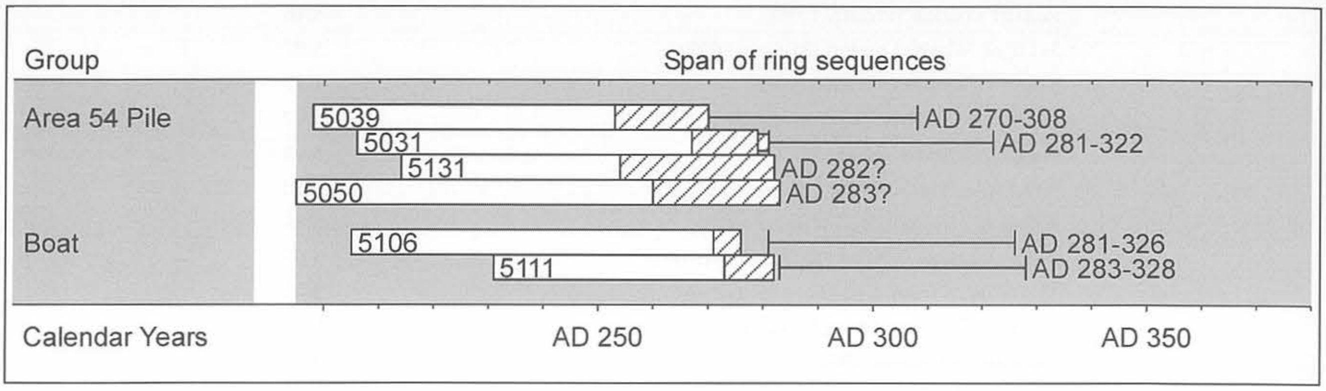


Figure 3.6.3 Ring sequence spans for the timber and stone structure in Area 54 and the boat.

Table 3.6.7 Ring-width data from the combined piles and boat timber chronology.

year	*ring widths (0.01mm)*										*number of samples*									
AD 195					395	267	380	359	206	217					1	1	1	2	2	2
AD 201	277	147	278	140	180	133	107	151	204	211	2	2	2	2	3	4	4	4	4	4
	222	231	238	195	183	134	162	192	214	180	4	4	4	5	5	5	5	5	5	5
	183	140	143	105	95	115	142	104	158	220	5	5	5	5	5	5	5	5	5	5
	216	173	189	211	219	161	129	272	209	171	6	6	6	6	6	6	6	6	6	6
	171	180	215	150	165	204	172	188	186	153	6	6	6	6	6	6	6	6	6	6
AD 251	139	148	153	178	192	139	164	154	141	136	6	6	6	6	6	6	6	6	6	6
	127	132	145	136	88	126	147	137	153	124	6	6	6	6	6	6	6	6	6	6
	152	176	173	158	147	142	175	115	124	131	5	5	5	5	5	5	4	4	4	3
	161	140	63								3	3	1							

Area 54 (Fig 3.6.3). This site master (Table 3.6.7) dated against Roman chronologies from London and elsewhere (Table 3.6.8) giving significant *t* values with a date range of AD 195–283. With bark surviving on three of the dated samples from the structure in Area 54, dating resolution is excellent. As has been noted indications of different felling seasons for undated samples from the same structure suggest that the structure was frequently repaired or that piles were stockpiled for use. The former interpretation seems most probable given the absolute dating of the piles with bark edge to AD 279, AD 282, and AD 283.

Dating resolution for the boat is not so fine, given the lack of bark edge on any dated samples. The estimated felling ranges of AD 281–326 and AD 283–328 for the two dated port-side planks imply construction in the last quarter of the 3rd century or first quarter of the 4th century. It is possible that the vessel was constructed soon after the timber structure in Area 54.

It is clear from this study that not only had suitable species been selected for specific purposes, but also that wood with certain growth or size characteristics had been chosen to meet specific needs. The majority of the wood exploited for construction of the stone and timber structure in Area 54 comprised oak boles in the round. These were selected on the basis of their diameter to obviate the need to convert larger, more

Table 3.6.8 Dating the Barland's Farm 89-year, six-timber oak chronology to AD 199–AD 283 inclusive: *t*-values with dated reference chronologies.

reference chronology	*t* value
Baynard's Castle, London (Morgan 1980)	4.39
County Hall Ship, London (Tyers 1994a)	3.55
Guildhall Yard, London (Tyers 1994b)	4.02
Guildhall, London (Tyers pers comm)	4.72
New Fresh Wharf, London (Hillam and Morgan 1986)	4.65
Peter's Hill, London (Hillam 1992)	5.47
Roman London (Hillam 1990)	3.46
Sunlight Wharf, London (Hillam 1992)	3.97
Tower of London (Hillam 1983)	4.17
Gloucester (Hillam pers comm)	3.92
Godmanchester (Hillam 1993)	3.93
Pevensey (Tyers 1994c)	5.50
Allistragh, Ireland (Baillie pers comm)	3.81
Balloo Cottage, Ireland (Baillie pers comm)	4.67
Mill Lough, Ireland (Baillie pers comm)	3.81
Teeshan Crannog, Ireland (Baillie pers comm)	6.83
Germany (Hollstein 1980)	3.21
Netherlands: Roman 1 (Jasma pers comm)	5.57

valuable wood down to a suitable cross section and to provide a minimum level of structural strength.

Oak was clearly selected preferentially for construction of the vessel: all structural elements with the exception of treenails and caulking were made from oak.

3.7 Environmental overview, by M J C Walker and A Caseldine

Palaeoecological evidence from Barland's Farm, in the form of pollen, plant macrofossil, diatom, and molluscan data provides an environmental context for the Romano-British boat. Overall the different records are broadly in agreement in terms of environmental reconstructions, although perhaps inevitably there are some differences in detail. Collectively the data indicate that the earliest deposits in the palaeochannel (that predate the boat) accumulated in a sluggish estuarine environment in which a marine influence was dominant. This is most strongly confirmed by the diatom data from Area 50 which show that the silts and clays that are broadly contemporary with those immediately underlying the Romano-British boat represent a brackish water regime with a marked tidal input. The pollen data contain some evidence for an initial freshwater influence. Small numbers of freshwater mollusca were also recovered from these sediments. Interestingly the earliest diatom records from Area 50 also show a mixed assemblage of freshwater and marine taxa, although these may predate the earliest sequences in the sediment column from beneath the boat. In addition the pollen records suggest an increasing marine influence, possibly associated with a relative rise in sea level. By contrast, however, since there are only limited indications in the plant macrofossil data for a freshwater element in the palaeochannel, there is little clear evidence for an increase in marine influence during the early part of the sequence.

The pollen and plant macrofossil data are in agreement, however, in indicating a landscape in the vicinity of the palaeochannel primarily of grassland and saltmarsh, with damper areas of sedge fen, alder carr, and occasional patches of *Sphagnum* mire. Further inland, occasional stands of oak and hazel may well have been present. In both the pollen and plant macrofossil records there are taxa that could be indicative of both arable and pastoral activity. There are interpretational problems here, however, as many of these plants are also found in coastal marsh and sand-dune communities. Nevertheless evidence for Roman farming has been reported from other sites of the Gwent Levels (Fulford *et al* 1994; Yates 2000b) and hence similar activities may have been practiced in the vicinity of Barland's Farm.

During and following the emplacement of the boat, the pollen, plant macrofossil, and molluscan records display a broad measure of agreement in indicating a salt-marsh environment around a tidal channel which was probably fairly high in the tidal range. The palaeobotanical data indicate the presence of dryland areas in the vicinity of the site, while the occurrence of numerous taxa associated with both arable and pastoral farming practices could again be taken as indicative of local agricultural activity (but see above). Although the local vegetation was one of grassland communities grading into areas of salt-marsh (see, for example, Rodwell 2000), there are indications of the continued presence of woodland stands of oak, ash, alder, and hazel in the hinterland of the palaeochannel. The short-lived expansion in woodland that is reflected in the pollen records would accord with the suggestion of managed, fast-growing oak woodland in close proximity to the site, during and/or after the burial of the boat within the sediments of the palaeochannel.

Plant macrofossils recovered from samples from the limber holes of the boat timbers include not only those of local salt-marsh species, but also weeds of cultivation, cereals, and other dryland plants. Some of these could have derived from cultivated fields nearby. If so this would give credence to the suggestion of local agricultural activity inferred from the pollen and plant macrofossils in the palaeochannel sediments. They could also, however, at least in part, represent plant material carried onto the boat itself. Equally the dryland plants could be the remnants of fodder or bedding for animals (suggesting that the boat might have been used to ferry livestock), while the cereal macrofossils could also reflect cargoes of cereals or even the use of cereal straw for dunnage. It is also interesting to note that the plant macrofossil record shows that both willow and hazel were used for caulking between the timbers of the vessel. There is, however, no evidence to link this woody material to trees or shrubs growing in the vicinity.

4

Finds and materials

4.1 Non-worked stone, by J Hall

4.1.1 Introduction

The twenty-three samples of stone examined were from the stone spread in Area 54 to the north of the boat in contexts 2373, 2374, 2375, and 2378 (Figs 2.5, 2.6, and 2.9). Examination showed that these stones could be classified into nine different rock types (lithologies) A to I.

4.1.2 Catalogue

1 2373 Description: a very well-cemented breccia. No fossils are visible. The matrix is brown/yellow in colour and effervesces with dilute HCl acid. It contains vesicles arranged randomly. There are areas of mineralisation. The clasts are up to 100mm in size with a low to mid sphericity, subangular, and brown/grey in colour. They effervesce slowly with dilute HCl acid.

The fragment is approx 260 × 185 × 180mm with a few small pieces in a bag.

Lithology: A

2 2374 (022) Description: pale grey in colour with brown iron staining. Very well cemented. Mainly quartz with some mica, and larger clasts of rock including mudstones. Grain size – very fine sand to fine sand. No fossils visible.

The fragment is 470 × 270 × 60mm. One flat weathered surface and no working.

Lithology: H

3 2374 (023) Description: light pink/brown to grey/green in colour. Very well cemented with siliceous matrix. Very pure quartz, grain size – fine sand. No fossils visible.

The fragment is 210 × 115 × 045mm. One partly worn surface and no working.

Lithology: H

4 2374 (024) Description: pale pinkish brown in colour. Very well cemented. Mainly quartz with some mica. Grain size – very fine sand to fine sand with occasional larger clasts of quartz or other material. No fossils visible.

The fragment is 460 × 210 × 75mm.

Lithology: H

5 2374 (025) Description: pale grey with a greenish tinge where grain size is smaller. Very well cemented with a siliceous matrix. Largely quartz variants with some lithic fragments. Grain size varies from fine sand up to 20mm pebbles. Bedding visible. No fossils visible.

The fragment is 270 × 200 × 120mm. One weathered surface.

Lithology: D

6 2374 (026) Description: pale grey/green in colour and with iron staining. Very well cemented. Largely quartz with some mica. Laminated bedding. Grain size – fine sand. Very occasional larger fragments. No fossils visible.

The fragment is 190 × 85 × 45mm. No worn surfaces. No working.

Lithology: H

7 2374 (075) Description: pale brown/grey on worn surface, darker grey/brown on broken surface with some iron staining. Very well cemented. Mainly quartz with some mica. Grain size – fine sand. No fossils visible.

The fragment is 102 × 148 × 32mm. One worn surface.

Lithology: H

8 2375 (073) Description: pinkish brown in colour with a slight greenish tinge. Well cemented. Mainly quartz with some mica. Grain size – fine to medium sand. Very well sorted. Mid to high sphericity, subrounded. No fossils visible.

The fragment is 140 × 186 × 0.40mm. No working.

Lithology: H

9 2378 (030) Description: pale grey in colour with a slight greenish tinge, not homogeneous. Very well cemented. Very poorly sorted. No fossils visible.

The fragment is 310 × 265 × 110mm. One weathered surface.

Lithology: D

10 2378 (031) Description: dark grey on worn surface, pale grey on broken surface with some indistinct bands of darker rock and Fe staining. Very well cemented. Mainly quartz variants with some darker mineral/rock fragments. Grain size – very fine sand grading up to fine/medium sand with larger pieces up to 14mm of quartz and quartzite pebbles. No fossils visible.

The fragment is 300 × 250 × 45mm. One worn surface. No working.

Lithology: D

11 2378 (032) Description: pale brown in colour. Very well cemented. Effervesces with dilute HCl acid. Oolitic with *c* 50% matrix. No fossils visible.

The fragment is 310 × 290 × 200mm. One weathered surface. No working.

Lithology: B

12 2378 (033) Description: pale grey/brown in colour, not homogeneous. Very well cemented with siliceous matrix. Mainly quartz with some lithic fragments, mainly a reddish sandstone. Mid- to high sphericity and sub-rounded grains. Not well sorted, medium sand to very coarse sand. Some bedding apparent. No fossils visible.

The fragment is 180 × 125 × 75mm. Some wear on three surfaces.

Lithology: D

13 2378 (034) Description: mid-greenish-grey in colour with some iron staining. Very well cemented. Quartz. Grain size – fine sand to medium sand ranging up to 12mm. Laminated bedding. No fossils visible.

The fragment is 180 × 160 × 85mm. One worn surface. No working.

Lithology: D

14 2378 (035) Description: pale greenish grey in colour on weathered surfaces. Very well-cemented and very fine grained. Signs of parallel bedding. Quartz variants and mica. No fossils visible.

The fragment is 145 × 140 × 40mm. One weathered surface, others are more freshly broken. No working.

Lithology: G

15 2378 (036) Description: pale grey weathered surface, mid-grey where fresher break. Very well cemented with a siliceous matrix. 95% quartz variants, grain size – fine sand with larger pebbles up to 20mm. Subangular. Signs of layers (not bedding planes). No fossils visible.

The fragment is 245 × 250 × 55mm. One worn surface. No working.

Lithology: E

16 2378 (037) Description: pale grey in colour on weathered surfaces. Very well cemented. Grain size – fine sand to very fine sand with very occasional quartz pebbles. No fossils visible.

The fragment is 340 × 160 × 65mm. One worn surface. No working.

Lithology: G

17 2378 (038) Description: pale brown/grey with some iron staining. Very well cemented. Quartz. Grain size – fine sand, well sorted with high sphericity. No fossils visible.

The fragment is 380 × 125 × 140mm. Worn on two sides. No working.

Lithology: I

18 2378 (039) Description: pale grey in colour. Very well cemented with a siliceous matrix. Largely quartz, some mica. Bedding visible. No fossils visible.

The fragment measures 104 × 73 × 40mm with one worn surface. No working.

Lithology: H

19 2378 (040) Description: mid-grey in colour. Very well cemented. Quartz and mica with some rose quartz and darker fragments. Grain size – fine to medium sand. No fossils visible.

The fragment is 105 × 70 × 40mm. One weathered surface. No working.

Lithology: F

20 2378 (041) Description: indeterminate colour with red and brown staining. Very well cemented with siliceous matrix. Grain size – medium sand to coarse sand with occasional larger pebbles. Mainly quartz variants with some lithic fragments. No fossils visible.

The fragment is 275 × 195 × 65mm. One weathered surface. No working.

Lithology: F

21 2378 (042) Description: mid-green/grey in colour. Very well cemented. Mainly quartz with occasional mica. Grain size – fine sand, well sorted. No fossils visible.

The fragment is 145 × 95 × 33mm with one worn surface. No working.

Lithology: E

22 2378 (043) Description: pale grey in colour with a slight greenish tinge. Very well cemented with a siliceous matrix. Grain size – coarse sand to very coarse sand. High sphericity sub-angular grains; the larger ones appear more rounded. Largely quartz and rose quartz. Signs of graded bedding. No fossils visible.

The fragment measures 75 × 70 × 40mm with one worn surface. No working.

Lithology: F

23 2378 (071) Description: pale grey to green in colour. Very hard, cryptocrystalline quartz with aligned vesicles with areas of visible individual quartz grains, grain size – very fine sand. Some large inclusions. No fossils visible.

The fragment is 170 × 100 × 85mm. Two weathered surfaces. No working.

Lithology: C

4.1.3 Lithology Descriptions

Lithology A A dolomitic breccia probably from the Triassic Dolomitic Conglomerate that outcrops north and south of Undy, ST 440 880 (BGS Chepstow Sheet 250).

Lithology B A very fine-grained oolitic limestone with *c* 50% matrix possibly from the Carboniferous Limestone Drybrook Limestone that outcrops north of Rogiet, ST 460 895 (BGS Chepstow Sheet 250).

Lithology C A chert?

Lithology D A poorly sorted quartzitic sandstone with larger pebbles of mainly quartz variants. Upper Carboniferous Millstone Grit (Squirrell and Downing 1969, 84).

Lithology E A very well-cemented fine-grained quartzitic sandstone with occasional large pebbles of quartz. Upper Carboniferous.

Lithology F A sugary quartzitic sandstone. Upper Carboniferous.

Lithology G Very fine-grained, well-cemented sandstone with very occasional larger quartz pebbles. Upper Carboniferous.

Lithology H Very well cemented, very fine to fine-grained micaceous sandstone. Upper Carboniferous.

Lithology I A very well-cemented, well-sorted quartz sandstone. Lower Carboniferous.

4.1.4 Conclusion

Lithologies D to G probably come from the Upper Carboniferous which outcrops to the north-west of the Newport area (Table 4.1.1). This represents 82.5% of the total number of stones which is broadly similar to the 72.2% of Upper Carboniferous material recorded from the Rumney Great Wharf (Fulford *et al* 1994). The other lithologies would also appear to be from relatively close to the site rather than imports. Most of the stones exhibit wear on one or more faces probably consistent with being used as part of a surface. There is no clear-cut division between the origins of stones from different contexts. It is interesting that certain rock types, eg the Brownstones of the Old Red Sandstone, are not represented at all. This could suggest selection of certain types of stones but might reflect more the source from which the stones were taken.

Table 4.1.1 Percentage lithologies by context

	2373	*2374*	*2375*	*2378*	*total*	*total (%)*
A	1				1	4.4
B				1	1	4.4
C				1	1	4.4
D		1		4	5	21.7
E				2	2	8.7
F				3	3	13.0
G				2	2	8.7
H		5	1	1	7	30.4
I				1	1	4.4
TOTAL	1	6	1	15	23	

4.2 Roman coarse pottery, by P Webster

4.2.1 Introduction

In view of the exceptional character of the remains and the unusual composition of the assemblage, all Roman pottery is listed (Table 4.2.1) and the more diagnostic pieces illustrated (Fig 4.2.1).

4.2.2 Catalogue

Listing is in numerical order of context.

Context 2001

1 2001(010) Jar in black-burnished ware (BB1); Gillam 1976, no.13 (early to mid-4th century) is a close but not exact parallel.

The context also contained a further BB1 jar sherd, 2000 (011), apparently with obtuse-angled lattice decoration below a horizontal groove. Such decoration was common in the late 3rd and 4th centuries.

Context 2340

The context yielded a further sherd from a BB1 jar, in this case a shoulder fragment with traces of decoration below a horizontal groove. Such decoration is of late 3rd- and 4th-century date and there seems no reason to suggest that the piece is not approximately contemporary with the other pottery from the site.

Context 2346

2 2346 (004) Rim of a jar in black-burnished ware (BB1). A late 3rd- or 4th-century date for the vessel is certain (cf Gillam 1976, nos 11–14). A vessel such as *ibid* no. 12 (early 4th century) seems most likely.

The context also included the following:

a Six sherds of BB1 from at least three vessels. One was a large jar decorated with obtuse angled lattice, a late 3rd- to 4th-century feature, 2346 (009) and (012); both these and no. 2 above could all be from the same vessel but none joins). Also present is a base, 2346 (013), from a jar of similar size to no. 2 above. A third vessel is implied by a small sherd, 2346 (005), which appears to be burnished internally and is, therefore, part of a bowl or dish.

Table 4.2.1 Vessel source and class

	jar	*flagon / handled jar*	*dish*	*total*	*%age*
South Wales Grey Ware	2		–	2	11
other local	1	–	–	1	5
BB1	11	1	1	13	68
other non-local	2	1	–	3	16
total	15	2	1	19	100
%age	84	11	5	100	

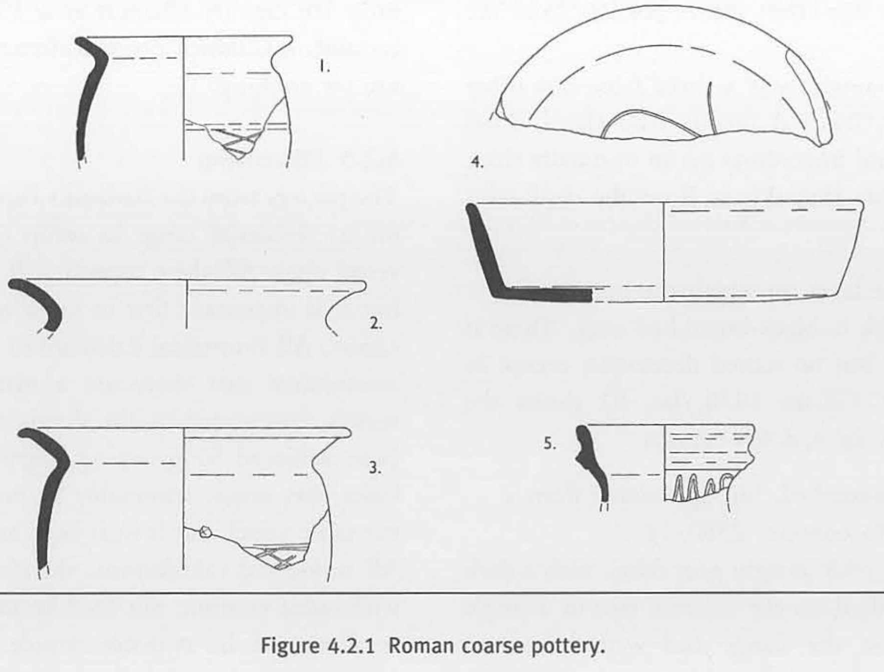


Figure 4.2.1 Roman coarse pottery.

b A jar sherd in light brown fabric with a dark grey surface, highly burnished externally. The fabric has small rounded quartz-like inclusions. While such highly 'polished' pieces are more typical of earlier Roman periods, there is little truly diagnostic about this sherd and it must be assumed that it is dated by its companions.

Context 2370 (final silting of channel)
There are sherds from two jars. One is in a light orange-buff fabric with a grey core which does not appear to be local in origin. There was probably a cordon at the neck/shoulder junction. The other is in a grey fabric with an external surface which was probably burnished. It may well be local.

Context 2374 (within the boat)
The base of a jar in black-burnished ware, 2374 (027).

Context 2378
Wall sherd 2378 (019) from a jar in dark grey fabric with plentiful grey-white inclusions and a micaceous surface. Part of the exterior is burnished and part left matt, suggesting a jar reminiscent of BB1 forms. Also found was a handle, 2378 (019), in a similar fabric. Neither of these two sherds appear to be in local grey fabric and it seems possible that, like the black-burnished ware, they are from a source on the other side of the Bristol Channel.

Context 2380 (overlying the north end of the boat)
3 2380 (081) Jar in black-burnished ware, cf Gillam 1976, nos 11–12 (late 3rd to early 4th century). There is a small lump of stone visible in the wall and it is probably not surprising that the vessel broke on a line through this. Also two other sherds possibly from the same vessel.

Also from this context was a sherd from one other jar in BB1, 2380 (044). A further BB1 sherd, 2380 (045), shows vertical burnishing on an unusually thick fabric; it is possible that this is from the neck of a flagon.

Context 2381 (the layer on which the boat rested)
4 2381 (088) Dish in black-burnished ware. There is a very slight bead but no scored decoration except in the basal interior. Gillam 1976, no. 82 shows the general type. Early to mid-4th century.

Context 2392 (unstratified, but apparently from a layer comparable to contexts 2380–1)
5 2392 (134) Jar neck in light grey fabric with a dark surface and burnished on the internal face in a single band externally on the flange and with burnished zig-zag on the neck. The interior surface, where not burnished, is rough. Jars of this general type were produced on both sides of the Bristol Channel (cf Spencer in Robinson 1988, 116). The production of granular grey pottery with a dark grey surface was, however, certainly typical of the Caldicot kilns in the late 3rd and early 4th centuries (Barnett *et al* 1990, 127) and there seems no reason why this piece should not be of local origin. Also a small sherd in grey fabric which, despite its brown core, may well be from the same vessel.

The context 2392 (130) also included three sherds of black-burnished ware:

a A wall sherd. The exterior has been burnished and has a single, nearly vertical, scored line. The interior is rough. It is presumably from a closed vessel, perhaps the lower wall of a jar with decoration which is either unusual or (more probably) has strayed from a matt zone above.

b The upper shoulder of a jar which does not appear to be one of those represented elsewhere in this catalogue.

c A body sherd from a jar.

Context 2393
A sherd of black-burnished ware burnt silvery grey, probably while in use, 2393 (135).

Context 2405
The context yielded four sherds (three joining) of a jar in highly fired mid-grey fabric with a part-burnished exterior. A vessel with an unburnished central zone (perhaps in imitation of BB1 jars) is likely. Such vessels were made at the Caldicot kilns in the mid-3rd to early 4th century (Barnett *et al* 1990), but this is not certainly a Caldicot product. External sooting suggests use for cooking.

4.2.3 Discussion

The pottery from the Barland's Farm sites is remarkable for its restricted range in terms of date, source, and vessel class. All these aspects will be examined below but it is important first to say a word about quantification. All numerical calculations are based upon the assumption that there are a maximum of nineteen vessels represented by the sherds catalogued. This has been achieved by grouping together rims, walls, and bases that might reasonably be expected to belong to the same vessel, but it is, at best, an informed estimate. All numerical calculations, therefore, must be viewed with some caution, not least because of the extremely small size of the available sample.

It is probably easiest to look at the assemblage in terms of source and vessel class (Table 4.2.1).

Even granted the small size of the assemblage, this is evidently an extremely unusual pattern of deposition. Comparison with figures from Usk (Manning 1993, 354–5) show that the dominance of just one source, black-burnished ware, is higher than might be expected, while South Wales Grey Ware is underrepresented, although this could be a result of the small sample. The very limited number of sources is, however, unusual, even in this small a group. Comparison with another set of Usk figures, that for vessel classes in three late groups which are approximately contemporary with the Barland's Farm material, shows a complete contrast (Manning 1993, 360). If wide-mouthed jars are omitted from the Usk jar total on the grounds that no vessels of this class are present at Barland's Farm, we find that 63 out of 161 vessels in the Usk groups are narrow- and medium-mouthed jars and that 39% of the Usk sample are jars compared with the massive 84% at Barland's Farm.

Turning to the date of the assemblage, although a date within the second half of the 3rd century would certainly suit everything in the assemblage, only eight vessels are sufficiently complete or sufficiently diagnostic to be more closely datable (two from context 2001, and one each from 2340, 2346, 2380, 2381, 2392, and 2405 – summarised in context order in Fig 4.2.2).

How the available information on chronology is treated will depend on the conception of how the pottery got into the ground. If it were likely to represent an accumulation over a period of time, then a long chronology would be justified. Even in this case, it is hard to see the available evidence representing more than a late 3rd- to mid-4th-century date range. Is it justified, however, to see the pottery as the result of casual accumulation over a medium to long period? The composition of the collection is certainly unusual and atypical. If it were accumulated from a variety of activities over a long period, surely the chances are high that it would include a greater variety, both of sources and particularly of vessel types. The character of the assemblage argues for something unusual and probably, therefore, short-lived. Even a single activity over a longer period would surely have attracted the

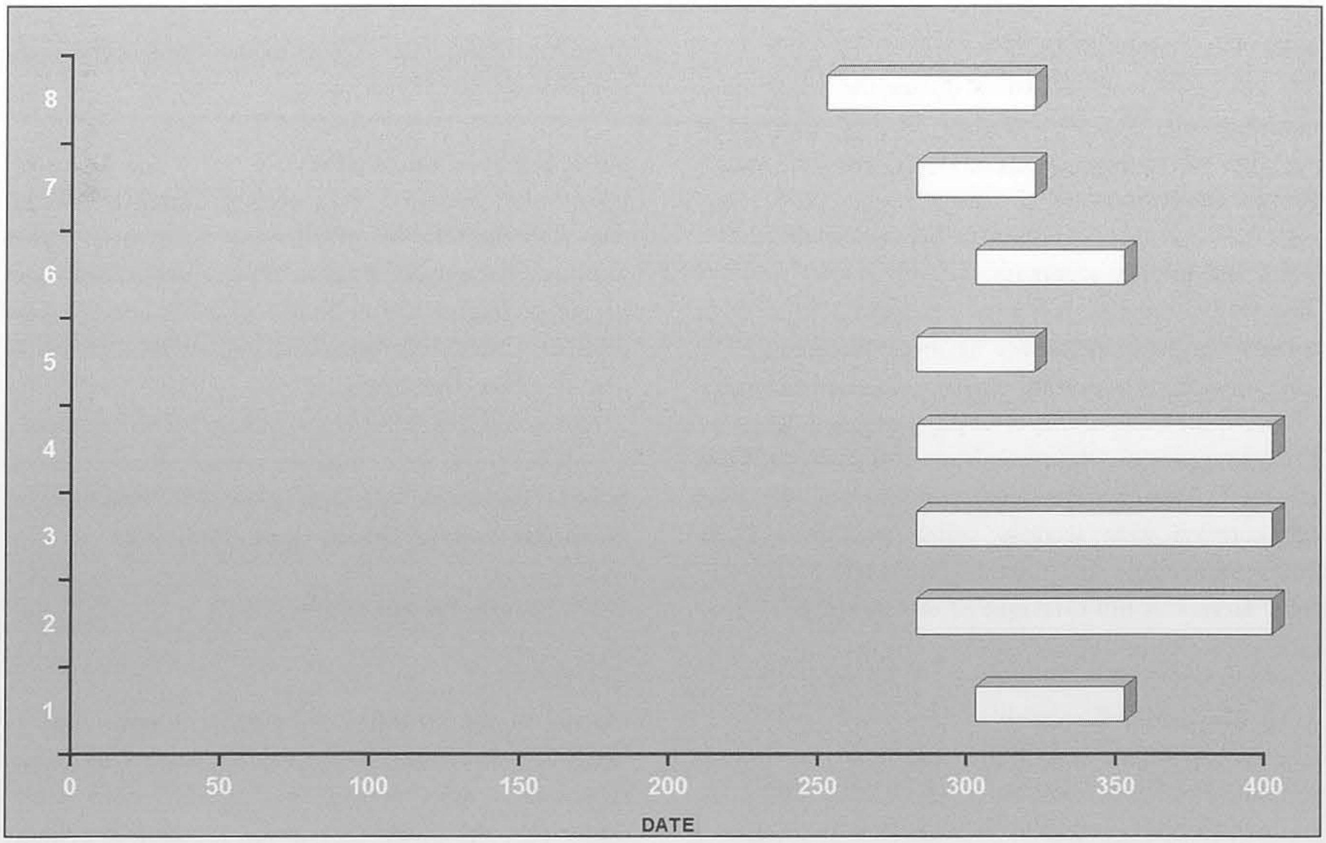


Figure 4.2.2 Date ranges of diagnostic pottery.

breakage of a greater range of forms, if not vessels from a greater range of sources.

If it is allowed that the pottery suggests unusual activity over a short period, then both these characteristics need to be defined. In terms of chronology this is reasonably easy. The pottery could all have been deposited at a single moment around the turn of the 3rd and 4th century, although a wider late 3rd- to early 4th-century date would perhaps be more prudent. The event that caused the deposition is more difficult to determine. It has been termed unusual mainly on the basis of the enormously high percentage of jars present and the general absence of vessels in other classes. This pattern is completely different from that found on domestic sites, whether civilian or military, and normal household rubbish disposal may be excluded. Use on boats such as that recovered can also probably be excluded, as this would presumably also show a domestic pattern. The stratigraphic distribution seems to exclude deposition of the pottery as part of the cargo of the boat excavated. It does not seem too fanciful, however, to suggest that the peculiar characteristics of this pottery might be explained in terms of trade across the Bristol Channel. It is not known how Romano-British coarse pottery vessels were packed for transport, but it would not seem impossible that vessels of a specific class would be packed together. Might, therefore, the unusual character of the Barland's Farm assemblage be the result of breakages in the loading or unloading of pottery jars somewhere in the vicinity of the area excavated? The excavation of the London quays has shown how vessels broken on the quay can get into extensions to the waterfront as infill (cf Dyson *et al* 1986, *passim*). Is a similar if smaller-scale version of this being seen at Barland's Farm? If so it should perhaps be noted that, although the jars represented are mainly from the south-west of England (BB1), other local and non-local sources are also represented. This may represent movement both in and out of a small quay, but this could equally be the by-product of local coastal trade – mixed cargoes picked up and sold on by coasters as they plied along the small inlets of the Bristol Channel.

4.3 Mammal bone, by M Locock

4.3.1 Excavation context

The animal bone was recovered during the stratigraphic excavation of Area 50 and Area 54, within layers of silt clay alluviation associated with the 3rd-century Roman structures.

4.3.2 Assemblage summary

The animal bone is in a good condition, although in some cases the bone surface has been weathered. The 134 bones came from twelve different contexts (Table 4.3.1), but as there is no significant variation between contexts, the assemblage has been analysed as a unit. Although the number of bones is not large, the contexts were securely sealed and there is no reason to suppose that there has been bias by taphonomic factors. A full catalogue of the animal bone is in archive.

4.3.3 Depositional context

The animal bones were weathered and a significant proportion (14.9%) had been gnawed by rodents or canines. In combination with the absence of articulated joints and unfused epiphyses, this can be taken to imply that the bone had been exposed for some time on the surface (perhaps at an occupation site elsewhere) prior to its deposition in the silts. A series of distinct dumping events spread over some time is the most probable source of the bone.

4.3.4 Evidence for butchery

Five bones retained evidence of butchery marks. Although the only identified species displaying marks was cow, the similar element representation and high degree of fragmentation found in other species (particularly horse, sheep/goat, and pig) suggests that they had also been butchered.

A cow skull from Area 54 context 2367 displayed a pole-axe hole in a medial position in the frontal bones. This is a typical Roman slaughter technique, as noted elsewhere in Britain (Luff 1982, 102).

4.3.5 Species present (Table 4.3.2)

4.3.5.1 Cow

Of the bones identified to species, 9 were cow, of which 5 were from the head and 2 were from other second-class meat bones. This representation would imply that the assemblage is the product of primary butchery, reflecting the discarding of the poorer bones. All bones that could be aged were of young adults.

Although the assemblage of large mammal bones may contain significant numbers of unclassified cow

Table 4.3.1 Context summary

	cow	*horse*	*deer*	*s/g*	*pig*	*dog*	*lge*	*med*	*un*	*total*
050/2001		1								1
050/2308									1	1
050/2345							1		1	2
050/2347	1									1
050/2348		1								1
054/2367	2	1						2		5
054/2370	1	3		4			9	2		19
054/2378	1			4			11	16		32
054/2380	3	3	1	18	1	3	10	14		53
054/2381	1			5			6	5		17
054/2383		1								1
054/2392								1		1
TOTAL	9	10	1	31	1	3	37	40	2	134

Table 4.3.2 Species summary

	NISP	*%*	*% identified*
sheep/goat	31	23.1	56.4
horse	10	7.4	18.2
cow	9	6.7	16.3
dog	3	2.2	5.5
deer	1	0.7	1.8
pig	1	0.7	1.8
subtotal	55	–	100.0
large mammal	37	27.6	–
medium mammal	40	29.8	–
total	134	100.0	–

NISP = number of identified specimens

bones (including rib and vertebrae which would balance the second-class bones), the evidence suggests that this is a classic primary waste deposit from a meat-maximising husbandry regime.

4.3.5.2 Horse

The horse assemblage was similar to that of cow; 9 of the 10 identified bones were second-class meat bones, including 2 skulls and 2 stray teeth. The presence of 2 foot-bones can be taken to confirm a primary butchery context.

The skulls in Area 54 contexts 2367 and 2370 are more mature than the cow examples.

Two metacarpals yielded metrical data: lengths (GL) of 246mm and 253mm, implying a withers height (using Kiesewalter factors – see von den Driesch and Boesneck 1974) of 1.58m and 1.63m respectively (*c* 16 hands). The horses would have been of medium size (a pony is defined as 10 hands); in contrast, those found at Rumney Great Wharf were much smaller (possibly pack horses; Hamilton-Dyer 1994, 199–200).

4.3.5.3 Sheep/goat

The sheep/goat assemblage is dominated by second-class bones (22); only 9 first-class bones were present. The age data from the 3 mandibles recovered (each showing deciduous dentition being replaced by permanent molars) suggests an age at slaughter of 12 to 18 months. This pattern is usually interpreted as a meat-maximising husbandry regime.

4.3.5.4 Other species

The presence of a pig skull and deer mandible is to be expected.

The dog bones from Area 54 context 2380 may have come from a single individual. The bones are gracile; the skull between the supra-orbital tori is vascular with a thin (and in some places absent) periosteal surface. This may be an example of an osteoporotic condition, osteogenesis imperfecta, or (as Baker and Brothwell prefer) nutritional secondary hyperparathyroidism; the condition is typically the result of an all-meat diet with little or no milk (Baker and Brothwell 1980, 52–3). It is not fatal, but the resulting bone weakness makes the animal liable to traumatic fracture and bone distortion. Noddle (1983, 62–3) reports a bow-legged lap-dog from Caerwent, perhaps another example.

4.3.6 Comparison with other sites

There have been few other animal bone assemblages reported from the area (Caseldine 1990, 85–6) and it is, therefore, difficult to assess whether the Barland's Farm collection is unusual.

An identified assemblage of over 1000 bones from Caerwent (Noddle 1983) included many cattle and horse and few sheep; unusually, however, dog was the most common species, suggesting that the depositional context was not domestic food waste.

The bones from the Fortress baths site, Caerleon, were also generally cattle-dominated, although there is an increase in sheep in the 4th century (notably the assemblage from the *frigidarium* drain (O'Connor 1986, 234).

The most directly comparable assemblage is that from the excavations of the field system at Rumney Great Wharf (Hamilton-Dyer 1994), where over 400 bones were found, mainly sheep/goat and horse.

4.3.7 Discussion

The small assemblage from Barland's Farm contains few surprises: a late Roman site would be expected to have sheep and cattle predominating and the other domesticates present in small numbers. Some interesting points emerge from the analysis, however.

The bones in general reflect an origin in primary butchery (the jointing of the carcass immediately after slaughter); it may be that the assemblage was produced by consumption at a local site, but it is also possible that meat was being processed for transport and sale elsewhere, perhaps in a salted condition. This pattern has been noted on the other side of the Estuary (Bell 1984, 84).

The age structure of the cattle could be taken to imply husbandry for meat production rather than dairying, in contrast to the population found at Caerleon in the 3rd century (O'Connor 1986, 236).

This pattern would support a model for exploitation of the Levels as a pastoral hinterland for the urban settlements at Caerleon and Caerwent, producing meat carcasses for consumption in the towns. Although this model is appealing and logical, the assemblage is far too small for firm conclusions and the shift in bone representation in 3rd- and 4th-century Caerleon to include primary butchery waste within the town (O'Connor op cit) suggests that it may be too sweeping.

4.4 Bird bone, by M Locock

4.4.1 Catalogue

54/2380 Anas-type (cf mallard) coracoid (95%).

4.4.2 Discussion

The presence of waterfowl in the assemblage is to be expected; perhaps more interesting is the absence of domestic fowl, common on most settlement sites.

4.5 Roman Footwear, by C van Driel-Murray

4.5.1 Catalogue (Fig 4.5.1)

Sole dimensions are given as: length/width at tread/ width at tread.

1 (Figs 4.5.2–4.5.5). Fragmented but relatively complete left, front-laced shoe with highly decorative nailing pattern set out in small, neat nails. Insole with heel stiffener sewn in position, two laminae thonged to under surface and a reinforcement strip laid along the outside edge. Lasting margins of the goatskin upper drawn around the laminae and partially thonged to them. Outer sole sewn with tunnel stitch to this unit. The upper is cut in one piece and joined by a side seam. Vamp slit folded back and whipped down to the inside, some felling stitches at the bottom of the slit suggestive of a cord reinforcement at this point. At least six lace holes are punched through the fold and impressions of a horizontal lace pass between them. Records made at the time of finding show additional fragments of the outside vamp as well as pieces of the inside quarter, suggesting that originally there were some eight or nine lace holes. A welt raised by

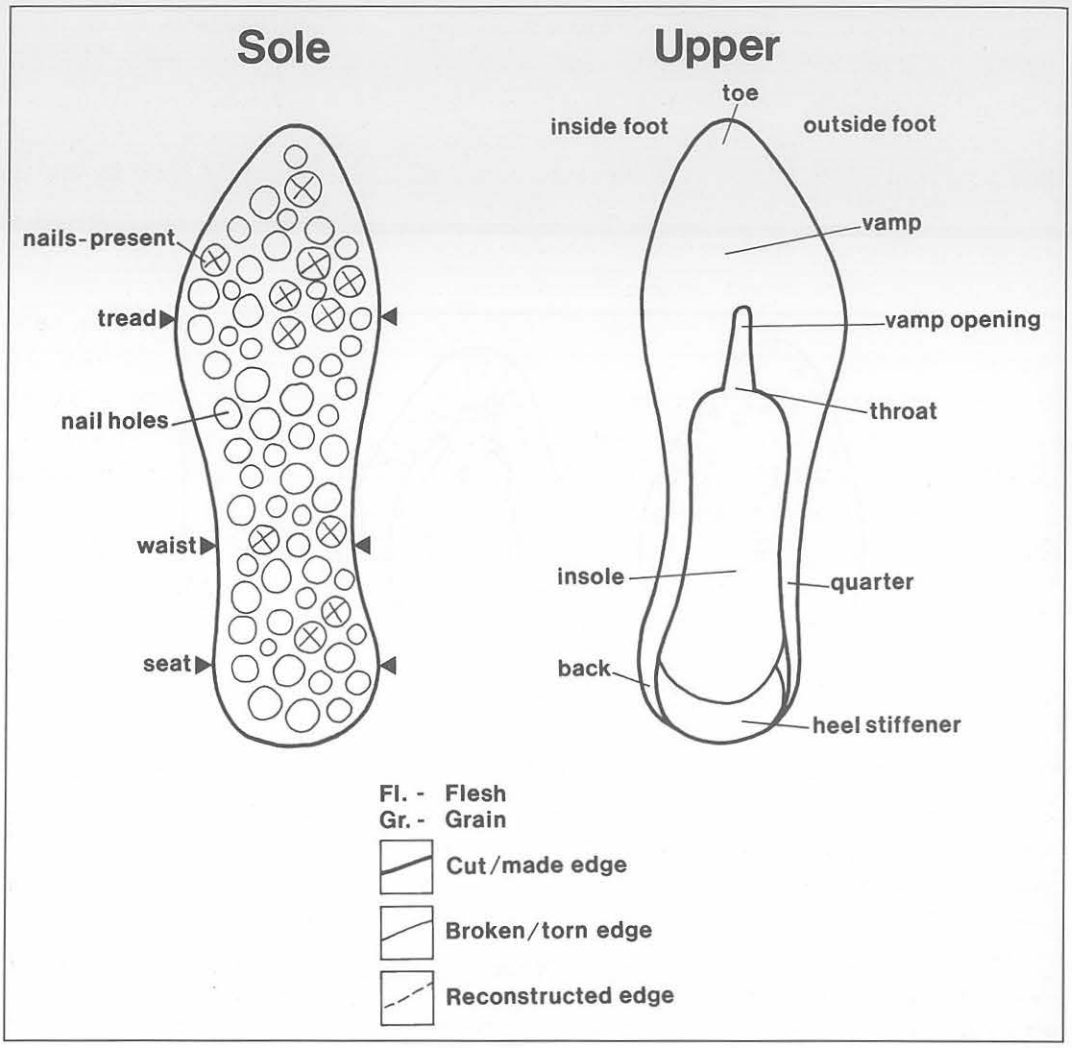


Figure 4.5.1
Legend for shoe illustrations.

decorative saddle stitch continues from the bottom of the vamp slit down to the toe. The vamp is heavily creased by use.

Context 2360, find 001. Outer sole: 276/90/59/70mm; insole: 270/86/55/66mm.

2 (Figs 4.5.6 and 4.5.7). Virtually complete left adult's shoe, upper in a very fragile condition. Insole with thonging of the laminae visible down length. Though originally heavily nailed (head diameter 9mm), outer sole severely worn: nails worn down to shafts and leather worn right through at seat, tread, and toe, necessitating the insertion of two or more pieces of leather (offcuts?) under the tread. These are held by large-headed replacement nails (head diameter 14mm). Two cuts on the insole may have something to do with this repair. Cowhide upper. The laboratory drawing shows it substantially more complete, with two pairs of eyelets present and the back of the upper crumpled down, but originally reaching above the ankle. The vamp is cut straight over the instep and there is probably a side seam, though the relevant fragments are now no longer *in situ.* When found, a thin thong was still knotted around one of the eyelets.

Context 2381, find 007. Outer sole: 273/105/80/77mm; insole: (246)/88/57/60mm

3 Decayed left bottom unit, nailed, adult in size. Remnants of insole with two pear-shaped laminae thonged down length, outer sole, heel stiffener and flakes of the lasting margin present. The laboratory drawing shows a more complete situation than now exists. Nailing pattern indistinguishable due to corrosion, probably a single peripheral row with a line down length of sole. Not illustrated (cf lab drawing).

Context 2381, find 003. Outer sole: (240)/(75)/-/60mm

4 (Figs 4.5.8 and 4.5.9). The find includes a toe from 003. Substantially complete left shoe, nailed, heel stiffener, two narrow laminae attached to insole by two separate thongs arranged in a diamond pattern, lasting margins whipped to the laminae in places, outer sole sewn to this unit with tunnel stitch. Surface of the

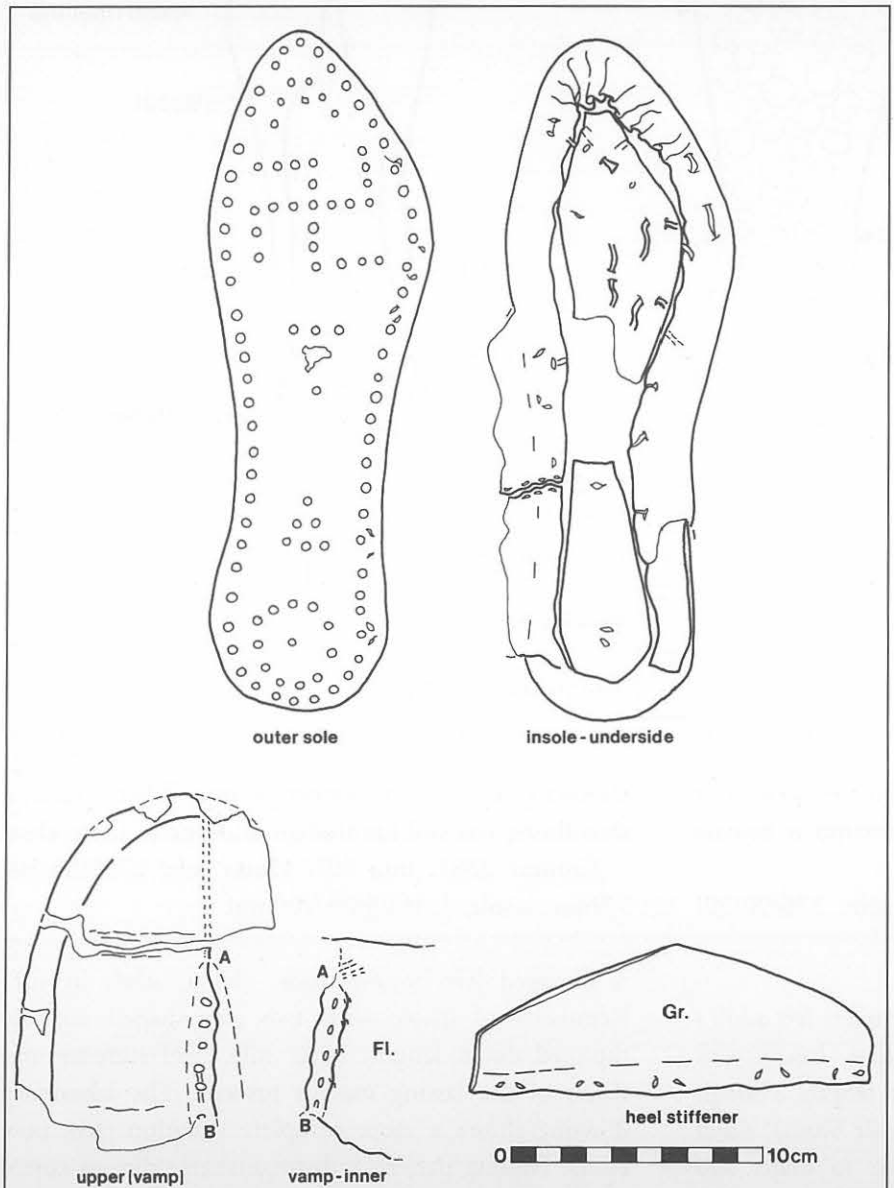


Figure 4.5.2 Shoe no.1: outer sole, insole from below showing laminae, surviving lasting margins, side seam and remnants of thong, surviving fragments of the vamp from outer (grain) side and from the inner (flesh side) to show stiched-down fold.

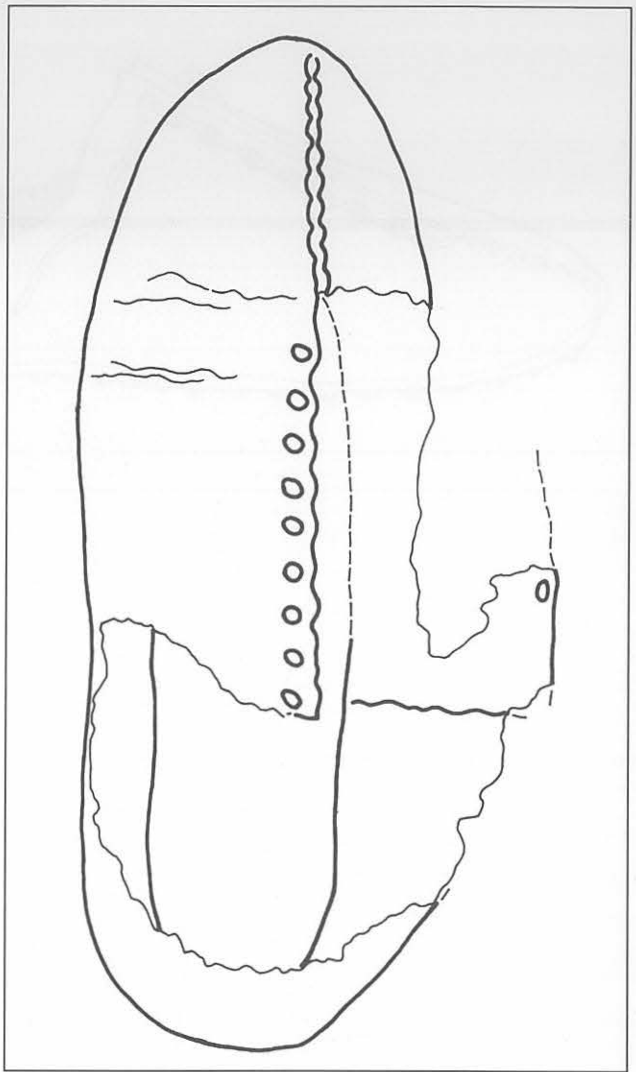


Figure 4.5.3
Sketch of shoe no.1 as found reconstructed from original documentation.

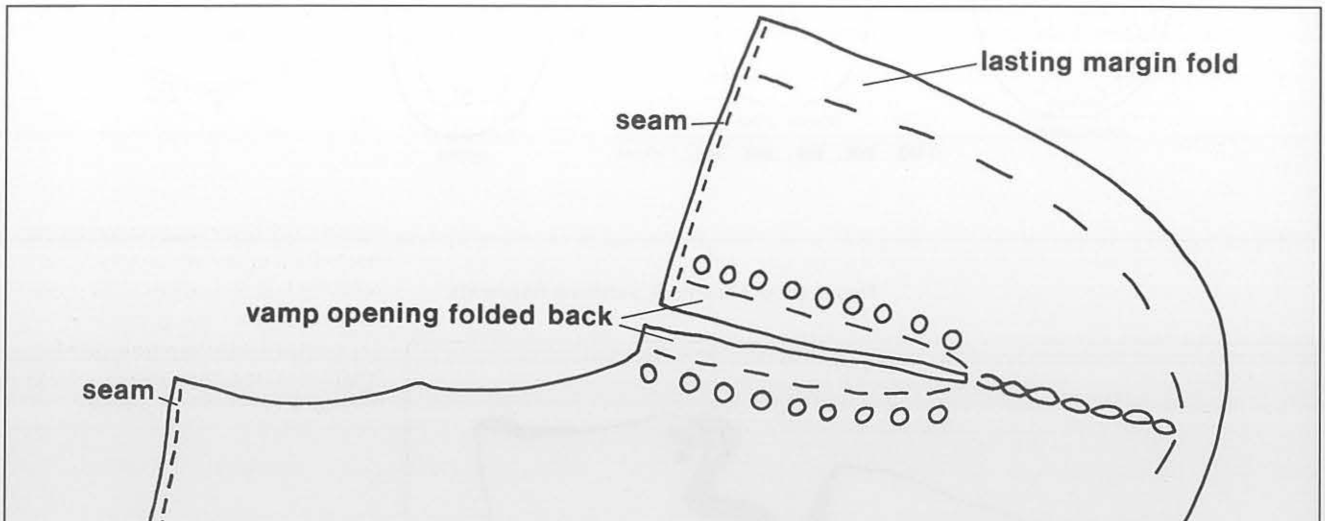


Figure 4.5.4 Suggested cutting pattern for shoe no.1.

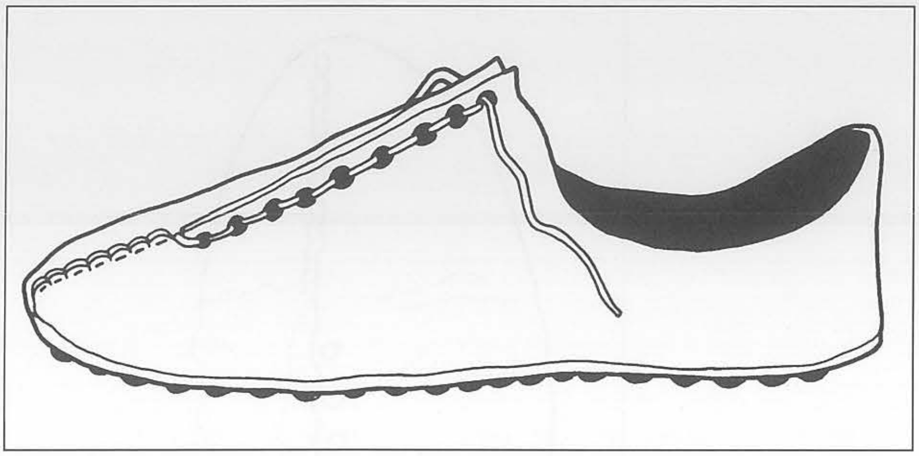


Figure 4.5.5
Reconstruction of shoe no.1.

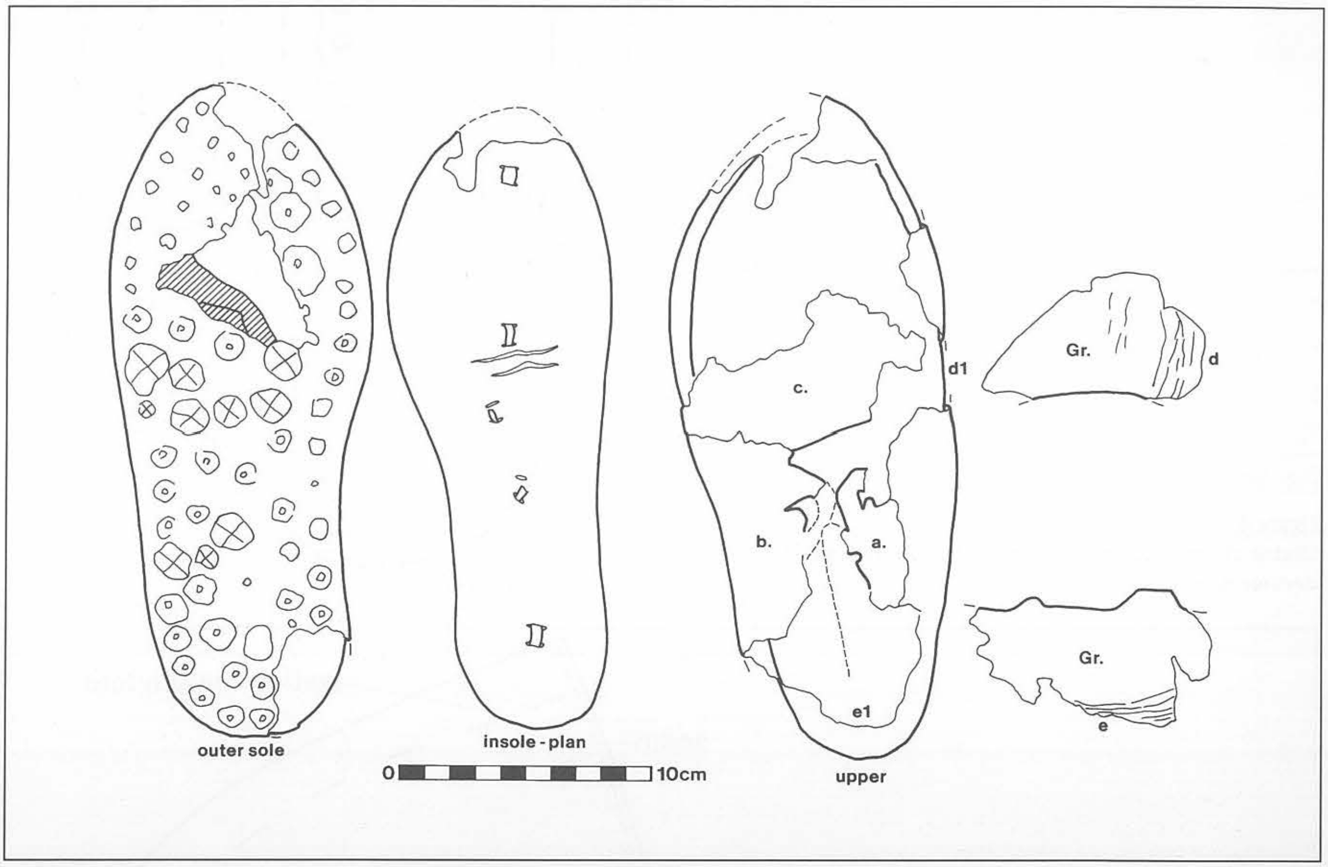


Figure 4.5.6 Shoe no.2, surviving fragments.

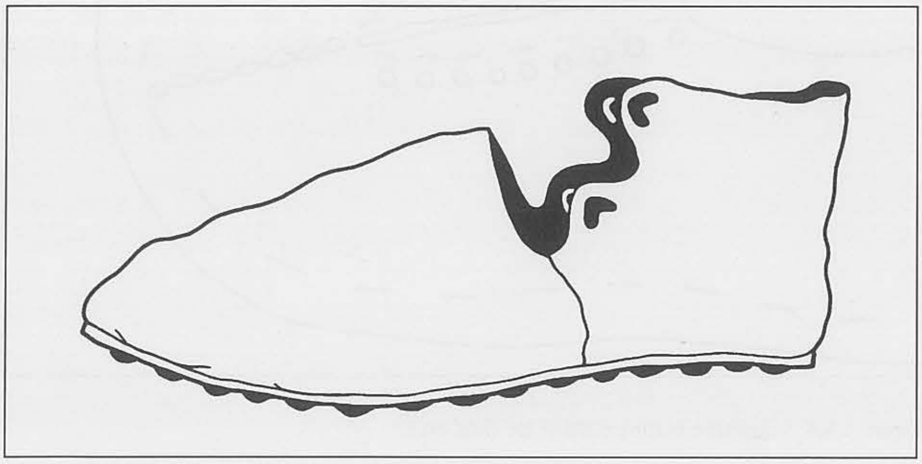


Figure 4.5.7
Reconstruction of shoe no.2.

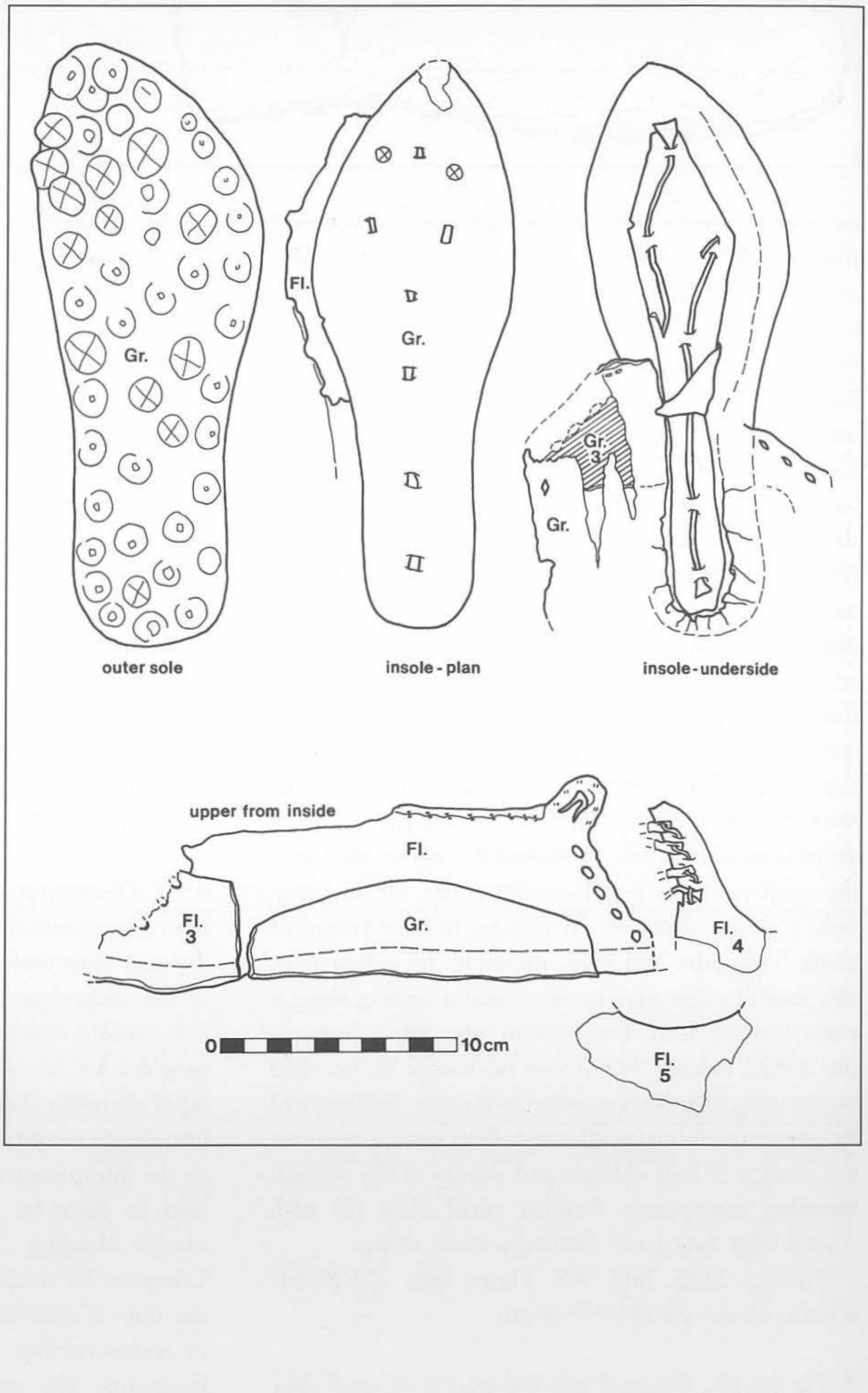


Figure 4.5.8
Surviving fragments of shoe no.4: outer sole, insole, insole from below with upper folded out to show tearing and position of repairs, surviving parts of quarter from inside, and (4 and 5) fragments from vamp.

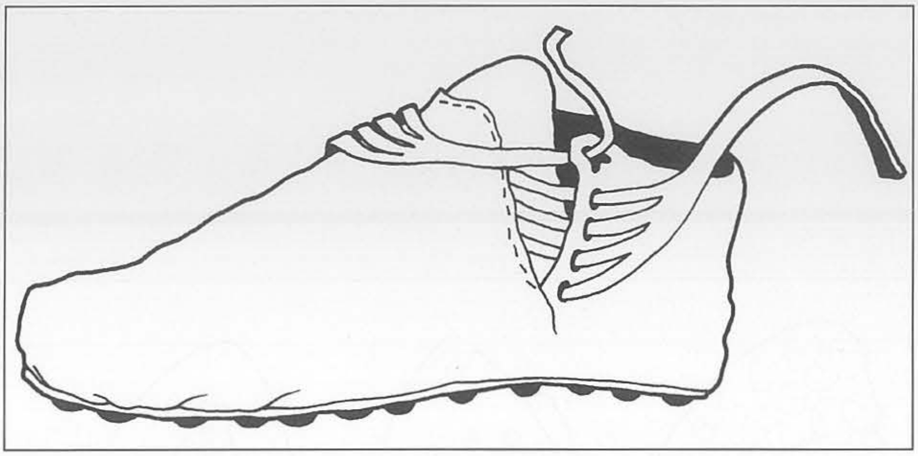


Figure 4.5.9
Reconstruction of shoe no.4.

outer sole is worn down to the nail shafts. Two small nails struck into the insole at the front, perhaps to secure repairs in the toe area, where at least four large-headed replacement nails have been inserted on the outside. The laboratory drawing shows scraps of the vamp remaining, but these are now gone, save for some remnants of the lasting margin. Quarters present, top edge folded in and whipped down. There is a side seam at the inside waist, but as the opposite side is damaged, it is unclear whether the vamp was separate from the quarter or whether the upper was cut in a single piece. Front closing boot, with projecting eyelet strengthened by a cord whipped round the inside edge and four (possibly five) lace holes below. The inside foot area is damaged and was repaired by an additional strip (3) carrying replacement lace holes. A scrap of the side seam remains, not the usual butt seam, but sewn through the folded edge of the two layers – again an indication of repair. A makeshift hole stabbed into the quarter may be a replacement eyelet. Of the vamp only a strip remains (4). It appears to have cut edges along both sides and may, therefore, be a lining, or the smooth edges may be the effect of tearing along a natural crease line. The bottom edge curls down to the lasting margin, but it can no longer be matched to surviving fragments attached to the sole. Still trapped by serpentine thonging (through flesh surface only) are the stumps of four delaminated thongs of the original fastening mechanism. Another small piece (5) with curved edge may come from the vamp throat.

Context 2393, find 009. Outer sole: 253/96/64/65mm; insole: 237/85/47/46mm

5 (Fig 4.5.10). Decayed seat and quarter of small shoe with thonged construction. Front missing as is outer sole. Insole of thick, smooth, relatively unworn cowhide, with irregular stitch holes around edge and a wide leather thong passing from the under surface (flesh) through the thickness of the sole to the edge. This is presumably the starting end of the thong used to sew all the elements of the shoe together. Cowhide heel stiffener, raised at the back, still partially attached to the lower part of the quarter and with a few flakes of the outer sole entrapped under the thonging. The quarter (smoothed calfskin?) is totally fragmented, but has a side seam, a peaked back, and a cusped top edge. It is richly decorated with openwork circles, squares, small triangles, impressed lines and swags, and stamped roundels. A crudely sewn side seam remains (butt-seam), probably sewn with twine or gut as the sewing material has decayed. Besides a large number of fragments of the upper, some flakes of the lasting margin remain, as does a larger flake (d) with various creases and indistinct impressions, which may come from the outer sole.

Context 2380, find 006. Insole: (105)/-/38/36mm

4.5.2 Discussion

Four recognisable shoes and a sole were recovered from deposits surrounding the boat. Though crucial parts of the shoe uppers have decayed and identification is not entirely certain, this group from Barland's Farm provides an interesting association of three different types of footwear current in the early 4th century. The immediate recording of these fragile finds was crucial to the interpretation, as parts of the uppers were only held in place by the underlying mud and did not survive cleaning. The author is grateful to Mrs J Compton for sending her colour photographs made at the time of excavation. These proved to be invaluable in reconstructing the original position of separated fragments. She was, however, unable to check the footwear again and the archive drawings, therefore, do not take account of the new information, although the reconstructions do.

Four of the shoes are of the standard Roman multi-

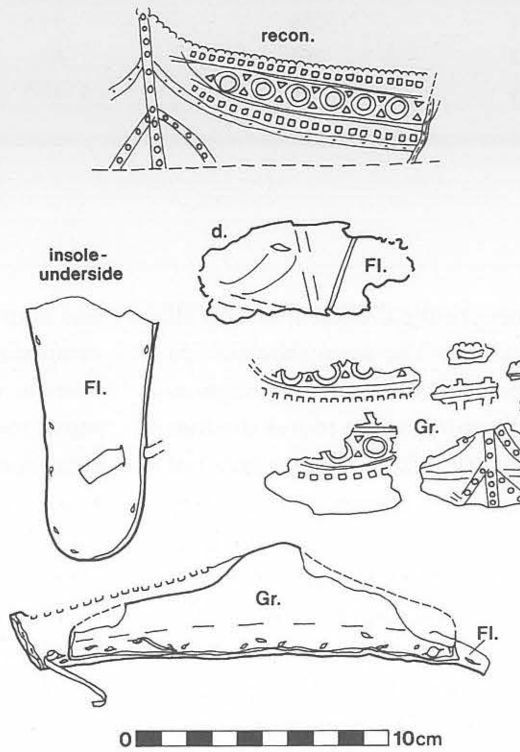


Figure 4.5.10
Surviving fragments of shoe no.5: largest portion of the quarter from flesh side; reconstruction of decorated quarter.

layer nailed construction and separation of the sole components reveals certain constructional details that are probably common to them all. In all cases the upper appears to have been cut as a single piece joined by a side seam. The edges of the upper (lasting margins) were braced over the insole, with the laminae thonged into position to fill the central gap. The lasting margins were smoothed down round the laminae by odd stitches (particularly noticeable in no. 1 below). After roughly securing the outer sole by means of cord or gut, leaving long tunnels on the inside of the outer sole and impressions of tacking on the lasting margins, the shoe would be transferred to an iron 'anvil' where the nails were struck in.

Both no. 2 and no. 4 are quite densely nailed, the pattern, if any, obscured by repair nailing. No. 3 appears to be more sparsely nailed, with a line around the edges and some studs down the centre. In contrast no. 1 is carefully and neatly nailed with small studs arranged in a series of elaborate patterns. An almost identical arrangement occurs on a pair of shoes accompanying a 4th-century burial from Kaiseraugst, Switzerland (Laur-Belart 1952, 98, Abb 28). Though circles and other patterns are common on footwear of all periods, swastika nailing seems to be confined to the late 3rd and the 4th centuries, occurring on both shoes and sandals either under the tread or the seat (from Mainz (Göpfrich 1986, Abb 44 no 101, Abb 45, 110) and unpublished examples from London). Since swastika and circle are solar symbols, such designs probably had a protective function (van Driel-Murray 1999b). As is to be expected in tracing out complex patterns, the studs of these shoes tend to be smaller, with a head diameter of 5–6mm as against the more usual 9–12mm domed heads. The iron used for the small nails also appears to be of better quality and these rarely wear down to the shapeless flattened mass that is a common feature on footwear of this period. The shapely, mildly pointed sole of no. 1 also accords with the greater care expended on this shoe and is again paralleled by the soles from Kaiseraugst. More typical of the period are the thick-waisted, rather blunt-nosed soles of the other three shoes in the group. Those from Barland's Farm do not display the almost straight sides nor the excessively rounded toes of 4th-century footwear from, for example, Usk (van Driel-Murray 1995, fig 35, from a well-dated context of the mid-4th century), Dalton Parlours (Mould 1990), or York (MacGregor 1978 figs 27–9), perhaps pointing to a date nearer the turn of the century.

Table 4.5.1 Foot lengths of Barland's Farm shoes

	Length (m)	*Continental size*	*British size*
no. 4	235	35.5	3
no. 2	265	40	6.5
no. 1	270	40.5	7

Curiously all four shoes are for the left foot and all are adult in size (Table 4.5.1). The sewn shoe (no. 5) is also left, for a smaller foot than no. 4, though as sewn footwear tends to fit more snugly round the foot than the rigid nailed shoes, the size difference may not actually have been very great. In Roman contexts, foot sizes of continental size 35 and above can, on aggregate, be considered as adult male, though in individual cases (such as the small group here) 'sexing' remains problematic. No allowance for shrinkage has been made here, as it is the author's experience that leather expands under waterlogged conditions. The professional conservation now in use restores it to more or less its original size (van Driel-Murray 1987).

Severe wear of the shoes, compounded by decay and general fragility, hampers the reconstruction of the uppers. Comparative material is relatively rare and the considerable individuality of footwear at this period also means that the solutions offered here are no more than working suggestions that are likely to be modified as more complexes become available.

Since only part of the vamp of no. 1 remains the reconstruction is speculative. Photographs taken at the time of discovery and the conservation record drawings indicate the presence of an additional fragment with two or three lace holes at the outside waist, as well as a large fragment of the inside quarter which extends right round the heel stiffener and has since separated (Fig 4.5.3). All these pieces were crumpled and displaced. None now remains in recognisable form, making it difficult to assess the original disposition or dimensions. On one of the photographs, the side seam is faintly visible and would seem then to have been at least 80mm high. An inside seam of this height would reach over the instep comfortably, but as it is also set very far back, it would not allow for ankle movement. It is, therefore, unlikely that a boot is concerned. Six lace holes remain and, with the two or three additional ones, would make for a shoe closing high over the instep, the quarters cut just under the ankle (Fig. 4.5.5). The horizontal lace impressions indicate that the shoe was entirely closed over the foot, with the edge of the vamp slit standing out slightly as a comb, a decorative element that is continued in the raised welt down the vamp toe. This welt is in fact also a memory of the vamp seam that was a common feature of earlier Roman footwear. Front-laced shoes and boots of this and related types begin to appear in the early 3rd century (Saalburg (Busch 1965, Taf 15, no 222) continuing well into the 4th (late contexts at Vindolanda and London, unpublished; York (MacGregor 1978, fig 27, no. 350) and (Göpfrich 1986, no. 91) Mainz). The height of the leg varies: that of the Saalburg example is exceptionally high. Elsewhere they usually close round the ankle with one or two pairs of eyelets, but the example from Mainz fastens just below the ankle and thus accords best with the evidence of the fragments belonging to no. 1.

Though substantially complete, boot no. 2 remains problematical since critical areas have decayed beyond recognition. Colour photographs taken at the time of excavation, however, reveal that most of the back was originally in place, but crumpled down and supported solely by the encasing mud: taken with the two eyelets, this suggests a boot closing just above the ankle, with two crescentic eyelets through which a separate, leather lace was knotted (Figs 4.5.6 and 4.5.7). A rather similar shoe comes from Gloucester (Goudge 1983, no. 7) and is dated to the 4th century. The surviving fragment *e* with its projecting tab, is probably the centre back. On the colour photograph, two overlapping fragments of the vamp could be discerned (fragments *c* and *d*) which probably fit to make a plain, triangular vamp, cut quite high over the instep and possibly requiring a tongue, though the condition of the surviving pieces is too poor for any stitching to be recognised. The upper is cut in one piece, probably with a seam at the inside foot, though this area is now missing. The shoe was very severely worn. The iron nails had been worn away in many places and elsewhere the heads had become flat and shapeless, though the shoe continued to be used till the leather of the seat and tread had also worn through. The hole was repaired by inserting a couple of cowhide offcuts which were secured by a number of irregularly placed, soft iron nails which are still in place.

No. 4 is the most complete of the shoes and in many ways the most interesting on account of its remarkably complex fastening method, one which is attested from the end of the 2nd century and which survives in Egypt (the only place where complexes of this date occur) till at least the 5th century. Essentially it is a boot with a high triangular vamp that is pulled up by a divided lace sewn to the vamp edge passing through a series of holes in the quarter (Fig 4.5.8). The torn ends of the lace still survive, thonged to a strip of leather that probably forms an internal reinforcement to the vamp (otherwise stitching of the tongue would be expected). The shoe is in poor condition and had been repaired in antiquity: a new panel was inserted at the side to replace torn-out lace holes. This would have required the renailing of part of the sole and which accounts for a group of large, flat-headed nails at the side and front of the sole. There were clearly also problems at the (now missing) vamp end and two nails were struck in from the inside of the shoe, probably to compensate for worn constructional sewing and torn lasting margins. Though the exact details are not entirely clear, a general reconstruction of the original appearance of the shoe can be offered on the basis of more complete examples from elsewhere. A spectacular example comes from a burial at Southfleet (BM 1922, fig 54) and others are known from Welzheim, Germany (van Driel-Murray 1999a), Vindolanda, and London (unpublished).

The fourth shoe (no. 5), though also made with the usual multi-layer construction, was not nailed but sewn using thin leather thong. From the position of surviving thongs it would seem that all the components were sewn together in one go. The upper with its elaborate openwork patterning has disintegrated, leaving no indication of the type or arrangement of either vamp or fastenings. What remains of the heel stiffener and the quarters suggests that the back rises to a point, a feature popular with sewn and especially single-piece *carbatinae* of the 4th century (London, Dowgate, and Vindolanda, unpublished). Such shoes are usually accompanied by a low-cut vamp and an ankle strap. The area of the foot exposed and the elaborate openwork are suggestive of use with (coloured?) hose.

These four shoes fit well into what can be expected in late 3rd- and early 4th-century contexts. The high closing vamps, side seams, wide, blunt sole shapes, and considerable variety in the treatment of uppers are all characteristic of the period, though continuing earlier styles and traditions. Illustrative is the retention of the vamp seam, characteristic of Roman footwear of the 2nd and 3rd centuries, as a decorative feature on no. 1 (other examples occur in Mainz (Göpfrich 1986, no 91) London, and Vindolanda, unpublished). A parallel trend, also illustrated by the shoes from York (MacGregor 1978 figs 27–9), is represented by the sewn shoe, no. 5. These relatively flimsy shoes, which occur in nailed, sewn, and even single-piece versions, are low cut exposing much of the foot, with a light fastening at the ankle. Such footwear introduces a number of new elements, foremost of which is technological simplification, coupled with the elaboration of surface treatment. In view of the lack of closely dated leather complexes for this period, it is not possible to draw any conclusions from the stratigraphic positions of the shoes. There is no reason, however, to suspect a long gap between the deposition of the first shoe (no. 4) and the last (no. 1). The shoes are too few in number to represent general settlement rubbish and more individual circumstances may account for their presence in and around the boat. On the other hand, the shoes are all so severely worn that there can be no question but that they were discarded as useless. The absence of two shoe types common enough in other complexes of the period – sandals and single-piece *carbatinae* – is noteworthy, but hardly significant in so small a group. Perhaps the most remarkable fact is that all the footwear is in the mainstream tradition of Roman footwear reflecting styles being worn throughout the Empire, from Hadrian's Wall to Egypt, thus once more reinforcing the essential unity of clothing styles in the provinces.

4.6 Coins, by R Hudson

Two coins were recovered from the immediate area of the boat as follows:

1 2392 (005) AE *ant.* Carausius 'RSR' mint *c* 287/8; legends blundered. Near RIC 598.

Obv. IMP CARAUSIUS PF AVG, rad. Dr. and cuir. Bust r.

Rev. ADVENTUS AUG emperor on horseback left with right hand raised and holding sceptre in left; captive below right forefoot of horse.

2 2392 (008) AE *follis* Diocletian Trier mint 296/7. RIC 181a.

Obv. IMP DIOCLETIANUS P AVG, laur. hd. r.

Rev. GENIO POPVLI ROMANI Genius standing left holding patera and cornucopia.

The slight degree of wear on the Diocletianic issue would indicate a date of loss within the first decade of the 4th century at least for this coin if not for both.

5

ROMAN SETTLEMENT AND ECONOMY

by A G Marvell

5.1 Introduction (Fig 5.1)

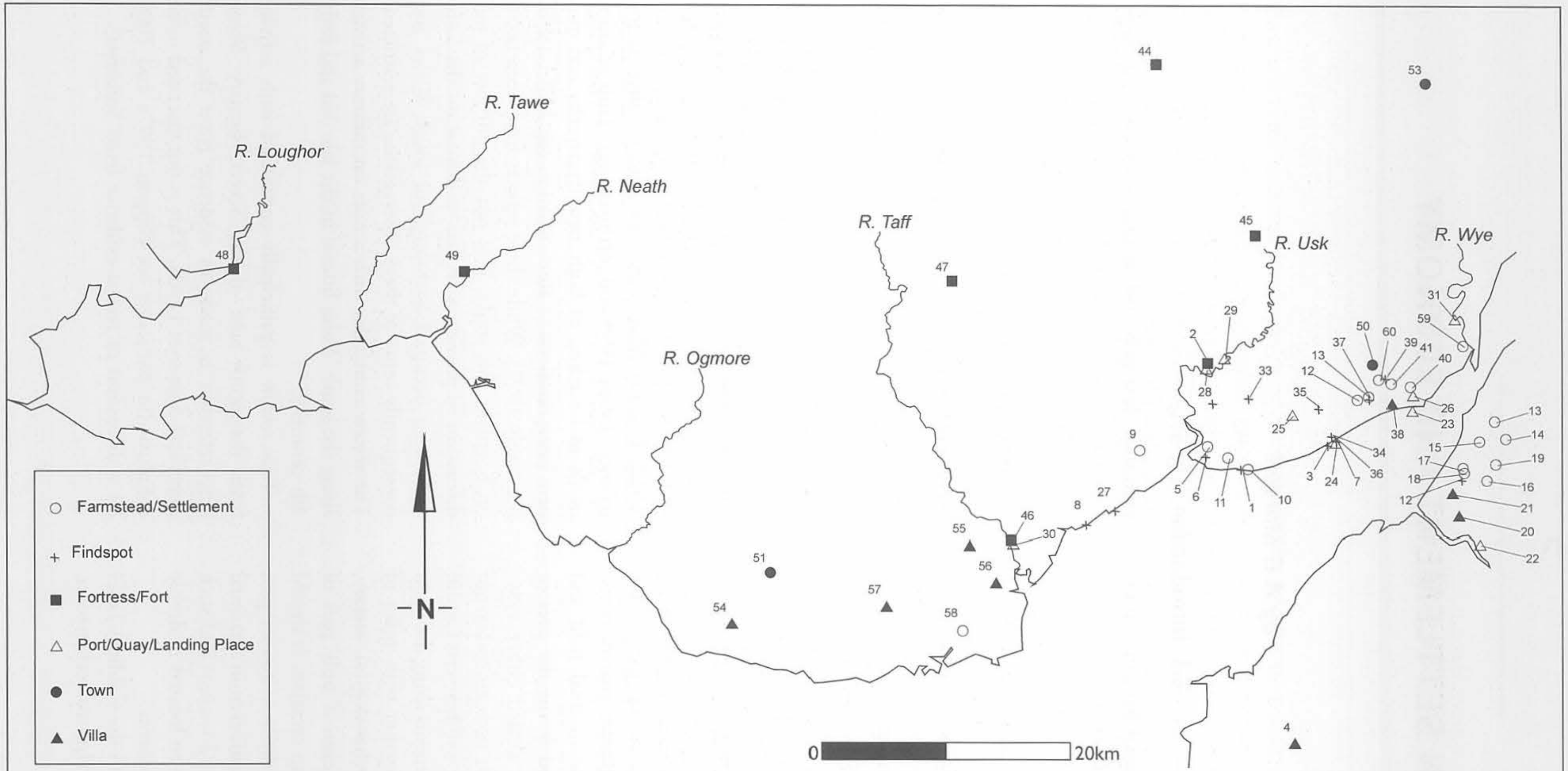
In considering the local and regional Roman context for the Barland's Farm vessel there are two key issues that need to be discussed in some detail: first the physical nature of the Gwent Levels in the Roman period; and secondly the form and extent of occupation within them and in the immediate hinterland.

To aid this discussion the results are available in both published and 'grey literature' from the expansion in archaeological exploration and research that has occurred on both sides of the Severn Estuary since the early 1980s. This has led to different, although sometimes only slightly modulated views on the nature of the Severn Levels in the Roman period. At the core of one position rest arguments that the Gwent Levels were the subject of an organised reclamation (Allen and Fulford 1986; Fulford *et al* 1994). A refinement of the argument is that only the central part of the Wentlooge Level avoided a post-Roman marine transgression with the result that the original field and drainage pattern has survived and forms the present landscape. This writer has never shared either viewpoint, not least for the reason that such an endeavour involving the construction of a sea wall between Cardiff and Caldicot with further embankments along the main rivers (Taff, Ebbw, and Usk), together with miles of drainage, has left no trace in the archaeological, literary, or epigraphic record. Moreover even if only part of the present landscape was a Roman creation, it should be expected that some traces of the activities of past occupants would have been identified, even in a pastoral environment. By contrast the record is silent and such sites that have been found have been located in deeply buried or severely eroded environments.

Recent discoveries particularly in the Caldicot Level suggest the presence of localised Roman reclamation, with sites close to buried natural watercourses (palaeochannels), rather than an ordered drainage grid forced upon the landscape. In the light of this the evidence for the claims advanced by Allen, Fulford, and Rippon has been reexamined. This together with a short description of the sites recently discovered and the implications for the form of the Gwent Levels in the Roman Period forms the first part of this chapter.

The second half of the chapter principally reviews the socio-economic environment within which our vessel would have operated. This includes consideration of fen-edge settlement, ports, quays, and other landing places, land exploitation, Romanisation, and economy and trade. There have been no complete overviews of south Wales in the Roman period since Webster (1984) and Robinson (1988), although a study for Cadw: Welsh Historic Monuments has partly redressed the balance (Evans 1999 and forthcoming). Thus account needs to be taken of both new discoveries and also new interpretations of Romanisation (eg Millet 1990; Mattingly 1997). While these aspects have been taken on board in this study, it is not the purpose of our discussion to provide a revised statement on the form of Roman occupation throughout south Wales and consequently some of these observations are restricted. The review concludes with a note on military activity along the south Wales littoral in the late 3rd and early 4th centuries.

This review is principally concerned with activity from the north side of the Severn Estuary. Some cross-reference is made to evidence from the north Avon and Somerset Levels. This is not intended to be definitive (in particular see Rippon 1997a and 2000 for a discussion of recent evidence from Somerset).



1 Goldcliff
2 Caerleon
3 Cold Harbour Pill
4 Wemberham Villa
5 Nash
6 Uskmouth
7 Magor Pill
8 Rumney Great Wharf
9 Great Pencarn Farm
10 Hill Farm, Goldcliff
11 Saltmarsh
12 Crooks Marsh
13 Redham Lane, Northwick
14 Rookery Farm
15 Ellinghurst Farm
16 Elmington Farm
17 Seabank Power Cable
18 N of Crooks Marsh Farm
19 Farm Lane
20 Kingsweston
21 Lawrence Weston
22 Sea Mills
23 Sudbrook
24 Magor Pill
25 Barland's Farm
26 Portskewett
27 Peterstone Gout
28 Caerleon Quay
29 Bulmore
30 Cardiff
31 Chepstow
32 Thompson's Farm
33 Llanwern
34 Undy
35 Magor
36 West End Farm, Undy
37 Ifton Village
38 Stoop Hill
39 Caldicott
40 Portskewett
41 Church Farm, Caldicott
42 Rogiet
43 Ifton
44 Abergavenny
45 Usk
46 Cardiff
47 Gelligaer
48 Loughor
49 Neath
50 Caerwent
51 Cowbridge
52 Abergavenny
53 Monmouth
54 Llantwit Major
55 Ely
56 Llandough
57 Whitton
58 Biglis
59 Thornwell
60 Caldicott

Figure 5.1 Map (with key) showing sites discussed. Derived from Ordnance Survey 1:50,000 sheets 170, 171, and 172. Crown Copyright.

5.2 Previous observations on Roman activity in the Gwent Levels

A Roman presence in the Gwent Levels was first indicated by the discovery of the Goldcliff Stone in 1878 (Morgan 1882, 1; Collingwood and Wright, 395); the stone records building work carried out by *Legio Secunda Augusta* based at Caerleon. Its location close to the present sea defences led to suggestions, first made by Morgan (1882, 7), that these had a Roman origin – a myth that inevitably became received fact. Thus when 2nd-century pottery and other finds were recovered in 1950 from the foreshore close to Cold Harbour Pill, Nash-Williams (1951, 254) suggested that this evidence represented a 'place where a legionary working-party established a temporary camping site while engaged on coast defence work in this area'. On the other side of the estuary the discovery of the Wemberham Villa in the north Somerset levels had led to similar claims that the sea defences ('embankments') there must be Roman in origin (Scarth 1886). As Knight (1962) first showed, however, Morgan's description (second-hand – he was not present at the actual finding and removal; 1882, 13–14) of the location of the Goldcliff stone did not support the contention that the sea defences were a Roman construction. Boon (1980, 28), while rightly pointing out that the inscription need allude to no more than the building of 'an embanked natural watercourse', thought it must be commemorating military rather than civilian activity, perhaps connected with a boundary 'between the legionary lands and those of the neighbouring Silurian *civitas*'.

Although Boon (1980) only had the data arising from chance discoveries at his disposal, he was sufficiently astute to recognise that the nature of this material indicated varied exploitation of the Levels. Thus the presence of military and civilian activity could be detected. Although pastoral land-use was clearly dominant, evidence for arable cultivation had also been found, particularly in north Somerset (Boon 1980, 26–7).

Somewhat at a tangent to the occasional archaeological discovery, geomorphologists had advanced arguments for and against a late/post-Roman transgression on the Severn Levels. Godwin (1943) had initially argued for the transgression, partly on the basis of the depth at which artefacts were being recovered, a viewpoint supported by Locke (1970) in his assessment of the Caldicot Level, although he recognised that he was not dealing with stratified material. On the other hand Hawkins (1971), writing with particular reference to the Somerset Levels, noted that many of the Romano-British artefacts were found at a relatively shallow depth of 0.2–0.6m. Consequently he suggested that the material found at a greater depth had either been disposed of or been washed into natural channels and gullies. Hawkins took the view that the condition of the Levels was intermediate between mud-flat and salt-marsh and thus unsuitable for cultivation, with exploitation restricted to the summer months. This viewpoint was rejected by Boon (1980, 26), as it was clearly not supported by available archaeological evidence.

Whereas the numerous findspots on the Somerset Levels had permitted the plotting of a settlement pattern, which is gradually being further explored through more extensive fieldwork, survey, and palaeoenvironmental analysis (Rippon 1997a; 2000), the extent of Roman exploitation on the north Avon, Caldicot, and Wentlooge Levels was less well known. On the Gwent Levels evidence was restricted to findspots at Goldcliff (Morgan 1882; Bell 1994), Nash (Jarvis and Webster 1991), Uskmouth (Barnett 1961; Jarvis and Webster 1991), and Magor Pill (Nash-Williams 1951) on the Caldicot Level and Rumney Great Wharf on the Wentlooge Level (Boon 1980, 26). Some fen-edge settlement was known along the Caldicot Level (Rippon 1996a, 34–5), but none had been found along the Wentlooge Level.

5.3 The Roman landscape – relict or buried?

Survey in the early 1980s on the foreshore and eroding mud cliff at Rumney Great Wharf at the west end of the Wentlooge Level resulted in the discovery of ditches 'associated with Romano-British pottery and other occupation debris' (Allen and Fulford 1986, 112–13). The excavators noted these features had a 'striking similarity in morphology and alignment . . . with those of trapezoidal section and rectangular plan behind the present sea defence' and this led them to conclude that 'the Wentlooge Level was systematically drained in the Roman period, and that many, if not all, of the rectangular-type ditch systems were originally cut in the Roman period'.

Subsequently extensive evaluation work was carried out behind the sea defences at Rumney Great Wharf for the Cardiff Bay Development Corporation on a site (0.5 × 0.2km) proposed for development as alternative feeding grounds for birds displaced through the then proposed barrage construction. This work led the excavators (Parkhouse and Parry 1990) to reject Allen and Fulford's hypothesis and suggest instead that the Roman land surface behind the sea wall had been buried. The key evidence for this was found in two of the evaluation trenches (101 and 108). Here two pairs of organic deposits (101 contexts 155 and 158, 108 contexts 286 and 288) separated by alluvial clays were found at a height of 0.4–0.6m above the latest peat formation (*ibid*, 46–8 pls 12 and 13, fig 16). The upper organic bands were described as 'very dark grey clay with (?)humified organic material and small quantities of macroscopic plant remains visible in small quantities throughout' (101/155) and 'dark grey organic clay layer with occasional pockets of peat and some macroscopic plant remains' (108/286). Archaeomagnetic dating carried out by the late Professor Tony Clarke gave dates of *c* 1880 cal BP. for context 108/286 and *c* 2200 cal BP for the lower organic stain 108/288 in the same evaluation trench. As the upper horizon in this trench was found at a height of 4.52m OD and *c* 1.2m below the present ground surface, it was not possible to accept Allen and Fulford's argument for a planned Roman reclamation of the Wentlooge Level. There was, however, no artefactual or other scientific dating evidence to confirm or refute the archaeomagnetic results.

Further fieldwork in the early 1990s led Fulford and others (Fulford *et al* 1994, 209–10) to reject Parkhouse and Parry's evidence and reaffirm, albeit more tentatively, the claim for 'a Romano-British origin of the Wentlooge Level'. While to varying degrees they have come to recognise that much of the Gwent Levels was subject to a late to post-Roman marine transgression, Rippon (1996a and 1997a) and Allen (1996) have continued to advance the claim that the regularly patterned core area around Peterstone is a largely relict Roman landscape. By obvious implication this then provides an example of what the whole of the Gwent Levels would once have looked like in Roman times.

More recent fieldwork in the Caldicot, north Avon, and Somerset Levels (Locock 1996, 1997a, 1997b, 1998a, and 1998b; Locock and Lawler 2000; Yates, 1997and 2000; Rippon 1994, 1995, 1996b, and 1997; Wessex 1994) suggests that there has been a late to post-Roman transgression (Rippon 1997a, 123–7). Thus even if the supposition that the core part of the Wentlooge Level is a relict Romano-British landscape is correct then, with the possible exception of parts of the north Somerset Level, it is isolated by comparison with the remainder of the Levels. It is necessary, therefore, to review this conflicting evidence in some detail if the form of the landscape through which our boat would have passed is to be established.

5.3.1 The Wentlooge Level

5.3.1.1 Rumney Great Wharf

The argument that at least the core part of the Wentlooge Level is a relict Roman landscape rests principally on the extrapolated physical and stratigraphic relationships of ditches mainly visible as features in an eroded mud cliff with the reen (drainage) ditches behind the present sea wall. The upper part of the eroding mud cliff on the foreshore consists of the 1–3m-thick Rumney Formation (Allen and Fulford 1986, 95), which is restricted solely to the area seaward of the present sea defence. In the Wentlooge Level an early post-medieval date for the commencement of this formation is apparent (*ibid*, 96). The Rumney Formation contains much washed-in cultural material of all periods, particularly in its lower part. In places, where not eroded, the Rumney Formation overlies a deposit known as 'the Wentlooge Palaeosol'. This is 'a conspicuous and resistant fossil soil, composed of an upper pale horizon (0.15–0.3m) with numerous fine rootlets that grades into a lower, darker horizon (0.2–0.4m) with fewer and also larger root channels'. This palaeosol is taken by Professors Allen, Fulford, and their colleagues to equate to the 'Wentlooge Surface' – ie it is 'equivalent to the ground surface landward of the sea-wall' (Fulford *et al* 1994, 177). In the foreshore area investigated by Allen and Fulford the 'Wentlooge Palaeosol' is the uppermost part of the Wentlooge Formation, a sequence of greenish to bluish-grey estuarine silts with peat band intercalations (Allen and Rae 1987; Allen and Fulford 1986, 94).

The stratigraphic relationships between the ditches recorded on the foreshore and the sedimentary sequence is described in the 1994 report (Fulford *et al* 1994, 178–81), with two critical exceptions (A25 and A26). One of these forms part of a group of four ditches (A26–A29) on a similar alignment. Three ditches in this group (A27–A29) continue through the Wentlooge Palaeosol and are filled with the later Rumney Formation; as the excavators note, this is the stratigraphic position for most of the ditches and indeed, as examination of their figure 3 shows, this group includes all the members that can be traced certainly across the line of the present sea defences (A14 is roughly aligned with a landward reen). These features, therefore, must have been cut *before* the construction of the sea wall and the commencement of the Rumney Formation; an early post-medieval *terminus ante quem* is implicit.

The date range for the 'Wentlooge Palaeosol' formation is unknown, but a sample of poorly preserved bone from a palaeochannel (feature 32 – *ibid*, fig 3c and 180–1) sealed by the 'Wentlooge Palaeosol' has a conventional (uncalibrated) radiocarbon date of 980 ± 60 BP (calibrated to AD 972–1214 @ 2 sigma 95.4% confidence CIO Groningen programme 1995). Because of the likelihood of contamination this is considered to provide a minimum age for the palaeochannel, but it clearly provides a *terminus ante quem* for the formation of the 'Wentlooge Palaeosol' and the features cut through it. The palaeochannel was cut by Ditch A32a which was filled with the Rumney Formation.

Five ditches (A5, A7, A10, A19, and A35) were shown to be sealed by the 'Wentlooge Palaeosol'; none can be linked to features on the landward side of the modern sea wall. In the case of A19 and A35 they are on different alignments from their neighbours which link with the landward reen system. These ditches, however, share similar stratigraphic relationships with a series of ditches and other features (recorded as sites B and C) that produced Romano-British material. All bar one of these features are clearly sealed by the 'Wentlooge Palaeosol' formation. The single exception (C1) was sealed only by the upper part of this formation (*ibid*, 181, 208 and fig 6). Although containing Roman material dating to the second half of the 3rd century, this feature lies on a different orientation from the other ditches at sites B and C and on plan is not convincing as a man-made feature (fig 5). Moreover a natural palaeochannel (C6; fig 4 and 187), which produced a '2nd century mortarium', 'was seen in plan to be cut by C1'.

Whereas the features forming site B all produced pottery (providing a broad date of AD 250–400), at site C only features C1 and C4 – probably a palaeochannel – produced significant quantities of datable evidence. As is clear from the relationships given in the report and outlined above not only must C1 be later than the other features forming site C, but it also cuts a palaeochannel (C6) containing Roman cultural material and a feature which would have impinged on site C. The material in C1 has to be residual.

A single sherd was noted from Ditch C2. Ditch C3 which on plan appears to cut C2 (fig 5) produced no supporting evidence for date. Fulford and his fellow excavators have argued that C3 represented a continuation of Ditch A26, but no stratigraphic relationships were provided. As Ditch A26 was part of the group A26–A29 with at least one certain continuation in the reen system behind the sea wall, this was then used to support the case that the whole system behind the sea wall was of Roman date. This on the evidence provided is clearly untenable.

A second strand to the argument was that feature C1 shared an alignment with two ditches (A25 and A26a) which also had clear continuations landward of the sea wall. The stratigraphic relationships of Ditch A25 with the immediately surrounding deposits are surprisingly not provided in the report, but Ditch A26a clearly cuts the 'Wentlooge Palaeosol' and is filled with the Rumney Formation. For reasons already given, this must therefore be medieval or later in date.

A key strand to the original argument for the Roman reclamation was the fact that the pottery from site B1 was unabraded (Allen and Fulford 1986, 102–5). Further that material came from the fill of a supposed shore-parallel ditch (X/Site B1) which 'was joined' to another feature on the foreshore (Ditch VI), with landward equivalents (fig 5). Ditch X/Site B1 was, however, later shown to be a sub-rectangular pit (Fulford *et al* 1994, 187 and fig 5), and clearly was not, therefore, 'joined' to Ditch VI (=*ibid*, Ditch A25); in fact Ditch B1 (=X) 'could not be seen in plan' (*ibid*, 177). Allen and Fulford (1986, 100) noted that the 'Romano-British material is distributed sparsely and unevenly throughout the visible confines of the ditch and ranges up, though in more scattered form, into the dark and even the pale zone of the Wentlooge Formation soil'. The published description and section of Ditch X (fig 6 – 'based on photographs and measured drawings') shows it to be clearly overlain by the 'Wentlooge [palaeosol] soil (pale zone)'. The fact that quantities of Romano-British material are found in the deposit overlying Ditch X/Site B1 should cause no particular surprise. Problems of residuality both within pottery collections and site phasing and interpretation are well known.

Great store is set on the unabraded nature of the pottery from site B1 (Allen and Fulford 1986, 102–5; Fulford *et al* 1994, 177) when compared with that collected from other sites (site C Allen and Fulford 1986, 106) and overlying deposits. Later excavation of the ditches at Site C (Fulford *et al* 1994, 181) produced unabraded pottery. As indicated above the published evidence clearly shows that the features at Sites B and

C are securely stratified below the 'Wentlooge Palaeosol' only to have become exposed following modern erosion. Prior to this the material within them (and even the few sherds from the 'Wentlooge Palaeosol') would have been unaffected by later disturbance and often lain in waterlogged conditions. Given that unabraded Roman material can occur in later contexts on dryland sites (see for example Barker 1986, 141), the recovery of unabraded pottery from securely stratified contexts in alluvium should cause no particular surprise. Indeed Parkhouse and Parry (1990, 78–80 and fig 27) advanced arguments to explain how cultural material displaying a lack of abrasion could have arrived in later features, particularly since Roman material was being recovered from horizons on the foreshore at a depth of 'over a metre below the 'Wentlooge Paleosol'. They were, however, using the then published relationships between Ditch X/Site B1 (Allen and Fulford 1986), which has since been corrected (Fulford *et al* 1994 – as noted above B1 was later identified as a sub-rectangular pit). There is no need, therefore, to go over their argument, which has now become irrelevant to the critique advanced here. What is of additional interest is that as well as small quantities of unabraded Roman pottery, the 'Wentlooge Palaeosol' at Rumney Great Wharf has produced meaningful quantities of medieval pottery and roof tiles (Allen 1996, 77–6, 80–1). Applying first principles of archaeological interpretation there is, therefore, no hard evidence to support the contention that the area inland of the seawall at Rumney Great Wharf is part of a relict Roman landscape. The alternative model of a stabilised Roman ground level at *c* 4.6m OD, as first suggested by Parkhouse and Parry (1990), must be preferred.

Much secondary evidence (Allen and Fulford 1986, 109–17) has been introduced to support the argument that the Wentlooge Level was a relict Roman reclamation. This evidence included:

- alignments of ditches landward and seaward of the present sea wall (and comparison of their form and size);
- consideration of field sizes and principal routeways landward of the sea wall;
- the imposition of the sea bank on the reclaimed landscape;
- the evidence of the Goldcliff stone for some form of construction activity by the military on the levels;
- the need for the drainage work to have been undertaken by the army because of the scale of operation required;
- imperial/military drainage works elsewhere in the Empire;
- the macro-economic need for reclamation, given the province's dependence on the Empire;
- the local need for new farming land to support the military at Caerleon and in particular for the pasture and supply of horses and other livestock, all conveniently managed by a '*procurator saltus*'.

Despite the absence of any evidence for centuriation, the arguments for the similar morphology of the drainage ditches and the apparent *iugera* multiples in size of many of the fields around Peterstone Great Wharf (Allen and Fulford 1986, 113), rested entirely on the assumption that Ditch X/Site B1 was part of the system, and therefore proved its antiquity (*ibid*, 110). That B1/Ditch X did not form part of the system has already been shown above, and was clearly known in 1994 (Fulford *et al* 1994, 187). Attempts to link parts of site C with the landward system (*ibid*, 209–10), have been shown above to be unsustainable.

Parkhouse and Parry (1990, 18–19) noted the difficulty in relating the organised reclamation of the Wentlooge Level to 'specific causes or motivations' in the absence of evidence (literary/epigraphic/other), particularly given the massive involvement of human resources. These were estimated at 7–9 million man hours for the excavation of some 320km of ditch system alone and Parkhouse and Parry contrasted this with the East Anglian Fenland where 'official involvement is ruled out'. Much of the other secondary evidence is speculation and no longer needs to be of any concern.

It would be overly harsh to be entirely negative about (and critical of) Professors Allen and Fulford's work at Rumney Great Wharf. Indeed their findings from the more secure Roman features, and particularly those at site B, provide significant evidence for the landform of the Wentlooge Level in the 2nd to 4th century. Examination of the pollen in and above Ditch B4 (Fulford *et al* 1994, 202–4) suggested a predominantly pastoral local environment with any cultivation some distance away. The pollen from the lower part of the overlying palaeosol provided some evidence for arable farming but with pasture continuing, followed by a decline in pasture and disturbance, possibly as a result of flooding. Examination of plant macrofossil remains from well B3 likewise implied a general damp pasture, but not salt-marsh. Beetles and weeds included species that could be associated with domestic animals grazing on pasture. In any area perhaps only occasionally reached by storm floods, cultivation was restricted but might have included flax.

5.3.1.2 Other evidence from the Wentlooge Level

The evidence for buried deposits from Rumney Great Wharf (Parkhouse and Parry 1990) has already been noted. More recently other fieldwork has identified similar deposits.

5.3.1.2.1 Cardiff–Newport Interceptor Sewer

Evaluation works at each of the nineteen pipeline shaft compounds on the route of the Cardiff–Newport Interceptor Sewer revealed two general episodes of stabilisation within the upper 3m of alluvial deposits, one represented by a gleyed layer within the upper Wentlooge Formation, the other by peats and peaty clays of the middle Wentlooge Formation (Yates *et al* 2001). The lower surface was encountered at heights varying between 4.48m OD and 3.37m OD and comprised Phragmites peats, dark fibrous peats, and peaty clays averaging 0.1m thick. A radiocarbon radiometric date of 1400–1050 cal BC @ 2 sigma (Wk–9823) was obtained from one sample. A later period of stabilisation was represented by three gleyed horizons encountered at heights of 4.62–5.17m. A radiocarbon AMS date of 3350–2910 cal BC @ 2 sigma (Wk–9822) was obtained from a small sample of disseminated organic material of unknown provenance in the gley (hence the necessity to employ AMS). The inconsistent date may be due to the incorporation of older material within the gley (Yates *et al* 2001, 74).

5.3.1.2.2 Western Valley Sewer

Evaluation works along the route of the Western Valley Sewer, a north–south route joining the Cardiff–Newport Interceptor Sewer near St Brides, Wentlooge, revealed three distinct buried surfaces within the upper 2.5 m of the sedimentary sequence (Yates *et al* 2001, 59).

The lowest surface, a thin peat or gleyed clay with a distinct organic horizon, was found at heights betwen 3.46m OD and 4.71m OD. A date of 1300–990 cal BC @ 2 sigma (Wk–9824) was obtained. The middle surface occurred between 3.70m OD and 4.81m OD and was dated to 1270–830 cal BC @ 2 sigma (Wk–9825). The uppermost buried surface occurred intermittently along the pipeline route between 5.16m OD and 5.61m OD and was typically represented by a blue-grey gleyed clay often associated with a thin black organic band. From the position of this horizon stratified within the clays of the upper Wentlooge Formation, the excavators assumed either a late prehistoric date or, if the present-day land surface was stabilised in the medieval period, a Roman date should be assumed (Yates *et al* 2001). Rippon (1996a, 88–90, fig 34) has identified 'in-fields', including an example at St Brides, as features of medieval reclamation on the Severn Levels.

5.3.1.2.3 Other findspots

The drowned soil profile was also detected during the construction of an electronics factory at the north-west end of the Wentlooge Level (NGR ST 238 794; Turner and Locock 1997). At Pencarn excavation revealed parts of a Roman settlement on the margin of the Level. This was sealed by marine clay that could only have reached the site as the result of a significant transgression (Yates 2000).

5.3.2 The Caldicot Level

5.3.2.1 Goldcliff, Hill Farm (ST 368 825)

Evaluation and other investigation work at Hill Farm, Goldcliff, on the western edge of the Caldicot Level, has been widely reported (Locock 1996, 1997a, 1998a, and 2000; Locock and Walker 1998). This has been supplemented by a permanent watching brief (Roberts 1999) carried out during the construction of the Gwent Levels Wetland Reserve – a wetland habitat creation built in mitigation for the effects of the Cardiff Bay Barrage. The site lies on the edge of the Caldicot Level east of Newport, immediately north of the bedrock promontory of Goldcliff 'island' and south of Goldcliff village, not far from the location of the Goldcliff Stone.

Previous work at Hill Farm undertaken by University of Wales: Lampeter (Bell 1994) had identified large square-sectioned ditches with an occupation horizon. This was associated with charcoal and pottery and found below 0.8m of alluvium at 5–5.3m OD. The excavation produced a large assemblage of pottery (512 sherds) indicating occupation from the early 2nd to the early 4th century implying the presence nearby of a settlement site, presumably a farmstead. As Bell (1994, 141–2) noted, the discovery of these remains clearly implied a marine transgression, perhaps in the Roman period. It had also been suggested (Rippon 1996a, 34 and fig 12) that an undated boundary and reen crossing the site, joining the sea defences at right-angles, and apparently earlier than a 'green lane' droveway, might have a Roman origin.

Further banks and ditches were located in the evaluation work (Locock 1996, 1997a, and 1998a; Locock and Walker 1998). They were clearly associated with a blue-grey gleyed horizon with rusty mottling and siderite granules at the base of the horizon below an organic component (charred reed). Following analysis this been shown (Locock 2000a; Locock and Walker 1998) to be a long-lived stabilised soil with its origins in the middle Iron Age and burial sometime after AD 350. As Locock (2000a) notes, the gap between the dates for mineral and organic deposits was 'sufficient to permit the construction of three phases of sea bank on the surface, covered by the vegetation; a centuries long timescale is therefore not inconceivable'.

Two of the 1997 trenches (T11 and T12) were used to examine the possible Roman feature identified by Rippon (1996a, 34). This work showed that the 'Rippon boundary' reen followed a natural channel of some antiquity and was presumably selected as the basis for the present reen system when created in the post-medieval period. There was no evidence for any bank directly associated with this channel.

A detailed account of the watching-brief findings has been prepared in advance of full publication (Roberts 1999). Observations in the vicinity of the new ponds confirmed that the man-made features associated with the horizon were generally restricted to the higher area near Hill Farm. Two were found, however, to drain into the natural channel underlying the putative Roman reen suggested by Rippon (1996a, 34). The horizon was found across the entire area covered at depths of between 4.7m and 5.5m OD. Three dates (2440 ± 40BP (Beta–125089), 1600 ± 40BP (Beta–126108), and 2360 ± 50BP (Beta–125090) obtained whilst works progressed (Roberts 1999) are consistent with those already published by Locock and Walker (1998). Other samples remain to be analysed and dated.

From current evidence a broad sequence of events can be constructed (Bell 1994; Locock 1997a; Locock and Walker 1998; Roberts 1999). It would appear that, in conjunction with marine inundation, silting continued across the area in the Iron Age with a halt in this process noted towards the end of the period. This stabilisation appears to occur initially during the late Iron Age in the higher elevations close to the shore of Goldcliff Island itself, presumably accelerated by the artificial works. It is also likely that at the end of the site's existence, when the entire soil surface was covered in reed beds at least in its final pre-flooding stages, the reversion to Wentlooge flooding may not have been catastrophic.

The evaluation and watching brief produced only a small quantity of stratified Roman material (from the ditches); the pottery gives a broad date range of mid-2nd to mid-4th century. The material is similar to the larger assemblage previously found (Bell 1994), where pottery predating the mid-2nd century was rare. As the small quantity of artefactual material from the ditch fills implies that this area is some distance from intensive occupation, it is, therefore, presumed that it was used for agriculture. It seems likely that an existing drainage system continued in use into the Roman period and that perhaps the Goldcliff stone recorded maintenance or repair to a long-lived ditch system beginning to come under threat from marine flooding; this and its implications are more fully discussed elsewhere (Locock and Walker 1998).

5.3.2.2 Saltmarsh (ST 358 828)

During the construction of replacement ditches (for removed reens) in the 'Saltmarsh' part of the Gwent Levels Wetland Reserve, a 'drowned' soil horizon of similar form to that found at Goldcliff was encountered intermittently at heights of 5.27–5.38m OD (Roberts 1999, 11). Five ditches were encountered, one cut by a former (post-medieval) reen. One V-shaped example generated twenty contexts including one conspicuous fill containing charcoal, daub, and pottery. Several intermittent gleys among the silt fills of the ditch indicate cycles of dry and wet interludes. Finds from this context included part of a *fibula* spring, samian ware (Drag 37), black-burnished wares, and local grey-wares, as well as *c* 185 animal bone fragments including horse, cow, and sheep. Other contexts produced mortaria. More than 250 sherds were recovered from the ditch sections examined. The pottery has a firm range of *c* AD 130–170; this date and the range of finds imply a settlement in close proximity but separate from those at Goldcliff and Nash (see below) and likely to have been a mixed farming community. An extensive collection of samples was taken from the 'drowned' soil horizon and the ditches, both for dating and pedogenesis. Their study will hopefully generate a useful data-set for understanding the process of stabilisation, occupation, and closure that can be compared with the Goldcliff results.

5.3.2.3 Nash (ST 337 840)

In 1973 during the construction of a Sewage Treatment Works at Nash near Newport, finds of Roman, medieval, and post-medieval pottery and bone were recovered from spoil heaps (Jarvis and Webster 1991).

Similar groups of material had been recovered during the construction of Uskmouth Power Station to the south-west in 1958 (Jarvis and Webster 1991; Barnett 1961) and a Roman or medieval stone coffin and inhumation had been found in 1950 to the north-east of the works (Barnett 1962).

Extensive evaluation works in 1997 for Dwr Cymru Welsh Water in advance of a proposed extension to the Waste Water Treatment Works revealed buried features with an undoubted Roman origin (Yates 1997). The stratigraphic sequence was consistent throughout the area evaluated, ie topsoil and subsoil overlying *c* 0.8m of alluvial clays.

These were found to be post-Roman flooding deposits and proved to be largely sterile within the trenches excavated. Below this a firm, plastic, grey silty clay containing black horizontal laminae was encountered. A darker band near the top of the horizon (5.0–5.5m OD) was taken to represent the fossilised topsoil. Associated cultural material implied that the buried soil was of Roman date. It proved a useful marker for detecting the presence of a number of shallow ditches crossing the site. These principally comprised smaller ditches that seemed to empty into a larger feature considered at the time of the evaluation to be a possible palaeochannel. In one evaluation trench (9), a series of parallel shallow features roughly 0.3m wide and spaced at intervals of around 0.6m to the east of a drainage ditch were interpreted as plough furrows.

Full excavation of the site was undertaken by Pre-Construct Archaeology (Meddens and Beasley 2001). Eight phases of activity were identified with the physical evidence of Roman occupation contained within Phases 2–4. An initial phase of drainage with isolated structural elements was followed by more complete reclamation and the development of field systems with cattle enclosures, waste disposal, isolated structural elements (postholes), cattle burials, and two human inhumations. Modifications to the system occurred in Phase 4, possibly as a consequence of increased flooding. Dating of the individual phases is not precise but from the pottery activity appears to extend from the late 1st/early 2nd century to the late 3rd century. The mechanical excavation of the site to a depth below the evaluation trenches, which were still open shortly before the excavation proceeded, removed the opportunity to map and sample extensively the fossilised ground surface. It also meant that many of the features excavated were truncated. As a consequence the palaeoenvironmental and palaeotopographical considerations are restricted, but activity seems to have occurred in an undefended landscape.

5.3.2.4 South East Coastal Strategy Pipeline

Observations along the route of this pipeline that ran east-west across the Caldicot Level from Nash to Caldicot and on to Sedbury in Gloucestershire were made by Pre-Construct Archaeology. They identified a Roman land surface with pottery near Magor, stone spreads with 1st-century pottery near Caldicot (ST 4350 8485), late 1st- to 2nd-century quarrying and a late 3rd- to early 4th-century building at Stoop Hill (Meddens 2001, 4–6). Possible ceramic cremation vessels were also found to the south of Caldicot (*ibid*, 6). No regular pattern of drainage was identified in what was a considerable transect through the landscape.

5.3.3 The North Avon Level

On the north Avon Level, observations at Crooks Marsh (NGR ST 5385 8155) during quarrying revealed evidence for a ditched field system 0.3–0.5m below the modern ground surface (Everton and Everton 1980; Juggins 1982). Allen and Fulford (1986, 116) observed other remains including a snail assemblage indicating dry to damp grassland.

Evaluation and other works for the Second Severn Crossing (Russett 1990; Lawler *et al* 1992; Wessex 1994) identified sites at Redham Lane, Northwick (NGR 565 860), Rookery Farm (ST 574 846) and Ellinghurst Farm (ST 553 844). The same programme of works also recorded a buried soil associated with Romano-British pottery at a depth of 0.7m (6.68m OD) at Awkley (ST 600 865) on the fen edge (Lawler *et al* 1992; Wessex 1994). At Northwick ditches were cut from a horizon (5.6m OD) 0.5m below the surface, at Rookery Farm in the low-lying back-fen 0.2m below the surface, and at Ellinghurst Farm 0.7m (5.5m OD). The Northwick site was further investigated in advance of construction (Barnes 1993; Wessex 1994, 16–21). The site is a complex of ditches and other minor features. It provided sufficient artefactual and environmental evidence to indicate 1st-century occupation and the likelihood of habitation nearby. Northwick continued to be in use until the 2nd or 3rd century. Romano-British pottery was also found at Whitehouse Farm (ST 550 847) and near Hallen (ST 543 804) through a watching brief maintained during construction of the M49 (Wessex 1994). A midden at Ellinghurst (Lawler *et al* 1992) appears to have been formed between the 1st and 3rd century implying the existence of a nearby settlement. The site at Awkley Interface, which dates from the mid-1st to late 3rd century, also produced mainly native material, but a few pieces of ceramic building material and one amphora fragment imply that there may have been a substantial Roman building nearby.

Earlier work in the vicinity of Hallen had identified an Iron Age settlement (Lawler *et al* 1992; Barnes 1993; Wessex 1994, 13–16). The site was associated with a buried soil horizon (*c* 5.7m OD; for a recent discussion of this and the associated auger survey data see Locock 2000a), which was further examined through an extensive auger survey carried out by Wessex Archaeology (Wessex 1994, 25–6). Data was captured along six transects (three north-east/south-west and three north-west/south-east) totalling 3.6km, with 410 auger bores taken and logged on site. Each bore was sunk to a depth of 2m using a 40mm Dutch auger. The survey recorded a putative Iron Age to Roman horizon in places producing pottery fragments, bone, and charcoal found at varied heights (Unit 3.1 *c* (?)3.75–5.80m OD, presumably reflecting underlying geological variations; Roman material appears at greater heights – in excess of 6.5m OD in the overlying Unit 3). The horizon was most consistently recorded towards the north end at Northwick, Greenditch, Awkley Hill, and Awkley Interchange. Smaller localised islands were found at Severn Beach, south-west of Easter Compton, and at Hallen and Hallen Marsh (Wessex 1994, 26).

Further sites have also been identified through other survey and field evaluation works. At Elmington Farm (ST 559 813) at the foot of Spaniorum Hill, a well-preserved occupation layer bounded by two ditches was found to date to the 1st to 2nd century (Young 1992; Rawes 1992). A probable Iron Age to Roman horizon was found at British Gas Seabank at a height of 5.2–5.3m OD (Insole 1996, 99). A watching brief on the adjoining power cable observed ditches containing 2nd-century Romano-British pottery at ST 5400 8229 (BARAS 1997) and 2nd-century pottery in the subsoil at ST 5408 8191, north of the Crooks Marsh site. Substantial quantities of Roman material have also been found near Farm Lane (ST 566 826; Bridget McGill pers comm), where they were associated with a distinct palaeosol.

Roman material has also been found at the southern end of the north Avon Level. At Rockingham Farm the main east ditch of the moated enclosure seems to be a reuse of a Roman survival, while Roman artefacts have also been recovered from the site (Lawler 1994a; Locock 1997b; Locock and Lawler 2000). More recently a palaeosol similar to that seen on the Wentlooge Level at Goldcliff and Nash has been found near Lawrence Weston Road at a height of 5.50–5.60m OD (Yates 1998, 4).

There is little evidence for habitation of these sites after the 3rd century – Northwick produced one sherd from a late Roman mortarium out of a total of 861 Roman sherds – and no pottery datable to later than the 3rd century was found on the other sites (Wessex 1994). The exception to this rule was the site at Crooks Marsh, which consisted of a series of small rectangular enclosures: the pottery here was almost all late 4th century, although a few shell-tempered sherds may be 5th century (Everton and Everton 1981). As yet this is the only evidence for late or sub-Roman habitation of the Levels. The site lies at *c* 6m OD, on a slight rise in the alluvium. Geotechnical data from the ICI Estates development implies that this would have overlooked a major palaeochannel (R Roberts 1997, 7), hence the general absence of the Roman land surface around Dyer's Common. The presence of 'infields' (see Rippon 1996a, 1997a, and 1997b) in the vicinity of the Crooks Marsh and Farm Lane sites points to early medieval reclamation here (Robinson and Marvell 1997), itself a further indication of the comparative suitability of this part of the Level for settlement.

These recent discoveries, mainly arising from extensive evaluation works, imply that the north Avon Level was colonised from the late Iron Age onwards. Some sites had a continuity of occupation into the Roman period while others were abandoned before the conquest or were *de novo* Roman creations. As at Goldcliff and Nash, drainage appears to be localised and site-specific. The Wessex auger survey indicated some parts of the level may have remained salt-marsh and uncolonised; this appears to be the case for example in the vicinity of Dyer's Common in the more low-lying part of the Level.

There seems to be a certain pattern to the Roman habitation of the north Avon Level. There are a series of farmsteads or villas along the edge of the alluvial plain, such as King's Weston (1950), Lawrence Weston (Parker 1983), and possibly Elmington (Rawes 1992; Young 1992). Settlement in the level occurs on apparent 'islands' of buried soil throughout the marsh, such as at Hallen, Crooks Marsh, and Rockingham, mostly located beside watercourses.

5.3.4 Somerset Levels

On the Somerset Levels the height of the Roman ground surface varies (Rippon 1997a 60–65, tables 3.3 and 3.4). There is a clear distinction between the clay belt in the central Somerset Levels where the Roman ground surface at *c* 4.5–5.2m OD is sealed by at least 0.5–1.0 m of alluvium and the north Somerset Levels where most but not all Roman horizons at *c* 5.5–5.8m OD lie close to the present surface. Roman settlement on the Somerset Levels has recently been well reviewed by Rippon (1997a, 65–90) supplemented by more recent fieldwork results that indicate a density of settlement and diversity of activity at present not paralleled elsewhere in the Severn Levels (Rippon 1997b, 1998b).

The diversity of settlement and land-use in the central Somerset Levels is reflected, for example, in the evidence from the north and south of the River Siger. To the south as far as the River Parrett, some of the area remained salt-marsh. Within and around it evidence for salt production has been found (Rippon 1997a, 72–4). Other areas, particularly those on coastal gravel or bedrock islands around Pawlett and Huntspill, were conducive to more intense settlement. To the north as far as the River Axe, the area has not only provided evidence for substantial stone buildings and buried landscapes of possible Roman date such as at Binham Moor, but also finds assemblages often associated with a horizon 0.5–0.8m or deeper below later alluvium (*ibid*, 74–6). The descriptions of some of the horizons are reminiscent of those found on the Caldicot and north Avon Levels.

Until recently evidence for Romano-British activity on the north Somerset Levels had taken the form of numerous scattered findspots, but little in the way of meaningful excavation or analysis. The Wemberham Villa (Scarth 1886; Boon 1980) has long indicated that high-status settlement existed. More recent survey and excavation by Rippon (1994, 1995, 1996b, 1997a, and 2000), particularly at Kenn Moor, Banwell Moor, and Puxton, has revealed buried Roman landscapes of ditched enclosures and sinuous palaeochannels close to the modern ground surface but overlain by the present pattern.

5.4 Defended or open landscape

The existence of a sea defence somewhere seaward of the present line is postulated by those requiring such a feature to support a theory of wide-scale managed reclamation (Allen and Fulford 1986; Fulford *et al* 1994; Cadw 1996; Rippon 1996a, 1997a and 2000; Meddens 2001). As shown above the archaeological evidence provided does not support the reclamation theory for the Wentlooge Level. The fact that the areas between some of the enclosures at Nash are the same as some post-medieval fields at Wentlooge (Meddens 2001, 2) is but a curious coincidence. There is no empirical evidence for the construction of sea defences in the Severn Levels. The association of the Goldcliff stone and the sea defences was long ago rejected (Knight 1962; Boon 1980, 27). As Boon noted 'the stone is so shaped as to have been plainly intended to be set in or besides an earthwork, we may infer that this was either an embanked natural watercourse, similar to the present stream which runs across the Level from the high ground to the north and debouches upon the Severn as Goldcliff Pill; or an artificial drain'. The factoid persists, however (eg Bell 1994, 142; Rippon 2000, 69). Localised evidence of palaeoenvironmental freshwater/marine change does not need to be explained by a breach of a putative sea wall (Meddens 2001).

The evidence from Goldcliff (Locock 1996 and 1998a) implies that the recorded bank and ditch system is a local response with Iron Age origins. The Nash and Saltmarsh sites appear to have a Roman origin and be cut out from an open landscape. This is also likely to be true for the Rumney Great Wharf site. All four sites have different commencement and closure dates. Moreover they have all produced evidence for multi-phased ditch systems. These systems have marked variations at each site. A similar pattern of localised settlement and exploitation is beginning to emerge on the north Avon Level. This phenomenon can also be seen on the Somerset Levels. Here some areas, such as that between the Rivers Axe and Siger, were reclaimed with suggested embankments for both courses, while others remained as salt-marsh with settlement only on slightly higher and dryer islands of gravel and bedrock nearer the coast (Rippon 1997a, 74–6, and 2000, 69–70).

As Rippon notes (1997a, 109; see also Allen and Rae 1988 and Toft 1992) Roman sea level was *c* 1.6m lower than today. Roman MHWST would thus have been *c* 4.8–5.5m OD, approximately 0–0.7m below the Roman ground surface. Rippon argues that as tides can exceed the metrological value by 0.5m and in storm conditions up to 1m embankments would have been needed, but a height of only 1–2m was all that would have been required.

One of the consequences of a lower Roman sea level would have been a change in estuarine conditions. The points of change where the Severn ceases to be riverine and becomes quasi-estuary and then true estuary would not have been the same as today, with concomitant implications for both tidal reach and possible flooding extents following a sea-level rise (Toft pers comm) and more significantly need for defence.

Allen (1996, 71) has contested that tidal levels along the Wentlooge coast could have been as high as if not higher than those of today. If correct this would have necessitated a massive Roman sea defence at Wentlooge. Rippon and Allen agree that the area landward of the present sea defences around Peterstone is an extant Roman landscape (ie has never been flooded). Rippon (1996a and 1997) argues that rising sea level resulted in the post-Roman flooding of the eastern and western extremes of the Wentlooge Levels, and Allen (1996, 70–2) that the whole of the Wentlooge Level has not been flooded since the supposed Roman reclamation. In either case traces of the Roman sea defences, both along the coast and alongside the main rivers (eg Rippon 1997a, fig 18), are required to have survived until the medieval/post-medieval setback and could reasonably have been expected to have left traces in the archaeological and possibly also the historical record. None have been found to date. Had only the reclamation of the Gwent Levels been planned in the Roman period, this would have involved the construction of a sea defence from Cardiff to Caldicot and along the Rivers Rhymney, Ebbw, and Usk as well as minor channels such as that used by our boat and the grid of ditches to facilitate the drainage of the enclosed land. Such an operation would only have been carried out by the army. It is inconceivable that no record or trace of such activity should survive. To this writer's knowledge there are no equivalent lengths of sea defences anywhere else in the Empire. Indeed the general preference seems to been to drain low-lying areas through canals (see White 1984, 110–12 and table 6). It is also unlikely that any sea defence on this scale would have been constructed as an earth bank, given that Roman engineers had the technical skill to build structures from waterproof cement (*pozzolana*) or with a surface lined with *opus signinum* acting as a sealant.

Rippon's shallow bank theory even as expanded by Meddens (2001) is also difficult to sustain for other reasons. Clearly evidence for such slight defences seaward of the present line may not survive, although any associated ditch should be present in the peat shelf. In other places complementary arrangements should exist. Such might be expected to be found, for example, on the south bank of the River Axe and north bank of the River Siger (see Rippon 1997a, 74–6 and fig 18). The only certain evidence for banks of this size has come from Goldcliff. Here as already noted they seem to be a local phenomenon (Locock 1998a), and more particularly would also have protruded above the late Roman inundation. The fieldwork evidence from the Caldicot, Wentlooge, and north Avon Levels (cited above) suggests a localised pattern of settlement on slightly 'higher/drier' areas, with changes as to location over time. Thus many of the 3rd-century creations are in different areas from those founded earlier. Such arrangements seem an inappropriate outcome to the effort and expenditure that would have been required to construct and maintain an artificial boundary. There is no need, however, to look further than the Fenlands of East Anglia to see a comparable pattern (Taylor 2000, 649–58).

5.5 The socio-economic environment

Now that there is no need to have any reasonable doubt about the general form of the Severn Levels at the time our vessel was operating, the evidence for places that our vessel could have physically visited can be considered, particularly in south Wales. The type of materials that would have been traded and the socio-economic background that both allowed and was developed around their production can also be considered. Our concern here is to bring forward primary evidence – the performance potential of the vessel both in terms of cargo and trading distance is considered elsewhere (see Chapter 10).

5.5.1 Ports, quays, and landing places

Our evidence for ports, quays, and other landing places in south Wales takes two forms: sites on or behind the fen edge and sites within the Levels. For the latter Rippon (1997a, 54), reviewing the evidence for the Severn Levels, suggests six sites as informal landing places – Sea Mills in Bristol; a complementary site near Sudbrook; a location near Magor Pill on the Caldicot Level; and Crandon Bridge, Combwich, and Cheddar on the Somerset Levels. The potential for Sea Mills (*Abonae*) has long been recognised (eg Boon 1945; Bennett 1985; Rivet and Smith 1979, 246). The Somerset sites need not concern us, but the Welsh evidence for both ports and other landing places needs to be expanded and discussed in some detail.

5.5.1.1 Sites within the Levels

The structures in the palaeochannel at Barland's Farm (See Chapter 2 above) provide the only certain evidence for a landing place within the Gwent Levels. Other evidence, however, particularly clusters of findspots in the intertidal zone, points to a number of other potential locations.

5.5.1.1.1 Sudbrook/Portskewett

At Sudbrook finds of Roman material have been made in the intertidal zone (Rippon 1997a, 54 citing Hudson 1977; National Museum of Wales Acc 85.209; Gwent SMR 1148g and 1154g (actually 1153g) – other material is also now known – Gwent SMRs 4406g, 4407g, and 5800g). These finds, evidence from the Nash-Williams excavations in the 1930s at Sudbrook Camp, recent evaluation observations at Portskewett (Lawler 1995), and some documentary evidence point to a complex pattern of activity on the west side of this key crossing point. That there is a landing place here need not be doubted, but whether there was an actual port in Roman times is not known.

The excavations at the promontory fort at Sudbrook (Nash-Williams 1939) produced significant quantities of 1st- and 3rd-century pottery and other material. On the eastern edge of the Caldicot Level, the site would clearly have had a slightly elevated view over the Severn and adjacent lands. Finds to the east of Sudbrook (Gwent SMRs 1148g and 1153g) are clustered around a small channel between Black and Charston Rocks which formed a key crossing point in the medieval and later periods. Slightly further to the east is a small inlet, St Pierre Pill (Gwent SMR 1154g), formerly *Pwll Meurig*. The Llandaff charters record 9th- and 10th-century land grants (nos 234, 240; Davies 1979, 123–5) that mention the site and its use as a landing place for ships (no. 240), but there is no evidence to hint at the existence of a Roman antecedent.

One of the sources (no. 234) also refers to the site of *Yscuit Cyst* (Portskewett). Although the present village is generally supposed to have a transplanted name, Roman material has been recovered opposite the putative site of the 'hunting lodge' built for Harold Godwinson and recorded in the Anglo-Saxon chronicle (Lawler 1995). The straight road from Portskewett to Crick has long been identified as a probable Roman road, providing a short spur to the coast from the main Caerwent road. Sections of apparent paving along the Portskewett road were recorded in the OS maps of the last century (though these remains have been lost to road-widening (Margary 1973, 324, route 60aa). There is no apparent link to Black Rock other than via Portskewett. The road leads directly towards the Scheduled medieval earthwork site and the church that may overlie part of the Roman remains. It is possible that the focus of attention in both the Roman and medieval periods may have been a harbour on the west side of the earthwork site at the head of a former navigable inlet (see Lawler 1995, fig 1). This inlet was the outfall of the Nedern/Troggy that was subsequently diverted to what is now Caldicot Pill, but its former course is preserved as the parish boundary. The early OS maps and the geological map show that the Scheduled earthwork site occupies a slight spur of solid ground close to the former line of the Nedern, at the point where it was joined by two streams. The confluence of these streams may have provided a convenient landing place for small craft. The value of a landing place at this point on the Nedern is that access could be gained from the tidal creek almost directly to solid ground.

5.5.1.1.2 Other sites

Apart from the sites discussed earlier – Nash, Goldcliff, Rumney Great Wharf, and Saltmarsh, which all lie close to palaeochannels, evidence is restricted to locations of Roman material on the foreshore. Significant quantities of material have been found in the intertidal zone at Rumney Great Wharf (Allen and Fulford 1986), Magor Pill (Nash-Williams 1951, Allen and Rippon 1997), and at Goldcliff (Locock 1998a). More recently further strews of material have been found near a palaeochannel at Redwick. These are presumed to have washed out from an eroded occupation site (N Nayling pers comm). Roman pottery was also found in 1931 behind the sea wall near Magor Pill during the construction of the Magor Sewage Treatment Works (Boon 1967). Either of the palaeochannels at Redwick or Magor Pill could have been the outfalls for the river in which our boat was found. Elsewhere along the coastline, despite extensive fieldwalking, there are fewer signs of Roman material (Bell and Neumann 1997, Locock 1998b). Although finds have been made near Chapel Farm in Undy (Locock 1998b; National Museum of Wales Acc 31.39; 85.218), off Peterstone Gout (Gwent SMR 05259g; Allen and Fulford 1987 fig 1) and Great Wharf in St Brides (Gwent SMR 06162g; Locock 1998b; National Museum of Wales Acc 61.1/1.16). At the major locations above, the sites lie on the west sides of major palaeochannels – also the case at Portskewett. The coexistence is clearly not coincidental and outside the major rivers (Usk, Ebbw, Rhymney, and Taff) these must represent the principal outfall routes across the Levels in the Roman period. The location of material alongside a palaeochannel in the intertidal zone is of course only one type of evidence and other watercourses must have been used. The course of some of these minor routes may not have survived the changes in topography following the post-Roman flooding. That for others may be reflected in the latter pattern (cf discussion of remains at Goldcliff above, section 5.3.2).

Where the buried drainage cannot be traced by conventional evaluation, borehole and/or infra-red photography survey may enable the buried channel pattern and other landing locations within the Levels to be traced.

5.5.1.2 Sites behind the Levels

5.5.1.2.1 Caerleon Quay

The only certain Roman quay is that excavated by Boon (1978) at Caerleon. In its primary form in the early 3rd century, the quay took the form of a simple mooring represented by a stone wall or revetment set on a brushwood bedding with a line of boning rods set out to mark the line of the face. The structure was set in the cut-back river or inlet bank face, with hard-standing to the rear. This was subsequently expanded in the mid- to late 3rd century by building an 8m-deep L-shaped extension, with stone walls on rubble and mud laid around oak posts (0.15m × 0.18m), with a terminal (0.28m^2). The smaller posts may have been from an earlier breakwater, the larger a mooring-post. Alongside the quay structure other walls, a drain, and possible piers are interpreted as forming part of a 'boat-house' (Boon 1978, 7 and fig 8). On the riverside the secondary quay was fronted by a landing stage represented by parallel pairs of posts *c* 2m apart. The remains of bracing members were found attached by nails to the quayside posts.

5.5.1.2.2 Other 'ports' and landing-places

A port attached to the major legionary base in south Wales is of course to be expected. It is also possible that the adjacent and related civil settlement at Bulmore may have been furnished with its own quay. A port must also have existed at Cardiff on the River Taff, where an auxiliary base was founded in the 1st century, later replaced with a Saxon Shore fort (Ward 1913, 1914; Nash-Williams 1969, 70–2; Webster, 1990, 35–9). Another probable location for a landing place is Chepstow, which stands at the confluence of the Rivers Wye and Severn, where appreciable quantities of Roman building materials have been found. If (as the Barland's Farm boat find confirms) the lesser channels crossing the Levels were navigable well inland, then other landing places and minor quays should be found close to the settlements along the fen edge.

5.5.2 Fen-edge settlement

Clearly activity within the levels cannot be considered in isolation. Fen-edge settlement for the Somerset and north Avon levels is summarised by Rippon (1997a, 77–80, 87–91, 92–4).

5.5.2.1 Caldicot Level

For the Caldicot Level Rippon (1996a, 34) noted a number of sites and finds, including the discovery of bronze coins, objects, and burials from Thompson's Farm, Liswerry (Gwent SMR 171g; Nash-Williams 1924 – not H M Davies 1924 as cited by Rippon 1996a, the latter being the manager of the quarry where the finds were made and who donated them to the National Museum of Wales; both inhumation and cremation evidence has been found and a Bath stone coffin was recovered in 1939). Other burials, pottery, and tiles have been found at Llanwern (Gwent SMR 2493g, 3717g, and 581g) and Undy, here including a Bath stone sarcophagus (Marvell, 1996). As Evans (1999a, 19) points out there should be settlements near these burial sites. Various finds have been recovered from Magor (Gwent SMR 2346g, 3597g, 3979g, and 3996g). Kilns and an enclosure have been examined at Caldicot (Barnett *et al* 1990). Residual pottery but in significant quantities is known from Undy (Page 1993; Page and Maylan 1993), while pottery, tiles, and burials and bronze objects were found at West End Farm, Undy (Gwent SMR 3937g). Coins have been reported from Ifton Village (Gwent SMR 0485g). A number of other locations can be added to this list. At the eastern margin of the Caldicot Level a possible villa site was identified from aerial photography at Stoop Hill by St Joseph (1953) and by a geophysical survey plot produced during assessment work on the Severn Second Crossing: English Approaches (Parkhouse and Lawler 1990; works carried out by Geophysical Surveys of Bradford). Some investigative work on the periphery of the site was carried out in 1992 (Ferris 1994, 11–17); the contexts of likely Romano-British pottery consisted of two gullies and a later cobble spread. Associated finds were of 2nd-century date. Vyner and Allen (1988) excavated a farmstead at Caldicot in 1977 and as mentioned above, Romano-British material has been found at Sudbrook Camp (Nash-Williams 1939). Another occupation site is suspected at Bishton (ST 38488729, Gwent SMR 6258g; Evans 1999, 19 and 79), where there is antiquarian evidence for a road (metalled road surface and limestone blocks). This is now considered to be a yard or floor on the basis that in good conditions the visible earthworks do not support the earlier interpretation (Evans 1999, 79). There is also evidence that Bishton was the centre of an early estate recorded in the Book of Llandaff (Davies 1979, 110), a matter discussed in more detail below.

Recent fieldwork has, however, started to show a more intensive settlement pattern. The discovery of a settlement at Portskewett has already been noted. This lies some 0.7km to the south-east of a substantial Roman building, perhaps a temple (Gwent SMR 495g), in the woodland on Portskewett Hill. At Church Farm, Caldicot, part of a farmstead was revealed through field evaluation (BARAS 1998) and subsequently excavated (Insole 2000). Associated pottery is of predominantly 3rd- and 4th-century date. At Rogiet a substantial stone structure was found in evaluation work. Two phases of construction were identified. The first was represented by a cobble foundation layer overlain by a rubble limestone block wall 18m long by 1m wide, with a single course surviving. The apparent absence of internal partitions led the excavator to suggest that it was possibly an agricultural building attached to a (?) domestic complex (Williams 1996, 9). The building was remodelled by the addition of two walls, whose form and size suggested that they were of a separate construction. Associated finds were of early to mid-2nd-century date. At Ifton ditches and a burial have been found in association with 3rd- and 4th-century pottery (Bateman 1997). The concentrations of material along the Caldicot Level suggest that the density of settlements may be one per kilometre (Evans 1999, 19)

5.5.2.2 Wentlooge Level

On the edge of the Wentlooge Level no evidence for fen-edge settlement had been found until recently. It is possible that the modern A48 was a Roman road running along the bedrock margin. In the winter of 1996/1997, evaluation and excavation works on the southern extreme of the LG Europe factory complex and adjacent perimeter distributor road at Coedkernew, Newport, revealed a complex of features and structures relating to two sites *c* 500m apart. The first area excavated (Yates 2000) was situated on the boundary between the 'hard' geology and the alluvial peats and clays of the Gwent Levels. The remains included an access road alongside a timber building. The building was set on clays and cobbles dumped over alluvial deposits and thus extended into the back-fen. It had floors formed from cobble spreads and a hearth. The function of the building is uncertain, but an agricultural association is the most feasible explanation. The excavator considers that the building probably formed an outlying part of a larger settlement or farmstead, probably situated on the glacial terraces to the north and east of the site (Yates 2000) and that the large amounts of pottery recovered were presumably debris from this settlement. The structure sealed an earlier drainage system extending inland. Finds suggested a late 2nd- to early 3rd-century date for the drainage ditches and an early to mid-3rd century date for the building. The site seems to have reached its apogee in the mid-3rd century followed by an apparent decline in the late 3rd century, with abandonment occurring no later than the start of the 4th century.

The second more easterly site was originally identified through evaluation. This revealed burnt spreads, possible features, and associated cultural material. A limited area was cleared and excavated in advance of the construction of a pipeline. This revealed a series of drainage ditches, some of which were later filled in and covered over with stones, perhaps resulting in the creation of causeways onto the lower ground. Finds indicate that activity in the area began soon after the middle of the 2nd century and that the assumed adjacent settlement continued to produce rubbish (in the form of broken pottery) until the end of the 3rd century. The excavators (Sell 1998; Yates and Roberts 1998) concluded that the area investigated formed part of a farmstead's holding rather than the actual settlement. The evidence suggests a drainage system on the fringe of the alluvium taking run-off from the higher gravels to the north onto what would at best have been wet pasture where cattle may also have been raised in a mixed economy.

5.5.3 The development of land-use and exploitation

Although at present there is only limited evidence for the settlement pattern within and on the fringes of the Gwent Levels, some general observations can be made about the character of this settlement pattern and its possible development. In part this can be made with reference to the better-recorded evidence from the hinterland.

5.5.3.1 Settlement locations

The pattern of exploitation in the Gwent Levels and on the adjacent fen edge suggests two distinct *loci* for settlement. The first of these is on the margin of the solid geology, where a number of sites have been identified (above) at or close to the interface between the hard and soft geology. The second favoured location seems to be along watercourses crossing the Levels. Evidence for this has predominantly been found in or close to the intertidal zone, where sites such as at Magor Pill (Nash-Williams 1951; Allen and Rippon 1994; Allen and Rippon forthcoming), Rumney Great Wharf (Allen and Fulford 1986, Fulford *et al* 1994), Goldcliff (Locock 1996 and 1998a), Nash (Yates 1997), and the Saltmarsh (Roberts 1999) all lie nearby or adjacent to palaeochannels.

Although within the Gwent Levels no certain evidence for buildings has yet been recovered and that for other structures is limited (eg the well at Rumney Great Wharf, Fulford *et al* 1994; the quay at Barland's Farm; the banks at Goldcliff, Locock 1998a), the clear evidence for field systems at Nash (Meddens and Beasley 2002), Rumney Great Wharf (Allen and Fulford 1986, Fulford *et al* 1994), Saltmarsh (Roberts 1999), and Goldcliff (Locock 1998a) together with the presence of appreciable quantities of cultural material and also burials at Nash must indicate the presence of dwellings in a stabilised and organised landscape.

As argued above the Roman land surface in the Severn Levels is buried, usually within 0.5–1m of the present ground surface and can be clearly seen as a marked change in the alluvial sequence. Such dating evidence that has come from sites and other remains in south Wales associated with this horizon in general for the Roman period implies a 2nd-century commencement with abandonment in the late 3rd to early 4th century. This compares to the north Avon Level, where occupation commences on several sites in the 1st century but few can be extended beyond the 3rd and the Somerset Levels where occupation ranges from the 1st to the 4th centuries (Rippon 1997a, 65–82 *passim*).

5.5.3.1.1 Evidence from Somerset

It is recent work in Somerset (Rippon 1998a and 2000) that perhaps best provides parallels for the likely nature of settlements in the Gwent Levels. Survey and limited excavation work on the north Somerset Level have revealed the form of buried Roman landscapes on Banwell Moor, Kenn Moor, and around the village of Puxton expanding on earlier work at Kenn Moor (Rippon 1994, 1995, and 2000). Each of these morphologically similar relict landscapes associated with natural creek systems falls into the same occupation date range and appears to have been of low status (Rippon 2000, 190–5). The sites in a freshwater environment date to the 3rd to 4th century. Rippon notes (1998, 50) that the work at Kenn Moor suggests a 'low-status agricultural settlement practicing both arable and animal husbandry, with some economic diversity provided by metal-working'. He is still of the opinion, however, that although the 'piecemeal approach to drainage' clearly indicates no 'overall planning or co-ordination', this could only be achieved by 'human intervention in [the] landscape (the construction of a sea wall) rather than natural factors (such as a gradual fall in relative sea level)'. He is tempted to see the low-status nature of the settlements, on the basis of the lack of imported pottery, as indicating that they were tenant farms attached to estate centres elsewhere (Rippon 1998, 54), but as explored below, such evidence may lead to other conclusions. What is apparent is that Banwell, Kenn, and Puxton provide a good indication of the likely form of the less intensively explored but earlier dated sites at Nash, Goldcliff, and Rumney Great Wharf on the Gwent Levels.

5.5.3.1.2 Continuity

Within the Levels there are few examples of continuity from the Iron Age to the Roman period, although the same areas may have been exploited. Thus at Goldcliff the Iron Age and Roman *foci* are clearly separate (Bell 1994; Locock 1998a). At Rumney Great Wharf, however, only a few Iron Age sherds were found in the assemblage reported by Boon (1975) and none from the later work (Allen and Fulford 1986; Fulford *et al* 1994). On the fen edge the buildings recently examined all have distinctly Roman characteristics in their form, construction techniques, and materials used (Williams 1996; BARAS 1998; Yates 2000) and are clearly new creations.

5.5.3.2 Conquest and change – a brief note

5.5.3.2.1 Military arrangements

The resistance of the Silures to Roman conquest is well known (Tacitus, *Annales* xii. 32–3 and 38–40; Frere 1978; Robinson 1988; Manning 1981; Millet 1990; Webster 1984) and it is to be expected that the processes of Romanisation would be limited at least initially (Millet 1990, 99–101). Control of land to the east of a line running from Abergavenny through Usk, Caerleon, and forward to Cardiff was achieved by the mid-50s AD. Even if resistance was subdued, the area westward was not occupied until after *c* AD 74. Organisation of land and the separation of military and civil control has been little studied (but see Manning 1981, 15–23 and particularly 22–3), with the exception of some consideration of the extent of the *territorium* and *prata* of the legionary fortresses at Caerleon (Boon 1987; Mason 1988) and Usk (Manning 1981). Many of the forts established by Frontinus were occupied continuously until at least the end of the first quarter of the 2nd century and some at later dates as well (for overviews see Davies 1980 and 1991). The fort at Gelligaer, for example, was occupied until at least the early 3rd century (Davies 1991). There is some evidence for a reoccupation of the coastal forts at Loughor and Neath in the late 2nd century, again reoccupied in the late 3rd to early 4th century (Heywood and Marvell 1992; Marvell and Owen-John 1997). It may be no coincidence that whereas some settlements in the eastern part of south Wales may have developed from *vici*, at others (eg Neath – Maynard 1993; Lawler 1994b) occupation was generally coterminous with that in the adjacent fort. This is a pattern apparent elsewhere in Wales (Davies 1990). From this it can be suggested either that the *vicani* had a close association with the army (as families or suppliers), or that without the military presence there was an insufficient economic or other stimulus to maintain the settlement at the location (Davies 1990, 72). It is possible that some lands and sites were retained under military control after the establishment of civil authority.

5.5.3.2.2 Civilian arrangements

The *Civitas Silurum* is commonly depicted as extending as far north as Brecon and west to a line from Loughor to Ammanford (Millet 1990; Wacher 1995). The core area of immediately *apparent* Roman civil influence, given known villa, small settlement, and farm locations (see Robinson 1988 fig 1b), is the lowland parts of Gwent, the Vale of Glamorgan, and possibly parts of Gower. Activity in the uplands appears to be far more restricted. This may simply be because the upland areas remained under military control (Manning 1981, 22–3), with restrictions on the development of settlement, or were just unsuitable for settlement in a predominantly agricultural economy. The problem is, however, exacerbated by our lack of knowledge of both Roman and Iron Age activity in the Glamorgan uplands and concomitantly the extent and form of romanising influences (Dowdell *et al* 1989, 29–30). Thus, for example, the extent of transhumance, a consistent phenomenon in later land-use, is unknown for the Roman period (E Evans pers comm).

5.5.3.2.3 Principal settlements

The location of the *civitas* capital at Caerwent (*Isca Silurum*) is well known. Elsewhere within the fertile coastal zone and eastern Gwent small towns are known at Cowbridge (?*Bomium*), Abergavenny (*Gobannium*), and Monmouth (*Blestium*). The last two probably developed from *vici* around earlier forts, while military material has also been found at Cowbridge (Parkhouse and Evans 1996). At Caerleon an extensive *cannabae* has been explored (Boon 1987; Evans 2000) and a *municipium* may have been established at Great Bulmore on the edge of the *territorium*. A settlement centred on industrial activity is also believed to have developed at Usk from the late 2nd century onwards (Manning 1989, 181). Industrial activity is also recorded at Cowbridge (Parkhouse and Evans 1996). Market centres are thus restricted and predominantly lie closer to the Marches.

5.5.3.2.4 The countryside

Within the countryside, Robinson (1988, x–xi) noted three type-site groups on the basis of form, style, and likely social trappings – villa, probable villa, and farmstead. He defined the villa group as sites that had the necessary form and style to have been country retreats, the probable villa site group as sites where no excavations had occurred, but where chance finds include building debris fragments (such as painted plaster, *tesserae*, and tiles) indicating structures of clear Roman style, and the farmstead group as sites of clearer lower social status than villas in both undefended and defended enclosures, the latter including reoccupation within some hillforts. This was a pattern that Robinson realized would become refined in time. More recent viewpoints might lead to different conclusions concerning the apparent lower-status sites (see Hingley 1997; Hanson 1997).

5.5.3.2.5 Acculturation issues

While the villa group includes sites which were or clearly could be estate centres, such as Llantwit Major, Ely, and Llandough, other sites with a late pre-Roman Iron Age tradition (like Whitton; Jarrett and Wrathmell 1981) may have had similar functions, although acquiring a 'villa' style in physical form only gradually. At other sites acculturation is limited to material remains (Robinson 1988, xi). At some sites the level of wealth reflected in the material collections (eg Biglis, Parkhouse 1988) implies that these were more than self-sufficient. It might be thought that they formed part of a network of small farmsteads servicing the estate centre, but there is presently insufficient evidence to support the hypothesis. This pattern of adoption of Roman artefacts but not architectural culture occurs even at sites close to the *civitas* capital (eg Thornwell, Hughes 1996; Caldicot, Vyner and Allen 1988). The inhabitants may have preferred or were perhaps required to live in indigenous dwellings (Hingley 1997, citing work by Booth and Keevil – see refs on p 95). Hingley considers the relationship of *civitas* capitals, small towns, and rural settlement, with particular regard to the continued construction of roundhouses in the Roman period and in some areas well into the 4th century. In a world where Romanisation is assessed in the form of adoption of new building forms, initially by the elite and then by the lower echelons of society, the continued use of roundhouses would be seen as a partial failure of hierarchial diffusion and their inhabitants as old-fashioned and culturally backward. New construction and continued use of roundhouses is not restricted to the fringes of provinces. Whereas reasons for this may be complex (as Booth and Keevil's work appears to indicate), the refusal 'to accept new ideas or materials may reflect positive acts of resistance to changes imposed from outside' and thus 'from this perspective, the roundhouse of Roman Britain could be statements of alternative values and identity' (Hingley 1997, 96). Whereas this may be true for some settlement continuing on land maintained before and after conquest, the pattern on newly reclaimed land may imply a different conclusion.

5.5.3.2.6 Estates

Rippon (1997a, 115) has noted the high density of villas on the English fen edge, particularly in north Somerset. He suggests that some of these may have been 'associated with extensive settlements, perhaps estate villages' (see discussion on the evidence from Banwell, Puxton, and Kenn above and Rippon 1994, 1995, and 1998). Estates centred on the fen edge, an ecotone, would have had the advantage of working both the lands of the Levels most suitable for pastoralism and the land on the solid geology which has more potential for arable farming. At Great Pencarn Farm, analysis of the charred deposits showed the production and processing of grain crops in the immediate vicinity of the site (Yates 2000), whereas palaeoenvironmental work on material from Rumney Great Wharf (Fulford *et al* 1994, 202) suggested a predominantly pastoral local environment with any cultivation some distance away. Plough marks revealed in evaluation works at Nash suggest the possibility of some crop production within that Level (Yates 1997), while charred cereals and cereal-type pollen have been recorded from Romano-British ditches at Goldcliff. As Boon has pointed out (1980, 26), the evidence from north Somerset supports the notion of arable as well as pastoral land-use.

There is no way of knowing the precise extent of these estates in south Wales. Estates recorded on the Llandaff charters, however (Davies 1979), that predate a fundamental shift in landholding practices may represent continuations from late Roman holdings. Various attempts have been made to match the Roman settlement pattern with the Llandaff estates. The most recent work (Evans 1999, 69–75) suggests a complex pattern. There are no known high-status sites within the estates, nor does it seem likely that villas are under-represented in the existing record. For the Gwent Levels and immediate hinterland the *Liber Llandevensis* records estates at Mathern (LL no 141, *c* AD 620, '*territorium*') to the east of Caldicot and more interestingly at Bishton (LL no 180b, *c* AD 710, '*Lann Catgualatyr*'). The boundary description can be translated as:

> From Aber Nant Alun into the marsh as the brook leads upwards to its source. From its source over the Cecin straight on at once to the top of the Sychnant [*Drybrook*] on another part of the Cecin. Along the Sychnant downwards as far as the pant in the wood. Along the Sychnant towards the right as it leads downwards as far as the ridge of the Allt near Cestill Dinan [*?Bishton Castle*]. Along the Cecin of the ridge of the Allt to Rhiw Merchiau. Along the Rhiw [*slope*] downwards as far as the spring of the Gyblè. Along the Gyblè downwards as far as the marsh. Through the marsh straight making for Hendrè Merchitir. From the Hendrè to the Dead Pools, westwards along the Cecin of Cethin through the marsh as far as Lontrè Tunbwlch. From the Lontrè of Tunbwlch straight through the marsh as far as Aber Nant Alan, where the boundary began.

The estate clearly lies at the interface of the Levels and higher ground and includes land on both. The western part of the boundary up to the Llan Allen stream can be traced (Evans 1999, 72); the post-transgression boundary through the marsh may be fossilised along the line of the Elver Pill Reen. The charter also includes shore rights: '*Lann Catgualatyr cum omni sua tellure cum silva et cum maritimis et cum omni sua liberatate*'. Rippon notes (1996a, 36) that this suggests that the estate extended to the River Severn, but the position of the shoreline in Roman times and following the retreat of the post-Roman marine transgression is uncertain. The Gyblè might be the watercourse in whose palaeochannel our boat was found (Evans 1999, 72).

Estates on the Caldicot Level must have been initially linked to the *civitas* capital at Caerwent, where the *Ordo Decuriones* would have been in place by the late 2nd century and possibly earlier (Brewer 1990, 80–2). It may not necessarily be a coincidence that the fen-edge sites here seem to be new creations, nor that these and those in the Level, with the exception of Goldcliff (and even here the Iron Age and Roman *foci* are not coterminous) have a mid- to late 2nd-century commencement.

If the scenario is correct that piecemeal reclaimed land (perhaps only previously available for seasonal use) was owned by estates centred on the fen edge, a late Roman transgression could, as Cunliffe recognised (1966), have had a major ripple effect on neighbouring lands and economies. The apparent collapse of many Roman rural settlements in south Wales in the mid- to late 4th century has never been readily explained. Some natural catastrophe, such as a transgression of the sea resulting in the loss of extensive lands in the Gwent Levels, might in part be a cause, but whether this was a reason for the demise of sites in the Vale of Glamorgan is debatable. More work is clearly needed before such hypotheses can be further advanced, particularly in the area of identifying past changes in sea level and estuarine conditions.

5.5.4 Economy and trade

Evidence for other economic and trading aspects of sites in an around the Gwent Levels is limited. Only a few general comments can be made, therefore, although clearly goods from both far afield and local sources would have passed along riverine trade routes.

Although not promulgated in the Western Empire and not necessarily reliable as a precise guide, Diocletian's Price Edict reminds us (see Duncan-Jones 1982, appendix 17) that the most cost-effective means of transport was by boat. It can reasonably be expected that continental cargoes came to the major ports (above section 5.5.1) and were thereafter redistributed in part by sea and river, whereas regionally and locally manufactured goods and materials were moved to and from minor quays and landing places as well as those at major centres. Our vessel should fit into the latter category, although Owain Roberts' work (below Chapter 10) shows that in theory comparatively long journeys could have been achieved in the right conditions.

5.5.4.1 Cargoes

Boon's (1978, 10–11) work at Caerleon Quay provides some evidence for cargoes comprising coal from the south-east margin of the south Wales coalfield (brought via the River Ebbw), iron ore, and Bath stone. Other material he considered to be 'rubbish thrown overboard form ships, or from the land'. Of other cargoes, Webster (above section 4.2) discusses the significance of the BB1 found at Barland's Farm in detail. Pottery assemblages at the sites in the Level and on the fen edge generally fall into the pattern well established in south Wales (Webster 1993). Allen and Fulford (1996) have plotted the distribution of Romano-British pottery types, specifically BB1, in south-western Britain. This shows that a high proportion of BB1 is to be expected on the Wentlooge Level in comparison to all other coarseware types (40% plus) and around 20% on the Caldicot Level as a percentage of the total assemblage. The recent work at Great Pencarn Farm fits this pattern (Yates 2000). Local pottery production is also attested at Caldicot (Barnett *et al*1990) and Llanederyn (Vyner and Evans 1978). On current evidence across the Levels faunal assemblages are mainly too small for meaningful comparison and analysis. There is, however, some evidence of industry in terms of salt production and ironworking (Rippon 1997a, 119). Salt production perhaps driven by military demand is a particular feature of the north Somerset Level. In or close to the Gwent Levels iron smelting is attested at Rumney Great Wharf (Allen and Fulford 1986 106–7), while evidence of iron processing is known from Stoop Hill (Ferris 1994) and also the indigenous farmstead at Thornwell Farm (Hughes 1996). Whether this was for simply local needs or as part of some secondary processing prior to export is unknown, but given the volumes of slag recovered the former is the more likely. Even if the setting of Barland's Farm and others in the Levels seems to be one dominated by pastoralism, the background influences of mineral exploitation, processing, and exportation can be seen (for a discussion of ironmaking in the wetlands of the Severn Estuary and particularly the Oldbury Level see Allen and Fulford 1987, 275–80).

5.5.4.2 Trade routes

At present there is probably insufficient information to establish trade routes with any reasonable degree of certainty; the physical and marine limitations are discussed elsewhere in this report (see Chapter 10 below). The known and some possible key port and minor landing-places were discussed above with particular reference to the Gwent Levels, but identifications in other parts of the Severn Estuary are also noted. Allen and Fulford (1987, 281–3) have discussed the use of the upper part of the Severn Estuary. Gloucester seems to have been a major port for incoming traffic. On the basis particularly of relative pottery distribution material was moved from there to smaller anchorages. They note on the basis of the high content of local ceramics that, in contrast to Gloucester, Sea Mills on the Avon was clearly less significant (Allen and Fulford 1987, 284). A considerable volume of continental traffic clearly came directly to Caerleon. There should also have been a direct supply to Caerwent, perhaps via Portskewett.

More meaningful analysis needs to be done to establish trade routes, but the general pattern seems to support the notion that continental imports came to major centres. These provided nodal points for local redistribution to minor landing-places and quays such as Barland's Farm. Local trade could have been more direct, perhaps reflected by the BB1 pottery assemblage here. Although some continental supply may have come from the Rhineland and the ports of northern Gaul, the main supply route must have been along the Atlantic seaboard, which continued to provide the main trade link between south Wales and the Mediterranean basin long after the Roman abandonment of Britain (see, for example, Alcock 1963; Wilkinson 1996). It remains but to note that 1st- and 2nd-century pottery and other finds, including *tegulae* and box tile, along with 4th-century glass, recovered from the small rocky island of Steep Holm may be associated with the site of a possible watch-tower or signal station (Rendell 1993). Such a location would have been (and still is) visible through much of the upper estuary; as McGrail notes below (Chapter 10), the Holms are invaluable mid-channel guides and an aid to ensuring that the more dangerous coastal waters are avoided.

5.6 A note on military coastal activity in the late 3rd to early 4th century

If constructed from newly or relatively recently cut timber, the date of our boat is of some interest as it was built at a time when increased activity is seen on the south Wales littoral. A so-called 'Saxon Shore' fort has long been known at Cardiff (Ward 1913 and 1914; Nash-Williams 1969), while reoccupation at the forts at Loughor (Marvell and Owen-John 1997, 227–8) and Neath (Heywood and Marvell 1992) is now attested. The excavations at the promontory fort at Sudbrook produced some 3rd-century pottery and other material (Nash-Williams 1939). An uncompleted building at Cold Knap, Barry, with a likely official function, possibly as a *mansio*, is of similar date (Evans *et al* 1985, 91–2). With the exception of Cardiff, the date for this activity is compressed into the very late 3rd to very early 4th century, implying a possible connection with the usurpation of Carausius and Allectus, although a slightly earlier reoccupation at some sites during the 'Gallic Empire' or in the reign of Probus is possible. With his naval experience as commander of the channel fleet, Carausius would have appreciated the need for the control of sea passages and concomitantly the littoral to ensure effective communication and supply and protect his dominion from the main empire in the south.

6

DOCUMENTATION AND DESCRIPTION OF THE BOAT TIMBERS, AND THEIR CONSERVATION

6.1 Cleaning and recording

Once all the pallets containing timbers had been stored in the custom-built water tank, project progress was reviewed and the nature and extent of further study of the timbers defined within an overall post-excavation assessment. A relatively standardised procedure was developed for the consistent recording of the timbers. First the various elements of a single timber were retrieved from store and cleaned using copious quantities of clean running water and brushes and fingertips to remove remaining sediment. The aim was to permit the identification of features such as tool marks without removing more ephemeral evidence such as caulking residues and 'shadows' left by formerly abutting timbers. The fibreglass-backed lifting blocks proved more difficult to handle – cleaning often revealed highly fragmented and partially displaced timbers. In some instances it proved difficult to confidently assign fragments to particular timbers or strakes or to identify the former position of fastenings.

Once cleaned each waterlogged timber was transferred to a bench constructed alongside the storage tank to allow detailed examination and the production of 1:5 scale drawings by Richard Brunning. While timber record sheets initiated during excavation continued to be used, the scale drawings became the main focus for detailed recording. Where possible the inboard and outboard faces, longitudinal profiles, and cross sections (both at existing breaks and cut edges) of the planks were drawn. The upper faces and the undersides of framing timbers were drawn in plan view along with the elevation of either the aft or forward face. The nature of the parent wood was indicated by drawing grain pattern including knots, the position of any sapwood, and ring/ray patterns where visible. These were accompanied by annotations on estimated ring counts, direction of growth and so on. Woodworking evidence such as bevels, joints, setting-out marks, and tool marks was noted and included metrical data on tool facets and jam curves (ie stop marks). The position of any additional samples taken, such as those for dendrochronology, were marked on the drawings.

In addition to overall photographs of individual timbers or fibreglass-backed lifting blocks, further photographs were taken of details such as tool marks and fastenings, usually under strong directional light.

Periodically the groups of recorded timbers were re-examined and compared with relevant drawings. Notes taken at this stage form the basis for the catalogue of timbers (Appendix 2), along with data derived from other specialist studies such as dendrochronology and wood technology. A simple database of timbers initially constructed during the post-excavation assessment provided a mechanism for rapidly updating elements of the timber record, particularly the function code of individually numbered fragments, to facilitate grouping of records as understanding of the vessel grew. It proved instructive on occasion to attempt partial reassembly to check relationships between contiguous timbers such as those abutting or joining the base of the stem post (Fig 6.1).

6.2 Post-excavation documentation of the boat

The hull of this boat (like most simple plank boats) consists essentially of transverse and longitudinal elements: the framing lies across the boat, while the plank-keel, the bottom planking, and the side strakes run fore-and-aft, as do the post and the mast-step timber. Each of these timbers had a unique timber number allocated to it during the excavation as is standard practice. In order to simplify post-excavation

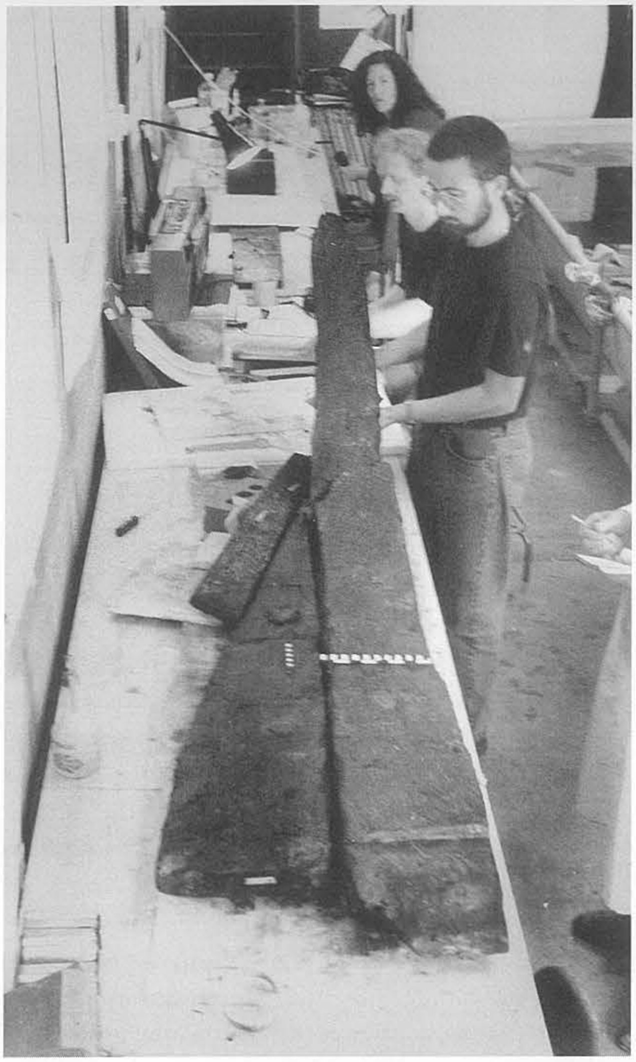


Figure 6.1 The post and adjoining planking temporarily reassembled.

research and focus attention on the boat as a structure, every timber and displaced fragment was also given a nautical code name that encapsulated both its function and its position in the boat (Fig 6.2). Similar systems have been used for some years by maritime archaeologists – see, for example, Olsen and Crumlin-Pedersen (1967), Fenwick (1972), and Steffy (1994, 194–8) – but they are not yet widely known among the general run of archaeologists who may be called on to excavate a boat.

On site the surviving (southern) end of the boat was identified as the bow, as it was closer than the northern end to the mast-step timber. The eastern side of the boat, the one with more surviving planking, thus became 'port' (P), and the western side 'starboard' (S). The planking was then numbered from the centreline outwards: the plank-keel became P1 and S1; the outer bottom planks P2 and S2; and the side strakes P3 to P7 and S3 to S5. Distinctively shaped planks on either side of the post, forward of the main hull, were called bow bottom planks, port (BP) and starboard (BS). The other two longitudinal timbers were each from a well-defined place in the boat and had a unique function and a readily recognisable shape. These were not given code names but remained 'post'; and 'mast-step timber' (MST). It sometimes happens during the post-excavation recording of boat timbers that the on-site identification of the bow has to be changed. Research on the Barland's Farm boat, however, confirmed the original identification.

The bottom of the boat between floors F4 and F17 consists of only four planks (P1, P2, S1, and S2), each one running the whole length of the bottom. On the other hand each side strake consists of at least two planks. Most of the individual planks within the strakes were recognised as such on site. Once all had been identified, each plank was given the suffix A, B, or C according to its relative position in the strake from forward. Thus the foremost plank in the lowest starboard-side strake became S3A and the aftermost surviving plank in the third side strake to port became P5C. Butts between individual planks were known, for example, as P5B/C. Seams where strakes met became P3/P4 and so forth.

It became clear during the excavation that the framing timbers were in discrete groups at stations which were about 0.5m apart centre to centre. These stations were numbered 1 to 17 from forward. Frame timbers were then given the appropriate number prefaced by F for frame, with the suffix Pt or St for those timbers which were mainly on the port or the starboard side. Subsequently it proved possible to divide the framing timbers into sub-types based on their function within the boat's structure:

- floor timbers, spanning the boat's bottom: F1, F16, and so on;
- half-frames, spanning bottom and one side: F12Pt, F15St;
- side timbers, spanning side planking: SF4Pt, SF9St, and so on.

At the majority of stations there were at most two side timbers, one to port and one to starboard, but at stations 3 and 4 there were extra ones. These were differentiated by a further suffix: F (forward); M (middle); A (aft). Thus there are side timbers such as SF3Pt (M) and SF4Pt (F).

This system worked well during excavation and afterwards. Most of the code names allocated to

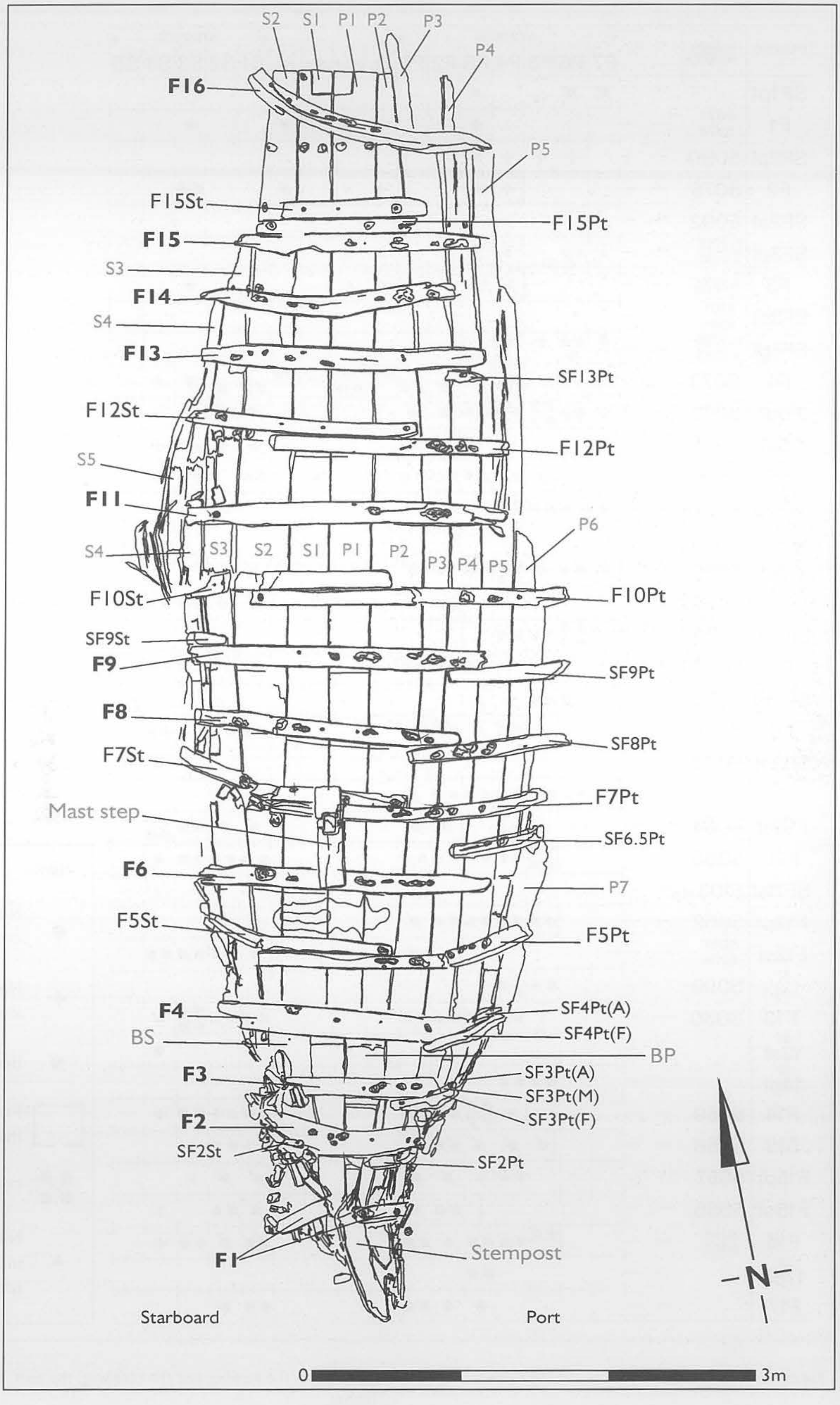


Figure 6.2
Plan of the boat *in situ* with timber codes.

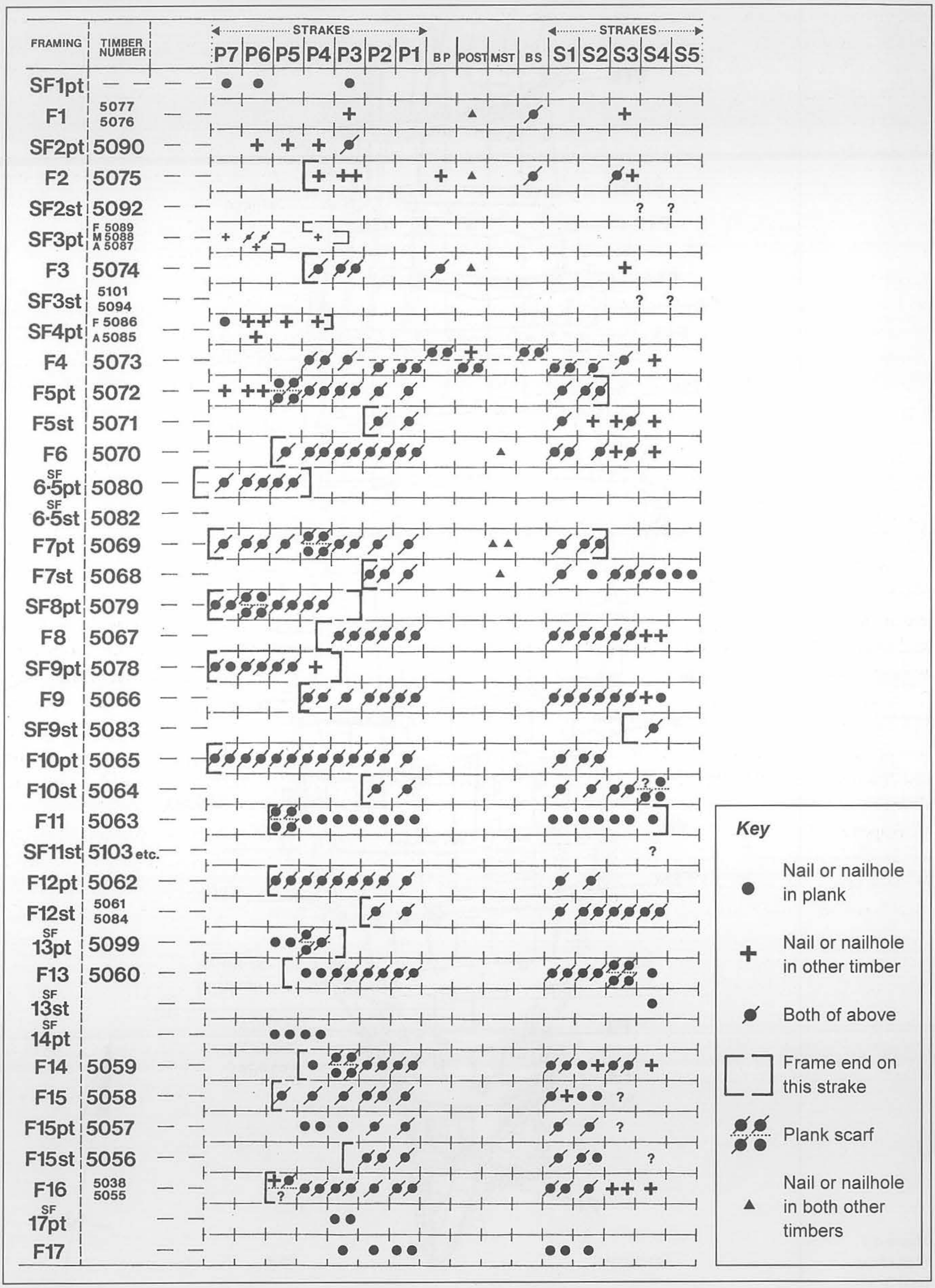


Figure 6.3 Diagram to show the surviving evidence for fastenings between the framing and the planking, the post, and the mast step timber.

fragments on site proved to be accurate when the timbers were subsequently examined in detail: the few that had wrong attributions were readily identified and renamed. Simple though it may be, such a system is extremely useful during post-excavation research. The code name immediately brings to mind the function and position of the timber concerned and even its shape and size; other characteristics may also be recalled. It may not be possible, however, to use this system in its entirety on every boat excavation. For example, on some sites it may be impossible to identify the bow and stern of the remains, the timbers may appear to have no regular pattern, and the precise function of some of them may not become clear until late in the research programme. Nevertheless aspects of this code-name system can undoubtedly be used with profit whenever a boat is found.

Photographs, drawings, notes made on site, and direct measurements were collected together to form a file for each timber. These were linked to the post-excavation 1:5 scale drawing by the code name. As dendro-dates, species identifications, and similar specialist reports became available, the information was included in each file. Using the archaeological site plan and sections (Figs 2.9, 2.12, and 2.13) and the rotated version of the photogrammetric plan and sections (Fig 2.11) as controls for the state of the timbers at two fixed points in time during the excavation, a detailed description was compiled for each timber under standard headings based on the file data and the 1:5 scale drawings. Summarised descriptions are published here in Appendix 2. In these descriptions faces and edges of the timbers are referred to as they appeared in the boat – 'inner', 'outer', 'forward', or 'after'. Individual files were compiled for 35 framing timbers, 23 planks (2 plank-keel elements, 2 outer bottom planks, 2 bow bottom planks, 5 starboard, and 12 port-side planks), 1 mast-step timber, and 1 post.

One aim of the post-excavation research was to establish the precise relationship of each timber to its neighbours in the boat. On-site photographs and marks indicating faying surfaces were useful here, but a more important task was to link nails and nail holes in the planking to corresponding remains in the framing. This was not a straightforward task since nails had seldom been driven at right-angles to plank and frame. Furthermore, as is inevitable in recording intractable, waterlogged, and often massive, timbers, it had not proved possible to record every nail or nail hole on the inner and outer faces of frames and planks. It was, therefore, sometimes difficult to differentiate between a hole in the inner face of a frame made by an emerging nail and one made by a hooked-back nail tip. The results of this lengthy investigation are shown in Fig 6.3.

The information gained in this manner from the documentation of the planking was cross-checked against that from the framing and any differences resolved so that accurate descriptions could be written. The 1:5 scale drawings were also annotated where necessary to clarify certain aspects. A set of 1:10 scale drawings of individual timbers was produced from the final version of the 1:5 drawings: these were subsequently used by Kelvin Thatcher of Fakenham, Norfolk, to make a wooden model of every plank and timber. These were assembled to produce a best-fit model of the boat (Fig 6.4). This is a model of the Barland's Farm boat 'as found', but with displaced timbers reinstated, timbers distorted by mechanical means immediately before excavation reshaped, fragmented timbers made whole, and the entire structure rotated to the vertical. Some very fragmented timbers – mainly planking high on the port bow and in strakes S4 and S5 which were discontinuous with many missing fragments – were not modelled.

Five and a half years after the excavation, when the conservation of the timbers had been completed, it proved possible to examine them for the first time since they had been recorded at 1:5 scale. Several anomalies were resolved, such as the different thicknesses and breadths of two planks meeting in a butt, and marks on the timbers that had proved difficult to interpret from the drawings alone were re-examined. Furthermore data was recorded that had not previously been noted – for example, the precise lengths of certain frames and planks and whether or not they were complete at the ends.

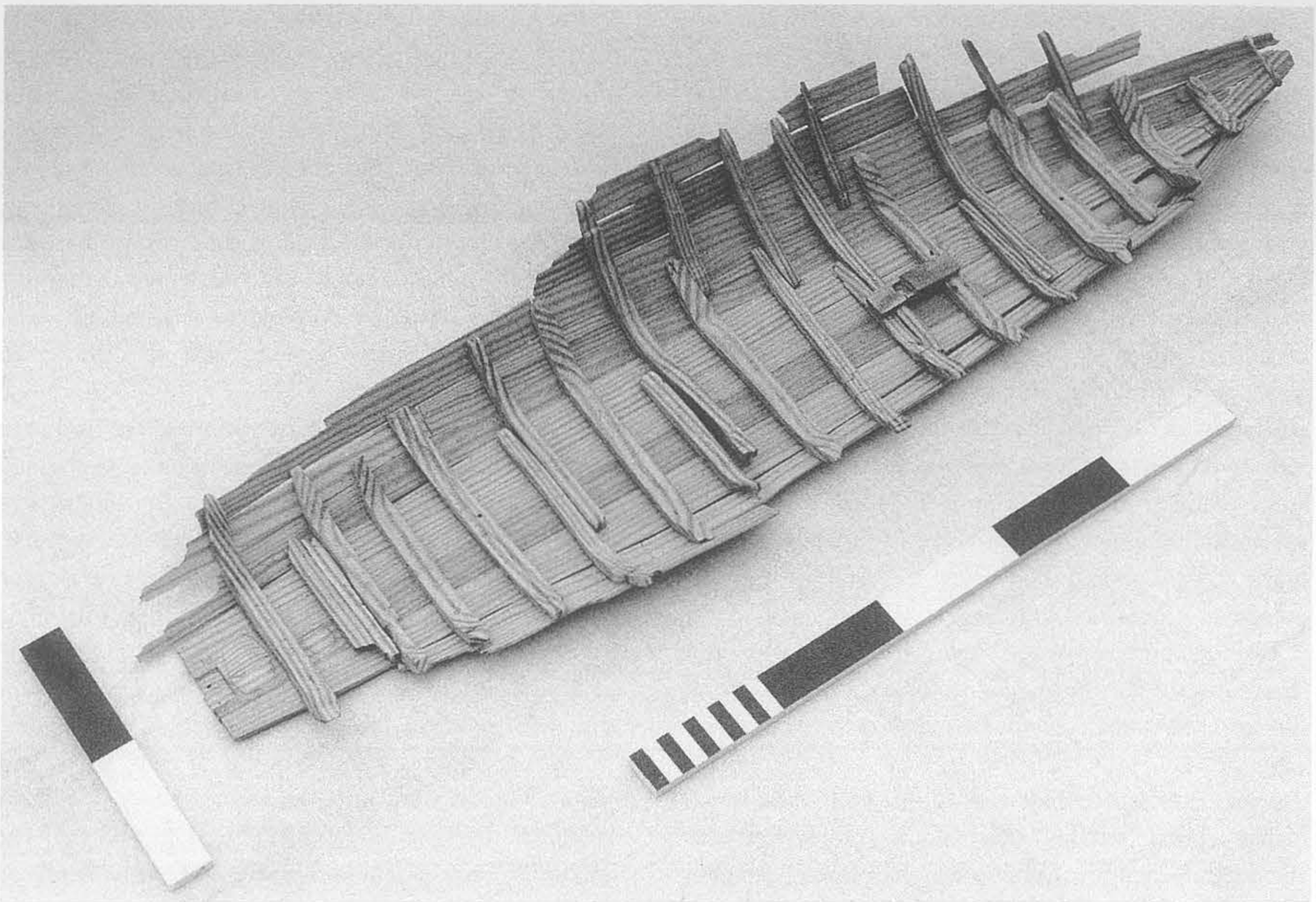


Figure 6.4 A 1:10 'as found' model of the boat based on post-excavation drawings of individual timbers. Timbers such as the post, which were displaced when excavated, have been reinstated. Whenever justifiable, fragmented timbers have been made whole and timbers distorted by mechanical means before the excavation have been rectified. It proved impossible to include several side timbers (eg SF2Pt and 13Pt), as their remains were too scanty to model. Some planking that was very fragmented (much of S4 and S5 and the forward parts of P5, P6, and P7) could also not be included. In this photograph the bow planking is held to the post by a rubber band. (Photograph by Timothy Edgar)

6.3 Hull structure

Four major groups of hull timbers have survived (Fig 6.2):

- the *plank-keel* (P1 and S1);
- the *stem post* (post);
- the *framing* (some whole, some in part) consisting of 3 bow floor timbers (F1 to F3), main floor timbers (F4, F6, F8, F9, F11, F13, F14, F15, and F16), 5 pairs of half-frames (F5, F7, F10, F12, and F15Pt and St), and 13 side timbers (SF2Pt, SF2St, SF3Pt (F, M, and A), SF3St, SF4Pt (F and A), SF6.5Pt, SF6.5St, SF8Pt, SF9Pt, SF9St, SF13Pt, SFX1, and SFX2), and possibly another at SF11St. The positions of other now missing framing timbers and of missing parts of surviving timbers can sometimes be deduced from patterns of holes in the planking and from other evidence;
- the *planking* consisting of 2 outer bottom planks (P2 and S2), 2 bow bottom planks (BP and BS), and parts of 8 side strakes: 5 to port (P3 to P7) and 3 to starboard (S3 to S5).

There is also a mast-step timber.

6.3.1 The plank-keel

The plank-keel (see Figs A2.1 and A2.2) consists of two adjacent planks (P1 and S1) each of which has been fashioned tangentially from a half log. A caulking of macerated and twisted hazel (*Corylus avellana*) and willow (*Salix* sp) withies, probably mixed with a resin, had been fastened by small nails to the inner edges of P1 and S1 before these planks were positioned alongside one another; a similar caulking was also fastened to the plank-keel's outer edges and ends before other planks were positioned there.

P1 and S1 are very similar in size, taper, and apparent growth rate, and both show signs at their upper end of dividing into two large branches. It seems likely, therefore, that they had both been converted from the same straight-grained parent oak. Dendrological examination has neither proved nor disproved this possibility. Both planks were positioned in the boat with their pith-facing face outboard: P1 with the end that came from the butt of its parent tree, aft; S1 with its butt end forward. Both planks retain the natural taper of their parent tree(s), their breadths being *c* 0.3m at the butt end and *c* 0.235m at the upper end. Thus when positioned together in a seam close to but not precisely on what was to become the boat's middle line, they form a plank-keel which is rectangular in cross section and near rectangular in plan, measuring *c* 7.18m in length, breadth (sided) *c* 0.53m at the ends, *c* 0.55m near amidships, and *c* 60mm thickness (moulded). The edges and the ends of this plank-keel are at right-angles to the faces. Sapwood has been left along the edges of both planks, towards the bow on P1 and towards the stern on S1, in both cases the less-substantial, upper parts of their parent log. Each element of the plank-keel would have weighed *c* 95 kg.

The position of framing timbers could clearly be seen on the inner faces of these plank-keel timbers

Figure 6.5 View towards the the bow of the boat after most of the framing had been removed. 'Ghosts' of frames can be seen on the plank-keel, the outer bottom planks, and on some of the side planking.

Figure 6.6 The forward end of the boat showing the lower end of the post in a half-lap scarf with the plank-keel. Floor F4 has been removed from above this scarf. Floors F2 and F1 have also been removed, but F3 is in position across the post and the bow bottom planks (BP and BS). Part of strake P3 is in the lower right of the picture. Photographic symbols mark the starboard outer bottom plank (S2). The arrow points north towards the stern (scale length 1m).

(Fig 6.5); underneath each floor and half-frame an area had been preserved of a distinctive colour and texture. Since it had been protected from erosion, it was at a slightly higher level than its surroundings – probably indicating the original thickness (moulding) of the plank-keel. After conservation these distinctions in colour, texture, and height had been markedly reduced.

6.3.1.1 Adjacent timbers

The plank-keel extends most of the length of the boat from a half-lap scarf with the stem post (5091 and 5024) to the corresponding scarf near the stern. Underneath floor F4 the forward end of the plank-keel to port and starboard of the stem post (Fig 6.6) is butted against the inboard parts of the after ends of the two bow bottom planks (BP and BS); similarly the plank-keel formerly butted aft against the now missing stern bottom planks.

Outer bottom planks P2 and S2 are positioned outboard of P1 and S1 respectively. The plank-keel protrudes by *c* 20mm below this outer bottom planking (Fig 6.7).

6.3.1.2 Fastenings (Fig 6.3)

Floor timbers F4 to F17 are individually fastened to each element of the plank-keel by two large nails. Exceptionally there appears to be only one nail fastening F15 to P1. One of each pair of nails fastening floor F4 to the plank-keel also passes through the stem post. Every half-frame, at stations 5, 7, 10, 12, and 15Pt and St, is fastened to each element of the plank-keel by one nail.

6.3.1.3 Builders' marks

A sequence of blind holes *c* 12 mm in diameter and 6 to 10 mm deep has been bored vertically into the inner face of the plank-keel close to the seam P1/S1 (Fig. 6.8). The foremost two holes are in S1 only. The next group lie in the seam and appear on both P1 and S1, while aft of F7St the holes are entirely on plank P1. With the bottom of the boat assembled, this alignment of blind holes lies equidistant from the outboard edges of the outer bottom planks and marks the boat's middle line. These holes are irregularly spaced with a mean of *c* 90 mm forward and *c* 150 mm

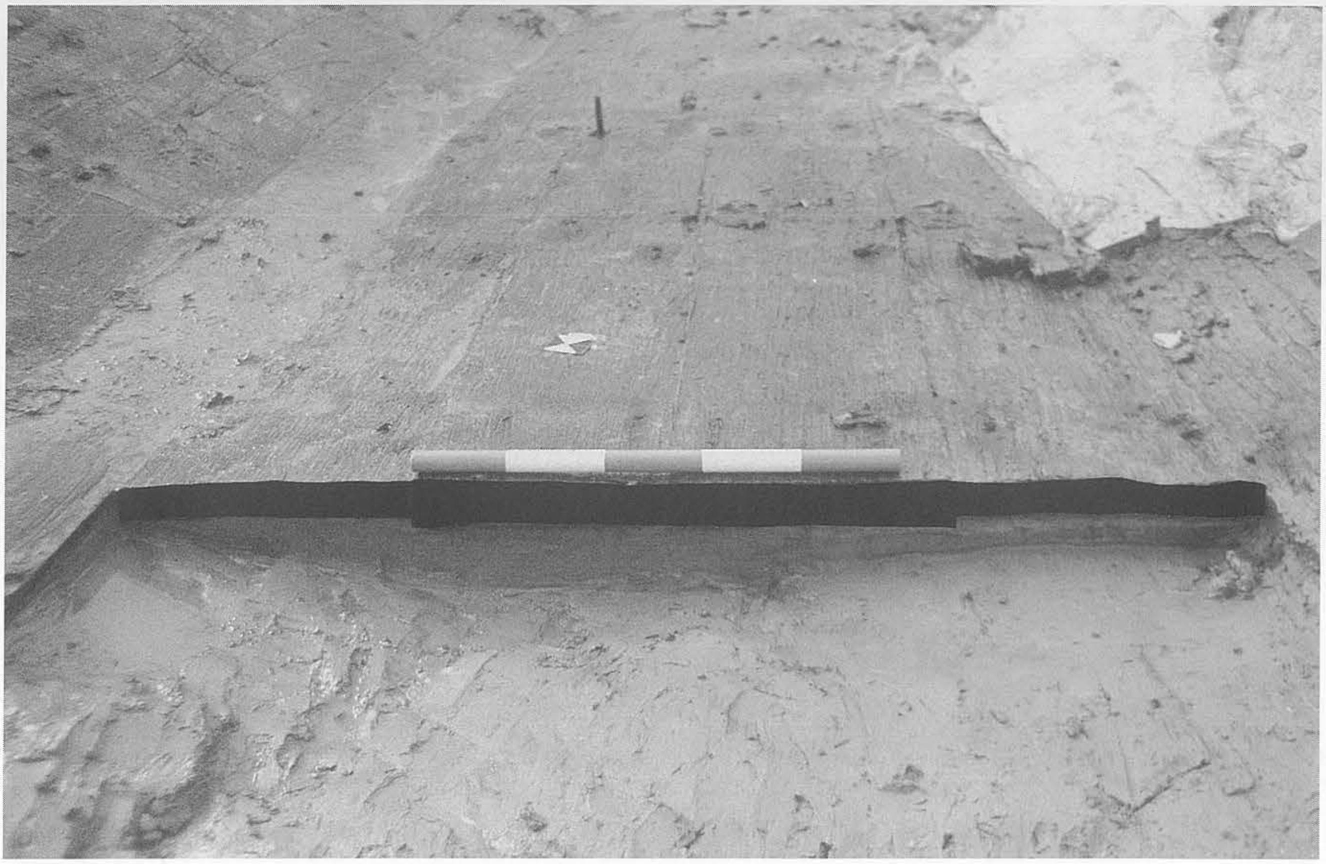


Figure 6.7 Photograph taken during the recovery of the planking showing the plank-keel (P1 and S1) projecting below the outer bottom planks in the section across the bottom of the boat (scale length 0.5m).

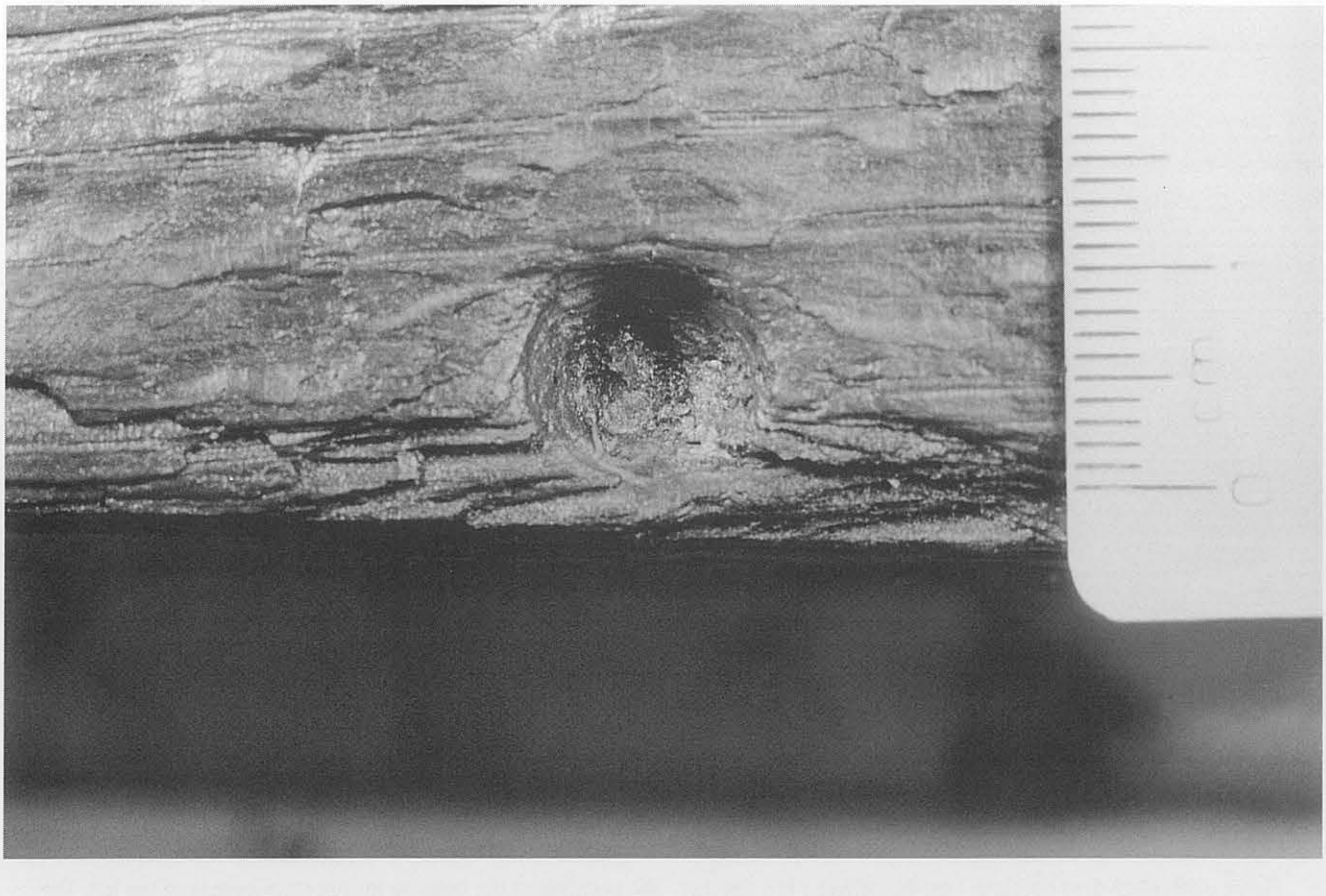


Figure 6.8 One of the blind holes bored into the inner face of the plank-keel close to the seam between P1 and S1.

Figure 6.9A Worn area on plank-keel P1 between half-frame F5St and floor F6.

Figure 6.9B Worn area on plank-keel P1 between F16 and F17. The port half of the housing for the stern post is to the left. The missing floor F17 would formerly have been at this station in a double notch joint with the post (see Fig 6.10).

elsewhere. There appear to be no such holes underneath frames F4, F6, F7Pt, F7St, F8, F13, and F17. The edges of the plank-keel are much damaged beneath F7Pt and St, however, and slightly damaged beneath F8. It is now not possible to be certain that blind holes were not once under the half-frames at station 7. It is unlikely that there were such holes under floor F8. On the other hand, it seems very probable that there were never any such holes under F4, F6, F13, and F17.

6.3.1.4 A repair?

Near the outer edge of S1 between stations 5 and 6, a treenail with an elliptical section 11 × 14mm has been driven obliquely from the inner face into seam S1/S2 where it has been shaped to match the edge of plank S1.

6.3.1.5 Signs of use

The two elements of the plank-keel are in relatively good condition, the inner face under the framing being especially well preserved (Fig 6.5). Two areas of the exposed parts of this inner face have been worn down during the working life of this boat (Fig 6.9):

- between half-frame F5St and floor F6 – worn down by 20 to 40mm; this wear extends to outer bottom planks P2 and S2 to form a curved area forward of the mast-step timber;
- between floors F16 and F17 – worn down by *c* 4mm near the P1/S1 seam, increasing to *c* 20mm on S1; this deeper area of wear on S1 extends beyond F16 to half-frame F15 St, thus forming a region of wear mainly on the starboard quarter of the boat.

6.3.2 The posts

6.3.2.1 The stem post (see Fig A2.3)

On excavation the stem post was found to be broken into two pieces. The lower part (5091) remained more or less in its original position, but the upper surviving part (5024) had been forced over to port and its end was incomplete. The lower, after part of the post runs horizontally for *c* 1.2m from its scarf with the plank-keel and forms with the bow bottom planks BP and BS a forward extension of the boat's bottom. Further forward the post resembles a 'conventional' stem, and curving upwards with a radius of *c* 1.15m, it reaches an incomplete vertical height of 0.68m above the bottom, at which point it lies at an angle of 33° to the horizontal.

The cross section of the post is generally rectangular, with a rounded forward face on the upper section. From the after end the moulding (thickness) increases and the siding (breadth) decreases so that the *m/s* ratio (see Glossary) gradually increases from 0.36 (thickness *c* one-third of breadth), to 0.86 (thickness almost equal to breadth) where the post begins to rise. The post tapers in siding (breadth) from this point so that at the surviving upper end the *m/s* ratio is 1.25 (thickness one quarter greater than breadth).

This post has been converted from a natural crook, probably through the half-log stage, since the grain generally flows along the post's curvature, albeit with some short grain in the upper parts. It was positioned in the boat with its face nearest the pith outboard and probably with its butt end aft. Originally it was probably some 0.9m longer than the length surviving (see section 8.2): such a post would have weighed *c* 62kg.

6.3.2.1.1 Adjacent timbers

Housings or recesses have been worked on both inner and outer faces at the after (lower) end of the post, forming in effect a projecting tongue. The outer housing (22 mm deep) forms a half-lap scarf with the plank-keel, while the inner one (20mm deep) is part of a double-notch joint with floor F4 (Fig 6.10). Bow frames F2 and F3 are notched to fit over the inner face of the post. F1 is not so joggled since by this station the inner face of the planking is flush with the inner face of the post.

The forward ends of the side strakes (P/S3 to 7) were formerly fastened to the port and starboard faces of the rising part of the post within rabbeted grooves which had been worked parallel to the stem's curved leading edge. The bottom bow planks BP and BS lie alongside the horizontal part of the stem and are fastened to it at their tip, just below the lower end of these rabbets.

6.3.2.1.2 Fastenings

The stem post, the plank-keel, and floor timber F4 are fastened together by two nails driven from below, one each through P1 and S1 (Fig 6.3). A third nail forward of these two further fastens post and floor (Fig 6.10). These nails are clenched inboard by turning the point through 180° (see Fig 7.3). The bow floor timbers are similarly fastened to the post by one nail each.

The two bow bottom planks are fastened to the post by spikes driven horizontally through their edges. The side planking is fastened by spikes within the post

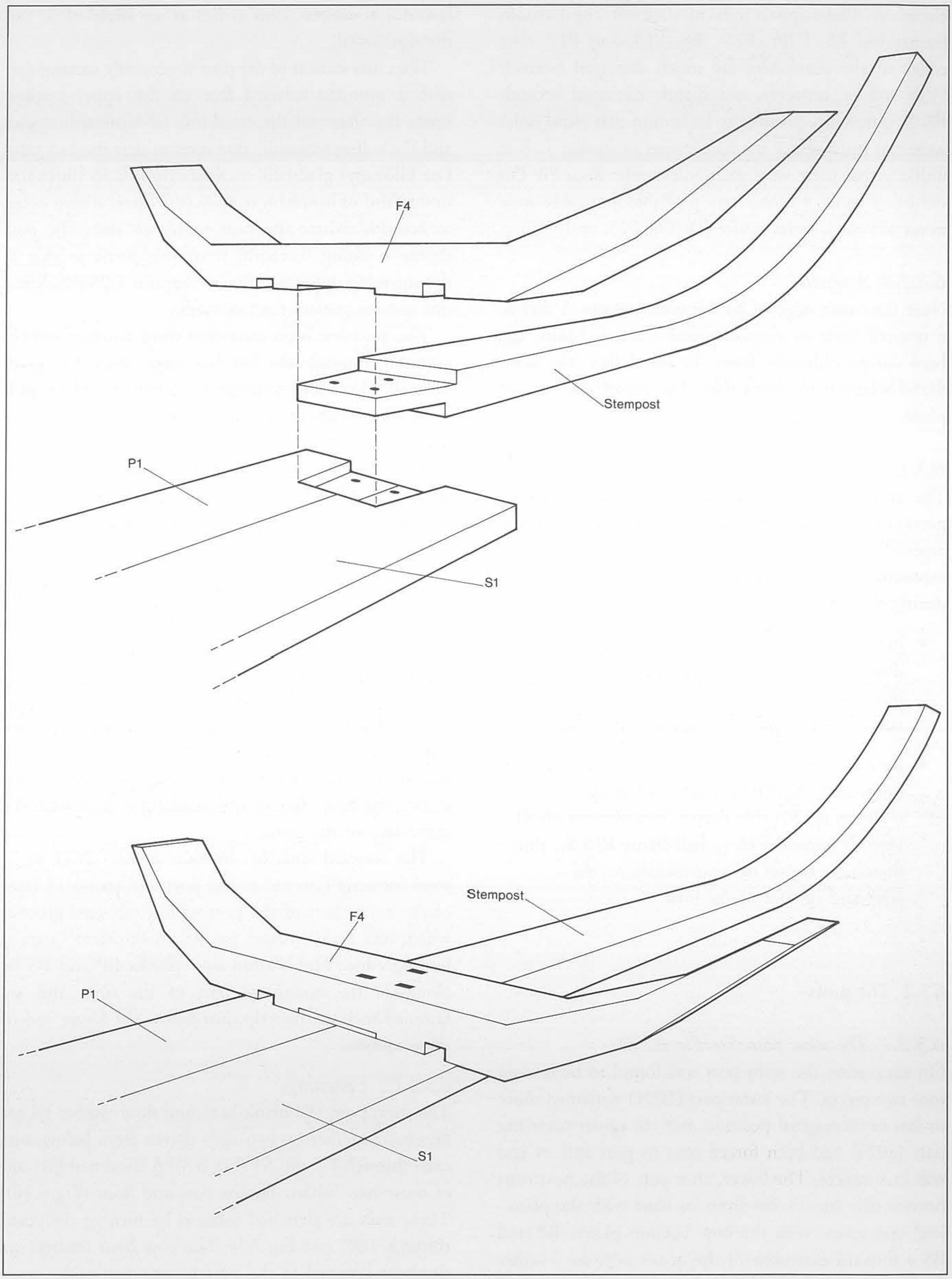


Figure 6.10 Diagram to show how the plank-keel, the stem post, and floor F4 are joined together – the post and the plank-keel in a half-lap scarf, the post and the floor in a double-notch joint. Two nails are driven from below through the plank-keel, the post and the floor. A third nail, further forward, is driven through post and floor.

rabbets. Caulking similar to that used elsewhere in the boat (Table 3.3.4) has been nailed along the outer edges of the horizontal part of the post and within the housing for the plank-keel.

6.3.2.2 The stern post

This timber did not survive to be excavated. The housing with nail holes in the upper face at the after end of the plank-keel shows that there had formerly been a stern post and suggests that it was generally similar in shape to the stem post. It seems likely, however, that its horizontal arm was shorter than that of the stem (see section 8.2).

6.3.3 The framing

6.3.3.1 The bow floor timbers (see Figs A2.4, A2.5, and A2.6)

The three timbers (F1, F2, and F3) each had or probably had side-frames associated with but not fastened to them; F3 had three to port, two of which were probably reinforcements. These bow floors were evenly spaced out along the stem post. Centre to centre, F2 was 0.47m aft of F1, while F3 was 0.43m aft of F2 and 0.45m forward of the stem post/plank-keel scarf.

Floor F1 is incomplete but timber 5138 may be the tip of its starboard arm. Floor F2 (Fig 6.11) is near complete, though damaged. Both these timbers extended across the bottom of the boat and up each side: F1 from P3 to S3; F2 from P4 to S4. Timber F3 appears to be complete yet does not extend up the starboard side, merely from P4 to S2 where its lower end was shaped to take against the lowest side strake S3. It could, therefore, be described as a half-frame. Fragmentary timber 5101 (described as side timber SF3St in Appendix 2) may, however, have originally been fastened at station 3 rather than aft of it: the two timbers together would then have formed a composite frame at this station. The starboard planking is too fragmentary to help in resolving this.

All three bow floors were fashioned from oak crooks formed at the junction of a side branch with a main limb. F1 and F3 were worked from roundwood while F2 was probably from a half log. F1 was installed in the boat with its butt end to starboard; the butt ends of F2 and F3 were to port. These frames have generally rectangular cross sections, with *m/s* ratios less than 1 (ie broader than deep). These sections are skewed, however, to match the rising stem post and the converging side planking. Unlike F2 and F3, F1 was not joggled to fit over the post. Floors F2 and F3 are not symmetrical. There was evidently insufficient wood on the branch element of the crook (fitted to starboard in both cases) to allow the horizontal element of each floor to have a constant moulded dimension: their moulded dimension to port is 20 to 25% greater than

Figure 6.11 Floor timber F2 notched to fit over the stem post.

to starboard. Some measure of this inequality is given by a comparison of the *m* × *s* products (a measure of massiveness) port and starboard: port – F2 20,350, F3 17,400; starboard – F2 15,750, F3 11,250. To ensure that the inner faces of these two floors were horizontal in the boat, notches cut in the two bow bottom planks to house the floors had to be significantly deeper to port (in BP) than to starboard (in BS). Floor F3 is the foremost floor timber in the boat with limber holes: these had been cut in the outer face of this timber above bow bottom planks BP and BS to allow bilge water to pass freely. These floors would originally have weighed *c* 7 kg (F1), 17kg (F2), and 12 kg (F3).

6.3.3.1.1 Fastenings (Fig 6.3)
Each of these floors was fastened by one nail to the stem post. F1 was further fastened by one nail each to BS (but not BP which does not reach so far forward), P3, S3, probably to S4, and possibly to P4. F2 was fastened by one nail to BP, BS, P4 (and possibly S4); and by two nails to the lowest side strakes P3 and S3. F3 was fastened by one nail to P4, S3, and BP and by two nails to P3.

6.3.3.1.2 Builders' marks or tool marks (Fig 6.12)
Floors F2 and F3 have shallow grooves cut across their outer faces: F2 – near seams P3/P4, P4/P5, S2/S3, and possibly P2/P3; F3 – near seams P3/P4 and P4/P5. The function of these grooves is discussed below (section 7.1.2 and Table 7.1).

6.3.3.2 The stern floor timbers

Model building during the reconstruction process (see section 8.2) suggests that there was only one stern floor (analogous to F3 in the bow), with associated side-frames. This floor, (F18) would have been positioned *c* 0.45m aft of F17.

6.3.3.3 The main floor timbers (see Figs A2.6–A2.15)

These are the nine, relatively massive timbers (F4, F6, F8, F9, F11, and F13–F16) that span the entire bottom of the boat (ie the plank-keel and the outer bottom planks) and curve part-way up both sides as far as the second or third side strakes (P4/5 and S4/5). In some cases, however (eg the port side of F9), the highest strake they overlap is not fastened to them. All these floors have a generally rectangular cross section in their

Figure 6.12 Three shallow grooves (marked with arrows) cut across the outer face of floor F2.

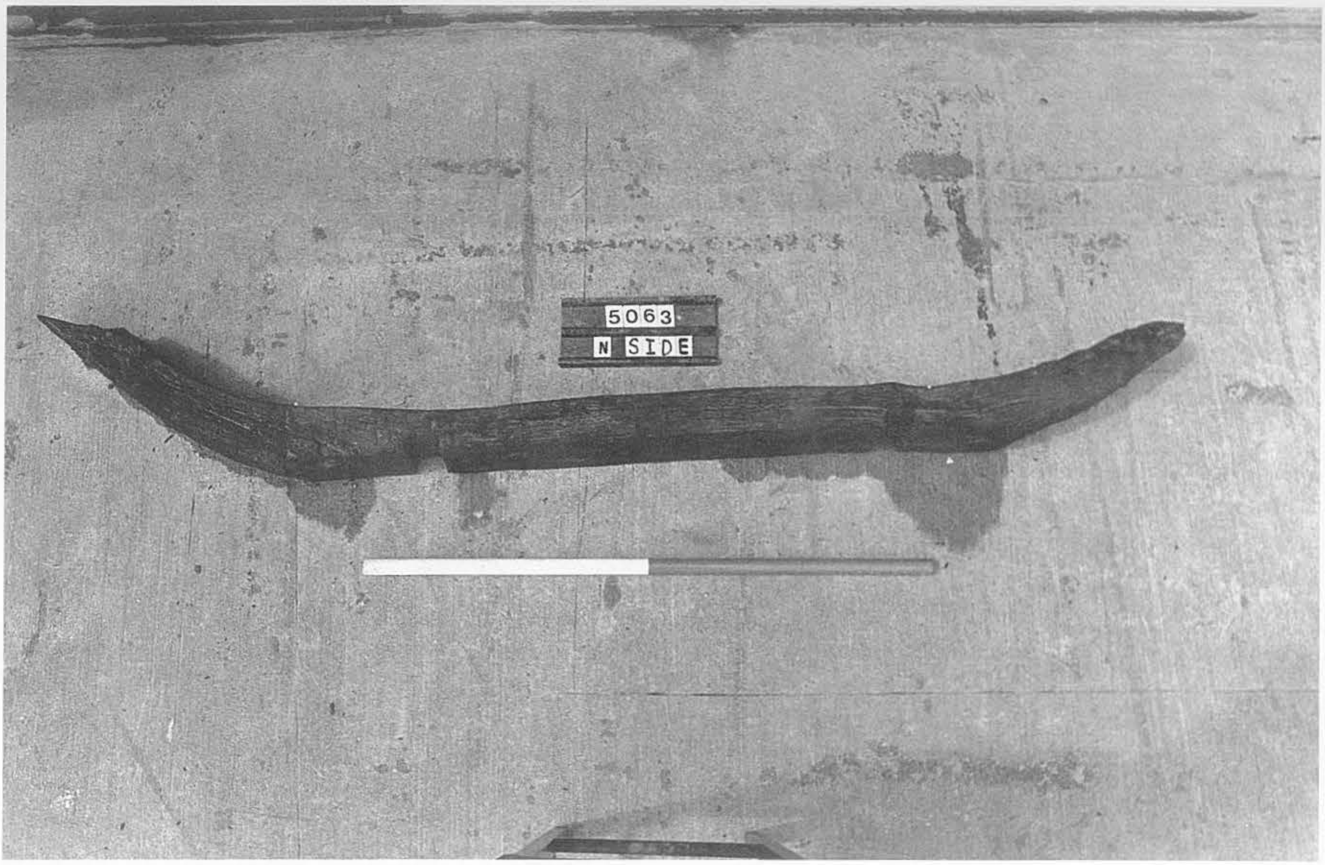


Figure 6.13 The after face of floor F11 showing asymmetry in the lengths of the port and starboard arms.

horizontal part with *m/s* ratios in the range 0.50 to 0.60 (they are roughly twice as broad as they are thick) except for F16 with a ratio of 0.76. Floors F6, F9, F11, F13, and F14 are similar in section with moulded dimensions (thickness) of 83 to 90mm and sidings (breadths) of 150 to 170mm. Floor F4's section shows that the hull planking is clearly converging towards the stem post at this station.

The three floors that survived very nearly complete (F8, F9, and F11) are not symmetrical about the boat's middle line. Floor F11, for example, extends from P5 to S4 and is fastened to both these strakes. Its port tip is 0.43m above the bottom planking, while its starboard tip is only 0.2m (Fig 6.13 and see Fig A2.11). It is clear from this that in the absence of other information those floors which now have a (near-) complete port arm and an incomplete one to starboard (F4, F6, F13, F15, and F16) need not originally have had arms of equal length.

Almost every one of these main floors has at least one surviving side timber associated with but not fastened to it. Using where necessary the arguments of symmetry, it may be said that in general each floor has one port side timber overlapping its forward face and one starboard side timber overlapping its after face. In this way each floor is extended discontinuously towards the top strake, port and starboard. The exceptions to this rule are: F4 which has two to port – one is probably a reinforcement; F6 which has none – there are two close by at station SF6.5 to port and starboard of the mast step. In F11 and F15–F17 the evidence is unclear or has not survived.

Some or all of these main floors were 'active' frames in the sense defined by Basch (1972): they determine (possibly in conjunction with half-frames), the shape of the boat's lower hull between the two keel/post scarfs and up to the second or third side strakes (P4/5 and S4/5). Without reference to the planking, these main floors show us the original shape of the bottom of this boat. She had a flat internal bottom transversely, with breadths varying from *c* 0.80m at the keel/post scarfs to *c* 1.3m near amidships. A hard chine led directly into gracefully curved sides with a radius of curvature around the bilge of *c* 0.78–0.88m (mean: 0.81 ± 0.04m). The sides had an initial flare outwards from the vertical which varied from *c* 60° near the keel/post scarfs to *c* 70° degrees amidships and somewhat aft of there. At the level of the upper edge of the first side strakes (P3 and S3), the boat's breadth increased from *c* 1.3m near the scarfs to *c* 1.7m near amidships. The flare of the sides at the level of the second/third side strakes (P4/5 and S4/5) increased from *c* 45° near the scarfs to *c* 50–55° near amidships. From the shape of these floors, the boat seems to have been nearly symmetrical in plan (ie 'double-ended'), but somewhat fuller aft of amidships than forward.

The foremost main floor (F4) is joggled to fit over the lower end of the stem post. With a notch in the post it forms a double-notch joint which is above the scarf between the post and the plank-keel (Fig 6.10). This floor is thus a fundamental structural timber since it locks the stem post to the plank-keel after it has been fastened in position. Fastening holes in strakes P1, P2, P3, S1, and S2 demonstrate that originally there was a corresponding floor near the stern (F17) which did not survive to be excavated. These floors must have been two of the earliest framing timbers to be fastened in position during construction (see section 9.3). The importance of these timbers is reflected in the size of F4. This floor, the shortest surviving, weighed when complete *c* 30kg, with an $m \times s$ product of 0.286m^2; the second shortest floor (F8) would have weighed a mere 12kg with an $m \times s$ of only 0.094m^2; F13 and F16 are *c* 0.3m longer than F4, but weigh only 17 to 20kg with an $m \times s$ product of 0.119 to 0.139m^2.

It is noticeable that the floor nearest the mid-point of the plank-keel (F11) is second only to F4 in mass. This timber, the longest floor in the boat, originally weighed *c* 25 kg and had an $m \times s$ product of 0.151m^2. Floor F9 which is nearest the mid-point of the reconstructed boat (see section 8.2), originally weighed *c* 19kg and had an $m \times s$ product of 0.134 m^2.

The boat's framing pattern and other evidence suggests that floor F15 was not part of the boat's structure when she was built but was installed subsequently to reinforce the hull (see section 7.6.1). Originally there would thus have been nine main floor timbers including the now missing F17. Measured centre to centre along the boat's middle line, and taking into account the displacement from their original stations (identified by frame 'ghosts' and nail holes on the bottom planking of floors F4, F14, and F16), the spacings between F8 and F9, F13 and F14, and F16 and F17 are: 0.55, 0.52 and 0.58m; while those between F4 and F6, F6 and F8, F9 and F11, F11 to F13, and F14 to F16 are: 1.12, 1.10, 1.07, 1.14, and 1.08m. These intervals clustering around 0.55m and 1.1m raise the possibility that these main floors were not spaced haphazardly, but placed at definite intervals that were, by and large, multiples of a unit of 0.27m or 0.28m – perhaps some human foot (see section 9.2.1 and also Tables 4.5.1, 6.2, 6.3 and 6.4).

The majority of floors were positioned in the boat so that the end that had been nearer the butt end of their parent tree was to port; the butt ends of F13 and F16 were to starboard. They were formed from natural crooks with, in most cases, the port arm and the horizontal portion of the floor fashioned from a main limb and the starboard arm from a branch; F13 and F16 were the exceptions. Two limber holes were cut in the outer face of each floor so that bilge water could flow freely to bailing stations. Generally these holes were in line with the outer bottom planks P2 and S2, but F4, being short, had its limber holes over the plank-keel P1 and S1 (F17 may have been similar). The breadths of the holes range from 45 to 61mm (mean: *c* 54mm) and their depths from 14 to 30mm (mean: *c* 22mm).

6.3.3.3.1 Fastenings (Fig 6.3)

Each floor is fastened to the plank-keel by two nails to P1 and two nails to S1, except that F15 is fastened by only one nail to P1. One of each pair of nails that fastened F4 to P1 and S1 also passes through the lower end of the stem post. Floor F17 probably had similar fastenings to F4.

The outer bottom planks (P2 and S2) are each fastened to every floor timber by two nails, except that there is only one nail each into F4 and into F17 where these two planks have reduced breadth. There also appears to be only one nail each into F16. P2 is narrow at this station, but S2 appears to be wide enough for two nails and one was probably omitted by mistake.

The general rule for the side strakes is that they are fastened to each floor by two nails except where there is room only for one nail at the ends of floors, eg F6 at P5, F14 at P4, and F15 at P5. Each plank end is fastened by two nails to its adjacent floor timber – in strake S3 at F13, strake P3 at F14, and probably in strake P5 at F16. Apparent deviations from this standard pattern are discussed below.

The after end of each bow bottom plank (BP and BS) is fastened to floor F4 by two nails. There were probably similar arrangements at the stern with F17.

The mast-step timber was fastened at its forward end to floor F6 by one spike which was driven from above and slightly entered the inner face of plank-keel S1.

Figure 6.14 The after face of side timber SF 8Pt showing the curve along its length. The lower end is to the right.

6.3.3.3.2 Builders' marks or tool marks?

Floors F4, F6, F8, F9, F11, and F13 have shallow grooves, generally 1 to 2mm deep, worked near horizontally across the outer face on one or both rising arms (Fig 6.12), similar to the marks noted on bow frames F2 and F3 and on some of the half-frames. All of these floors except F9 have such a mark in the vicinity of the port chine where the outer bottom plank P2 meets the lowest side strake P3. All except F8 and possibly F4 have a similar mark near the starboard chine. All except F13 have marks in the vicinity of one or more higher seams (P3/4, P4/5, and S3/4). The function of these grooves is discussed later (see section 7.1.2).

6.3.3.4 Side timbers (Fig 6.14)

With two exceptions noted below, side timbers are associated only with floor timbers (bow, main, and stern), side timbers to port being forward of their associated floor and those to starboard being aft. Side timbers lie alongside their floor, with their lower end overlapping the upper end of the floor at the level of the lower side strakes. Side timbers and floors are not fastened together, nor are auxiliary side timbers (where fitted) fastened to principal side timbers.

6.3.3.4.1 Surviving side timbers (Fig 6.2)

Elements of fifteen side timbers have survived: SF2Pt, SF2St, SF3Pt(F), SF3Pt(M), SF3Pt(A), SF3St, SF4Pt(F), SF4Pt(A), SF6.5Pt, SF6.5St, SF8Pt, SF9Pt, SF9St, SF13Pt, and possibly SF11St. At two stations (3 and 4) there is more than one timber. Near station 6 there are inter-frame timbers. It is uncertain whether there were side timbers at station 11.

At station 3

Side timber SF3Pt(M) is the principal timber at this station. SF3Pt(F) and (A) are auxiliaries, the latter acting as a wedge between bow floor F3 and SF3Pt(M). Timber SF3St may have been associated directly with floor F3 to form a composite frame, but here it is treated as a side timber.

At station 4

Side timber 4Pt(F) is the principal timber at this station. SF4Pt(A) is an auxiliary side timber.

At station 6.5
Side timbers 6.5Pt and St lie roughly halfway between floor F6, which has no associated side timbers, and F7Pt, which being a half-frame does not need a side timber. These two side timbers are positioned just forward of the mast-step timber (Fig 6.2) which probably explains their function and their unique position between stations.

At station 11
Timber SF11St consists of three fragments that appear on site plan 57 but they were not individually drawn and their whereabouts is now unknown. A single fastening hole through strake S4 suggests that there was a starboard-side timber aft of floor F11. No timbers or fastening holes can, however, be ascribed to a corresponding side timber SF11Pt. Side timber SF11St must, therefore, remain a possibility rather than a fact.

6.3.3.4.2 Deduced side timbers.
Other holes through the planking indicate that there were once side timbers fastened there which had not survived to be excavated:

- SF1Pt – holes through P7 and P6 forward of bow floor F1;
- SF13St – a hole through S4 aft of main floor F13; this matches the surviving timber SF13Pt;
- SF4Pt – holes through P5 and P4 forward of main floor F14;
- SF17Pt – two holes through P3 forward of the station of main floor F17.

6.3.3.4.3 Analogous side timbers
It follows from the pattern established above that it is likely that, when there is evidence for a side timber near the opposite end of a floor, there were formerly further side timbers at stations where the planking is either missing or fragmentary. These hypothetical side timbers are: SF1St; SF4St (a loose nail was found at this station on strake S3); SF8St; SF14St; and SF17St.

It is also possible, but less likely, that there was a side timber SF11Pt.

6.3.3.4.4 Displaced side timbers
Two timbers (SFX1 and SFX2) excavated within the waterside structure astern of the boat (see section 2.2.8), are probably displaced side timbers. SFX1, the upper (?) end of which appears complete, has three fastening holes and may have spanned one strake and parts of two others. The other timber (SFX2) is 1.02m long which is probably close to its original length. It has seven fastening holes and probably spanned three strakes (P or S4, 5 and 6) and parts of two others (P or S3 and 7). This timber is shaped longitudinally to match the curvature of the boat's side and probably came from a position in the boat away from the ends.

6.3.3.4.5 Floors without associated side timbers
The foregoing discussion suggests that the builder generally aimed to fit side timbers port and starboard at the same station as every floor timber, bow, main, and probably stern. The exceptions to this rule are:

- F6 – side timbers were fitted at nearby station 6.5 in connection with the mast; a side timber was, therefore, probably considered unnecessary at station 6;
- F11 – it is not certain that there were side timbers associated with this, the main floor nearest the mid-point of the plank-keel; examination of the planking after conservation did not resolve this;
- F15 – this floor is believed to have been added after the original building as a reinforcement (see section 7.6.1);
- F16 – no starboard-side strakes survived at this station; port-side strakes P3, P4, and P5 survived forward of F16 but no fastening holes for a port-side timber have been identified. For reasons of symmetry it is assumed that like most of the floors F16 had associated side timbers.

6.3.3.4.6 Parent logs
The side timbers that have survived can be divided into two groups:

A Those used as roundwood with the pith in or near the centre of the half-frames' cross section. There are two sub-groups here:

- smaller roundwood; parent limbs had girths between 0.31 and 0.38m (0.1 to 0.12m diameter); these include SF2Pt, SF2St, SF3Pt(F), SF3Pt(A), and SF4Pt(A);
- larger roundwood; parent limbs had girths from 0.41 to 0.5m (0.13 to 0.16m diameter). These include SF6.5Pt and SF9Pt.

B Those fashioned from segments of oak limbs; there are also two sub-groups here:

- segments of smaller limbs. Parent logs had girths of 0.72 to 0.82m (0.23 to 0.26m diam); these include SF4Pt(F) and SF3Pt(M), these two being the principal side timbers at their stations;

- segments of larger limbs; parent logs had girths of 2.07 to 2.83m (0.66 to 0.9m diam); these include SF8Pt and SF9Pt.

6.3.3.4.7 Conversion to side timbers

All the examples of smaller roundwood were converted into slight side timbers, in the bow at station 2 and as auxiliaries at stations 3 and 4. These were undoubtedly passive timbers fashioned to match the planking rather than determining the shape of the hull.

The larger roundwood and the segments were converted into more substantial side timbers. Those side timbers derived from segments of smaller limbs were fitted as the principal at stations 3 and 4 where there were also auxiliary side timbers. The side timbers derived from the larger roundwood (SF6.5Pt and SF9Pt) and those from segments of larger limbs (SF8Pt and SF9St) were fitted in the main hull of the boat and some of these may have been active frames determining the shape of the upper hull (see section 9.3.1). There is no significant difference in size between the side timbers in these two groups. It seems likely, therefore, that SF8Pt and SF9St were converted from offcuts from large limbs primarily used for a larger timber.

Five side timbers survive near complete in length (those listed in Table 6.1 except SF13Pt). SF8Pt extends from the lowest side strake P3 to the top strake P7. It is fastened to all these strakes except P3 that it is shaped to take against. SF9Pt extends from P4 to P7 and is fastened to all these strakes. SF6.5Pt, although broken near the top edge of P7, extends from *c* 0.13m above the sheer line to strake P4. It is fastened to P7, P6, and P5 and is shaped to take against P4. The upper end of SF4Pt(F) is broken, but a hole in a detached part of strake P7 may be where it was once fastened. It was also fastened to strakes P6, P5, and P4 where it ends. SF3Pt(M) extends from P7 to P3 and is fastened to all these except for P3 which it takes against. Side timber SF13Pt has not survived beyond strake P5. It is fastened to that strake and to P4 and takes against P3 (Table 6.1).

The lower part of each side timber overlaps its associated floor with lengths of overlap recorded varying from 0.23 to 0.36m. The lower ends of side timbers lie on either strake P3 or P4. The auxiliary side timber SF3Pt(F) has its upper end on strake P4, the remaining side timbers either extend to P7 or their upper end no longer exists. SF6.5Pt extends above the top of P7, while the other (near-) complete side timbers end somewhere on P7.

The data in Table 6.1 and the discussion above suggest that the builder did not have a standard length of side timber in mind. The minimum requirements were probably that each one should overlap its associated floor by at least one strake's breadth and that each should extend to strake P7 if at all possible. The timber available was matched to the station and to the height above the outer bottom plank of the upper ends of each individual floor. The side timbers were shaped along their length either to the curve of upper hull required, if active frames, or to match the planking already fastened to other frames, if passive (see section 9.3.1). Such curvature (Fig 6.14) is especially noticeable on SF4Pt(F), SF6.5Pt, SF8Pt, and SF9Pt. The cross sections of the side timbers are generally rectangular,

Table 6.1 Nails fastening selected side timbers to planking.

side timbers	*above sheer*	*fastened to*				
		P7	P6	P5	P4	P3
3Pt (M)	–	***1***	2	1	1	***ta***
4Pt (F)	–	***1***	2	1	***1***	-
6.5Pt	Y	1/2	2	2	***ta***	-
8Pt	–	***2***	2+2	2	2	***ta***
9Pt	–	***2***	2	2	***1***	-
13Pt	–	–	–	2	2+1	***ta***

Notes:
1 The side timbers chosen are those which have one or both ends (near-) complete.
2 ***Bold italic lettering*** = side timber (near) complete at this station.
3 'ta' = side timber takes against this strake.
4 '1/2' = one or possibly two nails
5 '2+2' and '2+1' = a strake butt with nails in each plank.
6 'Y' = side timber extends above sheer.

the moulded dimension being generally less than the siding (*m/s* in the range 0.6 to 0.93), except for two auxiliary side timbers which had sidings less than mouldings. Several of the smaller side timbers had been left with one face rounded.

The fastening rule which can be deduced from the data in Fig 6.3 and Table 6.1 is that strakes and principal side timbers were fastened together by two nails except at the lower ends of the latter where there was either one nail (9Pt) or no nail (6.5Pt, 8Pt, and 13Pt). Side timbers in the bows, where the planking is not so broad, were generally fastened by one nail except where there was room for two.

Planks within strakes were generally butted at floors or half-frames, but two planks in strake 6 were butted at SF8Pt and two in strake 4 at SF13Pt. The two planks butted at SF8Pt were each fastened by two nails; the butted planks at SF13Pt were each fastened by one nail, while a third nail seems to have been driven more or less through the butt – this may have been an error. Since SF8Pt is fastened to P4 and P5, there seems to be no structural reason why this side timber should not take a butted joint. On the other hand SF13Pt is not fastened to strake P3, merely shaped to take against it. It is, therefore, difficult to see how and when the butted planks in strake P4 were fastened to it, unless this was done after this side timber had been fastened to P5 and possibly to other, higher strakes (see section 9.3.4).

6.3.3.4.8 Boatbuilders' or tool marks (Fig 6.12)
There is a possible groove on the outer face of SF8Pt near seam P2/P3, similar to those found on many of the floors and half-frames.

6.3.3.4.9 Signs of use (Fig 6.15)
Towards the top of SF6.5Pt there is a 10mm groove angled downwards from outboard. The upper, outer end of this groove appears to be aligned with a sub-rectangular hole, 50 × 30mm through strake P7 (see section 6.3.4.4.9 and Fig 6.20). Since this side timber is abreast the mast step timber, it seems possible that this groove may have been for rigging (see section 8.3.1.3)

6.3.3.5 The half-frames (Fig 6.16)

There are five pairs of half-frames, port and starboard at stations 5, 7, 10, 12, and 15. Members of a pair lie alongside, but are not fastened to each other. The timbers in a pair overlap across the bottom of the boat. The forward member then rises up the port side, the

Figure 6.15 An angled groove cut into the after face of side timber SF6.5Pt towards its upper end. Inboard is to the right.

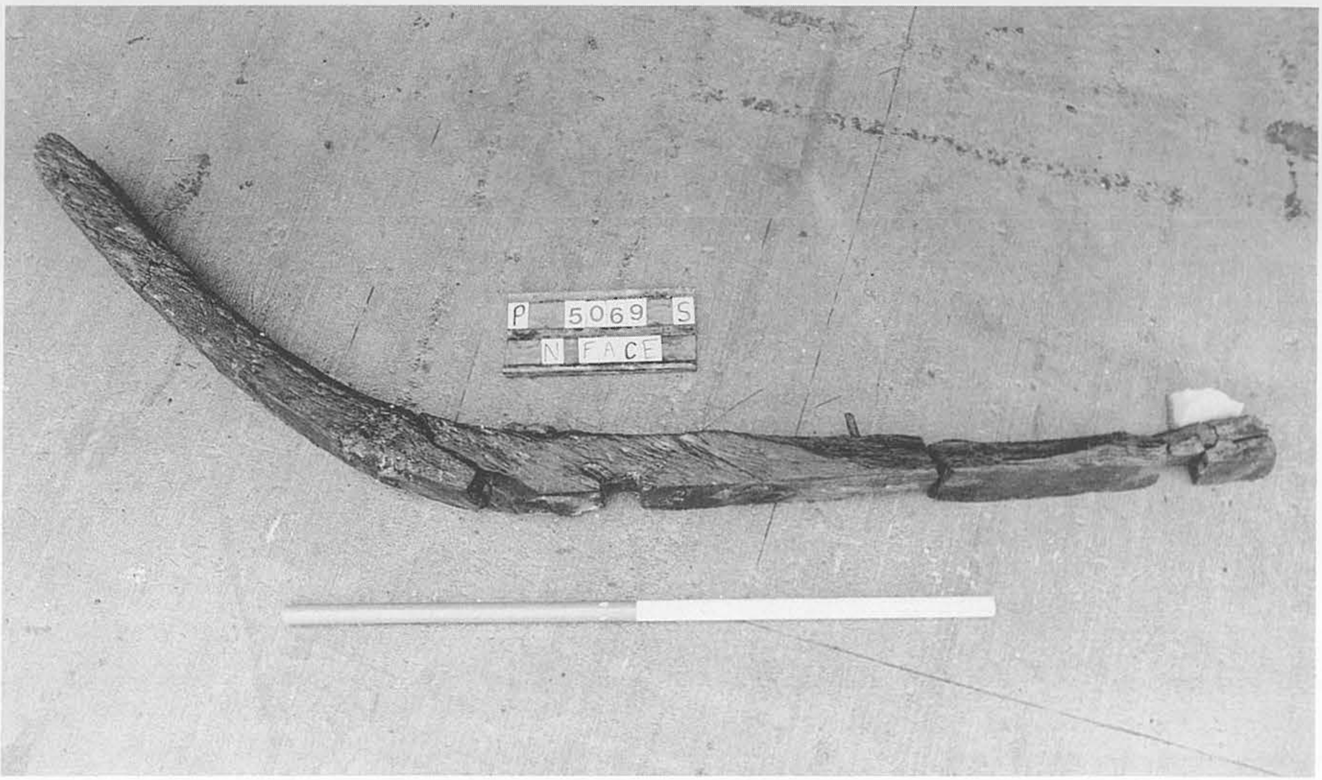


Figure 6.16 The after face of half-frame F7Pt showing (to the left) the curvature of the port side of the boat. Two limber holes are visible in the horizontal part of this half-frame. Note also the short grain.

after up the starboard. As a pair they extend from near the top of the port side to near the top of the starboard side. They do not have side-frames associated with them. In general terms the port half-frames are complete or very nearly so, the starboard ones fragmentary and displaced.

Of the port half-frames, 5Pt, 7Pt, and 10Pt extend from P7 – deduced to be the top strake – to S2, with the lower end of F5Pt shaped to take against the lowest side strake S3. F5Pt and 7Pt do not reach the upper edge of the top strake, but 10Pt probably does so and may protrude above it. F12Pt, which also appears to be complete at its upper end, extends only from P5 to S2 where it is broken. A 'ghost' on S2 shows, however, that it formerly extended right across that outer bottom plank. The upper ends of the starboard half-frames do not survive, the highest being 7St which is broken off at S5; F5St, 10St, and 12St now end at strake S4. Since F12Pt appears not to have extended to the top strake, it cannot be assumed that these starboard half-frames formerly extended higher than, say, S5. It seems likely, however, that by analogy with the port half-frames at stations 5, 7, and 10, some of them probably reached to S7.

Of the three framing timbers at station 15 (Figs 6.2 and 6.17), the foremost (F15) is a floor that was probably added as a reinforcement during the boat's useful life (see section 7.6.1). The other two timbers now extend only from P3 to S2. The general framing pattern and the relatively slight dimensions of these two suggest, however, that they were originally half-frames rather than floor timbers. Furthermore there are fastening holes in strakes P3 and P4 which are in line with the forward one of these two timbers. The lower end of this timber although broken appears to have stopped short of S3. Thus this timber almost certainly formerly extended across the bottom of the boat and up the port side. The lower end of the after member of this pair has certainly been fashioned to take against P3; the starboard planking here has not survived. It seems most likely, therefore, that the central and after timbers at station 15 are the remains of a pair of half-frames, F15 Pt being the central one and F15 St the after one.

The cross sections of half-frames are generally rectangular and there is no sign of planking convergence on any of them. The *m/s* ratios of the horizontal part of these timbers lie in the range 0.71 to 0.86 (their thickness is 70 to 90% of their breadth) except for 7St (0.48) and 12St (0.60). These latter half-frames, with $m \times s$ products in the region of $0.06m^2$, are clearly much slighter timbers than the remaining half-frames

Figure 6.17 Looking aft towards the stone structure. From the bottom of this photograph the timbers are: floor F15; half-frame F15Pt; half-frame F15St; and floor F16.

which have $m \times s$ in the range 0.08 to 0.12m². Except for 7St and 12St again, the horizontal parts of the half-frames have similar moulded dimensions (thickness), in the range 80 to 90mm that is similar to that of five of the main floors. This suggests that it may have been possible to fit bottom boards (a decking of loose planks) on these floors and half-frames in the midships section between, say, F6 and F15St.

Some or all of these pairs of half-frames may have been 'active' frames which, depending on the sequence of building, either determined the shape of the boat's hull between the two keel/post scarfs from the lowest (P3, S3) to the highest (P7, S7) side strakes (possibly in conjunction with main floors), or they merely determined the shape of the upper hull, from strake 5 to strake 7 (possibly in conjunction with side-frames). From this set of half-frames derives a general impression of the main body of the lower hull similar to that from the main floors – a flat bottom and gracefully curving sides, with a radius of 0.85 to 0.90m (mean: 0.87m ± 0.02m), flaring outwards at 60 to 70° (Fig 6.16). Additionally the half-frames show that this flare is reduced to 30 to 40° in the upper hull, ie the sides become more upright. At their respective stations half-frames 5Pt and 7Pt show that the sheer line (ie the upper edge of the top strake P7) was more than 0.85m and 0.75m above the bottom planking. As recorded F10Pt appears to have a vertical arm that would have extended above the sheer line: this needs to be investigated when the timbers are reassembled for display.

Taken as a pair it is noticeable that the half-frames nearest to the centre of the boat (F10Pt and St) are more massive than the others. The two half-frames at this station and at station 5 are reasonably well matched within their pairs. Half-frames F7St and 12St on the other hand are significantly slighter than their partners.

Measured along the boat's centreline from centre of pair to centre of pair the half-frames are spaced from forward: 1.11m; 1.65m; 1.11m; and 1.63m. These intervals appear to cluster around 1.11m and 1.64m (Tables 6.2 and see Table 6.4). As with the intervals between the main floors (see section 6.3.3.3) this clustering raises the possibility that these half-frames were placed at intervals based on a unit of 0.27m or 0.28m – possibly some human foot. An alternative way of looking at these half-frames is that they are more or less midway between adjacent main floors. Spacings in this case are then: F4 /0.56m /F5 /0.55m

Table 6.2 Frame spacings

station	*type of framing*	*distance from F4*	*spacing*
4	A	0	0
5	B	0.56	0.56
6	A or A*	1.11	0.55
7	B	1.67	0.56
8	A	2.24	0.57
9	A	2.79	0.55
10	B	3.32	0.53
–		3.59	mid-length of plank-keel
11	A or A*	3.86	0.54
12	B	4.43	0.57
13	A	5.00	0.57
14	A	5.52	0.52
15	B	6.06	0.54
16	A	6.60	0.54
17	A	7.18	0.58

Notes:
1 Distances are in metres and from centre to centre.
2 Floor F15 is omitted since it is considered to be secondary.
3 Type A framing groups have a floor and associated side timbers.
Type A* framing groups have, on present evidence, only a floor.
Type B framing groups have a pair of half-frames.

/F6/ 0.56m/ F7/ 0.57m/F8; F9/ 0.53m/ F10 /0.54m/ F11/ 0.57m /F12/ 0.57m/ F13; F14/ 0.54m/ F15/ 0.54m /F16. These measurements cluster around 0.55m, a multiple of 0.275m.

Half-frames 10Pt, 12Pt, and 12St were positioned in the framework with the butt ends of their parent timbers to port, while the butt of 7St was probably to starboard. They had all been fashioned from natural oak crooks. The port arms of F10Pt and 12Pt each came from a main limb, while their horizontal parts came from a branch. In a corresponding manner, the starboard arm of F7St came from a main limb and its horizontal part from a branch. F12St, however, unusually in this boat, had its starboard arm from a branch and its horizontal portion from a main limb. Two limber holes were cut in the outer face of each floor. The breadths of these holes range from 40 to 60mm (mean *c* 52mm) and their depths from 15 to 30mm (mean *c* 21mm). These ranges and means are similar to those for the main floor limber holes.

6.3.3.5.1 Fastenings (Fig 6.3)

Each half-frame is fastened to the plank-keel by one nail each to P1 and S1.The outer bottom planks P2 and S2 are generally fastened to each half-frame by two nails except near the lower end of a half-frame where there may be only one. Apparent anomalies (in that they should have two nails but actually have one) are: on S2 – F5St, 7St and 10St; on P2 – F7Pt and 15Pt. As the three starboard frames and the adjacent planking are broken at these positions, evidence for fastenings may, therefore, have been lost. One of the two nails fastening the outer bottom plank P2 to F15St has been, unusually, driven from inboard and clenched by turning the tip through only 90° to lie along the outer face of P2.

The side strakes are fastened to each half-frame by two nails except where there is a butt when there are four, ie two in each plank. Anomalies here are: on P3 – F15Pt; on P5 – F7Pt.

This analysis leaves the single nail fastenings of P2 at F7Pt and F15Pt, P3 at F15Pt, and P5 at F7Pt as probable mistakes.

The after end of the mast-step timber overlaps half-frames F7 Pt and St and is fastened to each one by a spike driven from above. Another spike appears to have been driven from within the mast step itself at an angle into the forward edge of F7Pt.

6.3.3.5.2 Builders' marks or tool marks? (Fig 6.12)

Each timber in the pair of half-frames at stations 7, 10, and 12 has one or more shallow, near-horizontal grooves worked across its outer face (see Table 7.1).

6.3.3.6 The framing pattern

The plank-keel is 7.18m long with its mid-point between half-frame F10St and floor F11. The two key floor timbers (F4 and 17) are positioned over the ends of this plank-keel and they effectively define the extent of the main hull of this boat (Fig 6.2). Three types of framing groups can be recognised within this main hull:

A A floor timber with associated side timbers. This type is at stations 4, 8, 9, 13, 14, 16 (probably), and 17. Floor F15 is not included as it is considered to have been fitted some time after the boat was built.

A* A floor timber. Stations 6 and 11 are provisionally identified as having this type.

B A pair of half-frames. This type is at stations 5, 7, 10, 12, and 15.

The sequence of floors and half-frames within the main hull and the spacing intervals between consecutive floors (types A and A*), between consecutive half-frames (type B) and between framing groups of all types may throw some light on the techniques and the mind-set of the boatbuilder (Tables 6.2 to 6.4). The only difference between types A and A* is that the two floors in the latter group do not appear to have associated side timbers. In terms of the general framing pattern, this distinction is a minor one. The framing pattern is, therefore, investigated on the assumption that there is no significant difference between framing group types A and A*.

6.3.3.6.1 Sequence of framing timbers
If F11 is taken as a 'master frame' there is a certain regularity in the sequence of floors and half-frames (Table 6.2). From F11 (which is type A), towards both the bow and the stern, the timber group sequence is: B A A B A; after that the sequence breaks down with B A forward but only A aft. Whether there are structural reasons for this sequence is not immediately clear. Taking F10 or F9 as 'master-frame' leads to no discernible pattern.

6.3.3.6.2 Spacing between timbers
Four measures of spacing may be considered:

1 The fourteen framing groups (F4–F17) within the main hull are spaced, centre to centre, at intervals ranging from 0.52m to 0.58m (Table 6.2): the mean and standard deviation is: 0.552m ± 0.017m (n=13).

2 The spacing between the floor timbers alone (Table 6.3), centre to centre, ranges from 0.52 to 0.58m with a mean and standard deviation of 0.550m ± 0.024m (n=3); and from 1.07 to 1.14m with a mean and standard deviation of 1.106m ± 0.027m (n=5): if these measurements are standardised and pooled the combined mean and standard deviation is: 0.552m ± 0.019m (n=8).

Table 6.3 Spacing between floors.

station	*distance from F4*	*spacing of floors*
post	1.90	–
4	0	0
6	1.11	1.11
8	2.24	1.13
9	2.79	0.55
11	3.86	1.07
13	5.00	1.14
14	5.52	0.52
16	6.60	1.08
17	7.18	0.58
post	8.28	–

Table 6.4 Spacing between half-frames.

station	*distance from F4*	*spacing of half-frames*
post	1.90	–
5	0.56	0
7	1.67	1.11
10	3.32	1.65
12	4.43	1.11
15	6.06	1.63
post	8.28	–

3 The spacing between half-frames alone (Table 6.4), centre to centre, is 1.11m (n=2); and from 1.65 to 1.63m with a mean of 1.64 (n=2). If these measurements are standardised and pooled the combined mean and standard deviation is: 0.547m ± 0.012m (n=4).

4 The spacings between each half-frame and the floor timbers on each side of it range from 0.53 to 0.58m; the mean and standard deviation is: 0.554m ± 0.016m (n=10).

The data in these four measures of spacings contain some duplication. Independence and non-duplication between the data in two or more of these measures depend on the sequence of positioning the floors and half-frames. If, for example, the floors were first positioned and then the half-frames were placed halfway between some of them, data in group 2 (floors alone) would be independent of data in group 4 (half-frames and adjacent floors) and, therefore, conclusions could be drawn from both these spacing measures.

Other sequences are possible (see Fig 9.1), but whatever the sequence the four groups of measurements cannot all be used together. Which groups can validly be used depends on the building sequence and this is considered further below (sections 9.3.4–9.3.5). Nevertheless the fact that all four measures have means which are very close together (0.547 to 0.554m) and have very low standard deviations (the greatest is only 19mm) suggests that a unit of measurement was used to position framing timbers in the main hull of this boat, one that was equivalent to *c* 0.551m. If natural units were used this would be approximately two human feet. In this case the unit of measure would be equivalent to *c* 0.275m.

6.3.3.7 Other framing timbers

The evidence for other framing elements is indirect and sparse: it is considered in Section 8.2. Suffice it to point out here that the hull defined by the timbers excavated would, from a theoretical structural viewpoint, need further stiffening using such timbers as crossbeams with knees and/or beam shelves. Such crossbeams could also be used as thwarts with one also used as a mast beam.

6.3.4 The planking (Fig 6.2)

6.3.4.1 The outer bottom planks (see Figs A2.39 and A2.40)

The two outer bottom planks lie outboard of the plank-keel, P2 to port and S2 to starboard. They extend most of the length of the boat's bottom from floor F4 to F17 and at their forward end they butt respectively against bow bottom planks BP and BS. Originally they probably also butted against similar planks aft. P2 and S2 are similar in size and shape and it is likely that they came from the same parent oak. Both planks were fashioned tangentially close to the pith of their parent tree and were positioned in the boat with their pith-facing face outboard, P2 with its butt end forward, S2 with its butt end aft. The inboard edge of each plank matches the corresponding edge of the plank-keel, while the outboard edge of each has been worked to a curved shape in plan to form the outer edge (chine) of the boat's bottom. The planks are both 7.18m in length, the same as the plank-keel; breadths are: forward P2 – 0.175m and S2 – 0.105m; aft P2 – 0.104m and S2 – 0.175m; thickness *c* 45mm. Each outer bottom plank would have weighed *c* 70kg.

When the outer bottom planks are tightly positioned alongside the plank-keel, which is 0.53m broad at the ends and 0.55m amidships, the four planks together (P2, P1, S1, and S2) form a planked area which is 0.81m broad at bow and stern and 1.27m broad amidships. This is extended by the bow bottom planks to meet the lower part of the stem post. There was probably a similar, but shorter extension aft, making the total length of the bottom *c* 9.5m, including an upcurve over the final 0.45m at each end to match the rising posts.

The outer bottom planks have a rectangular cross section. Their ends and the inboard edges are normal to the plank faces and their outboard edges have each been worked to a bevel with a rounded lower corner. Both bevels are shaped to take a plank 30mm thick (the lowest side strake) at a flare angle of *c* 70 to 80°.

As on the plank-keel, 'ghosts' or 'shadows' of the framing timbers can be seen on the upper face of each outer bottom plank. Additionally the position of the limber holes is outlined.

6.3.4.1.1 Fastenings (Fig 6.3)

Each outer bottom plank was fastened by one nail at the ends to floors F4 and F17 and by two nails to F6, F8, F9, F11, F13–F15, and F17. Plank P2 was fastened to F16 by two nails, but S2 by only one – this latter is probably a mistake. The pattern of fastenings to the half-frames is not so obviously regular. Plank P2 is fastened by two nails to F7St, F10Pt, and F12Pt; S2 is fastened by two nails to F5Pt, F7Pt, F10Pt, F12St, and F15St. The single nail fastenings of P2 to F5St,

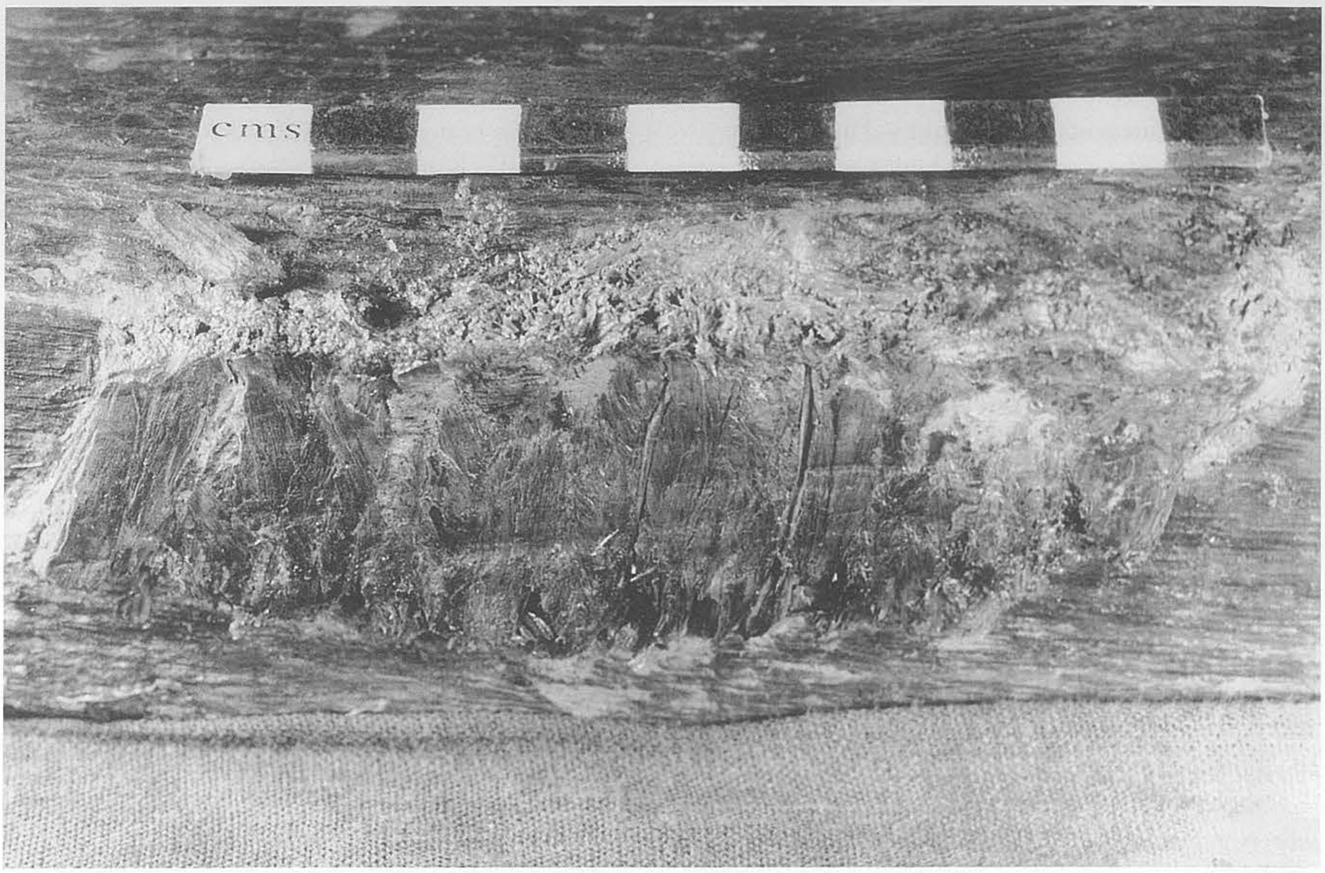


Figure 6.18 Caulking along an edge of outer bottom plank S2.

F12St, and F15St and those of S2 to F12Pt and F15Pt are explicable as they each are close to the end of a half-frame. The single nails between S2 and F5St, F7St, and F10St may be more apparent than real since these three half-frames were found to be broken near this position and evidence for nails in frames and planking may have been lost. This leaves only the single nail fastenings of P2 to F5Pt and F7Pt as probable mistakes amongst the half-frame fastenings.

Caulking (Fig 6.18) similar to that found elsewhere in the boat (Table 3.3.4) was found on both edges of S2 and impressions of small nails were noted in several places along the inboard edge of P2.

6.3.4.1.2 Repairs

An extra nail had been driven unusually from inboard through half-frame F15St and outer bottom plank P2 and clenched by turning the tip through (exceptionally) 90° so that it points aft along the outer face of the plank.

6.3.4.1.3 Signs of use

Between half-frame F5St and floor F6 (Fig 6.9A) the worn area on the inner face of the plank-keel (see section 6.3.1.5) is extended to the outer bottom planks. Plank P2 is worn down by *c* 13mm next to P1 decreasing to *c* 7mm near P3. There is also slight wear on S2 next to plank-keel element S1.

As on the plank-keel there is a groove 1 or 2 mm deep on the outer face of plank S2 near the leading edge of floor F6.

6.3.4.2 The bow bottom planks (see Figs A2.41 and A2.42)

The two bow bottom planks BP and BS lie to port and starboard alongside the horizontal part of the stem post from near bow floor F1 to main floor F4 where they butt with the outer bottom planks (P2 and S2) and with part of the plank-keel (P1 and S1). They thus extend the boat's main bottom planking forward by *c* 1.4m. The lowest side strakes P3 and S3 are outboard of the bow bottom planks.

These planks are generally fashioned tangentially, but towards the bow where they have both been given a graceful hewn curve to match the lowest part of the rising stem post, plank BP has been worked across the pith of its parent oak. This plank has been positioned in the boat so that its face, which is mostly pith-facing, is inboard. BS has its corresponding face outboard, which is the norm for this boat's planking. Both planks have their butt end aft.

The forward end of each plank is a squared point; the after end and the edge next to the post are normal to the plank faces. The outboard edge has a bevel of *c* 10° from the vertical, giving the adjoining lowest side strakes (P3 and S3) a corresponding flare of *c* 80°. At its forward end the outer face of BS (and possibly BP) is chamfered next to the post for a distance of *c* 0.25m to match the curve of the sides.

The planks' breadths decrease regularly from aft, where they are 0.28 to 0.29m broad, thereby continuing the incurving of the outer edges of the outer bottom planks towards the post, where they are *c* 30mm broad. BP is 1.36m in length and BS 1.42m. Although generally of rectangular cross section, these two planks do not have a constant thickness since they are effectively transition strakes between the main part of the bottom planking, the side planking, and the post. Aft they are 50mm thick alongside the post and the plank-keel, decreasing to 40mm next to the outer bottom planks and the lowest side strakes. Further forward they increase to *c* 70mm to match the post, reducing to *c* 50mm as the post curves upwards. They remain generally thinner, however, at their outboard edges where they meet the lowest side strakes. It seems likely that these planks were overthick when fastened in position and their outer faces were then adzed to shape to match the adjoining planking and the post. When finished such planks would each have weighed 10 to 12kg.

Notches worked across the inner faces of the bow bottom planks are housings for main floor F4 and bow floors F2 and F3. Since the horizontal portions of these floor timbers are not symmetrical port and starboard and do not have a constant moulded dimension (thickness), these notches are different in the two bow planks. In BP they are *c* 25mm deep for F2, F3, and the forward 100mm of F4, while in BS, F2 has a notch 12mm deep, there is no notch for F3, and there is only a shallow depression for F4. It seems likely that these differential housings are to allow the inner faces of the bow floors to lie horizontally. The housings for F2 and F3, which would probably have been cut after BP and BS had been fastened to the post and to floor F4, do not ensure a tight fit to these two bow floors. On the other hand the housing for the port side of F4, which would have been cut before BP was fastened, gives a tighter fit, probably to reinforce the vital double-notch joint between floor and post.

6.3.4.2.2 Fastenings

Each bow bottom plank is fastened at its forward end by a horizontal spike through its edges to the post just aft of the lower end of the rabbet for the side strakes and by two nails to floor F4. Bow floor F1 is fastened by one nail to BS (BP does not extend this far forward). F2 is fastened by one nail each to the two planks. F3 is fastened by one nail to BP; a nail fastening F3 to lowest side strake S3 just clips BS.

6.3.4.3 The stern bottom planks

It is likely that there were two planks similar to but shorter than BP and BS in the stern of this boat (see section 8.2).

6.3.4.4 The port-side strakes (Fig 6.19 and see Figs A2.43–A2.54)

Elements of five port-side strakes (P3 to P7) have survived. Individual planks within each strake from the bow (southern end) are:

P3(A) 5122; (A*) 5121(part); (B) 5110; (C) 5109;
P4(A) 5118; (B) 5117; (C) 5108;
P5(A) 5129; (B) 5119; (C) 5106;
P6(A) 5130; (B) 5120;
P7(A) 5121.

6.3.4.4.1 Strake P3

Approximately 9.85m of the lowest side strake (P3) survives, extending from the stem post to aft of F17, where it has a broken end. Plank P3A and fragment P3A*, *c* 0.8m in length, are in a reasonable condition. The foremost *c* 2m of plank P3B, a substantial plank some 7m in length, is broken and pieces are missing. This section is so fragile that the inner face cannot be recorded until its conservation is completed. The remainder of this plank is in a reasonable condition and 'ghosts' of the framing timbers from F6 to F9 have been preserved on its inner face. Plank P3C is just over 2m in length. A large part of the upper edge aft is missing.

The lower edge of P3 is curved longitudinally so that the breadth of this strake tapers from each end, where it is 0.26m, towards the centre of the boat, where it is 0.17m. This distinctive shape is needed so that its lower edge fits the curve of the outer bottom plank P2 and so that its upper edge runs near horizontally in its seam with strake P4.

The cross section is rectangular. Plank thickness increases from *c* 20mm forward to 25 to 30mm in the central parts of the boat.

The forward ends of plank P3A and fragment P3A*

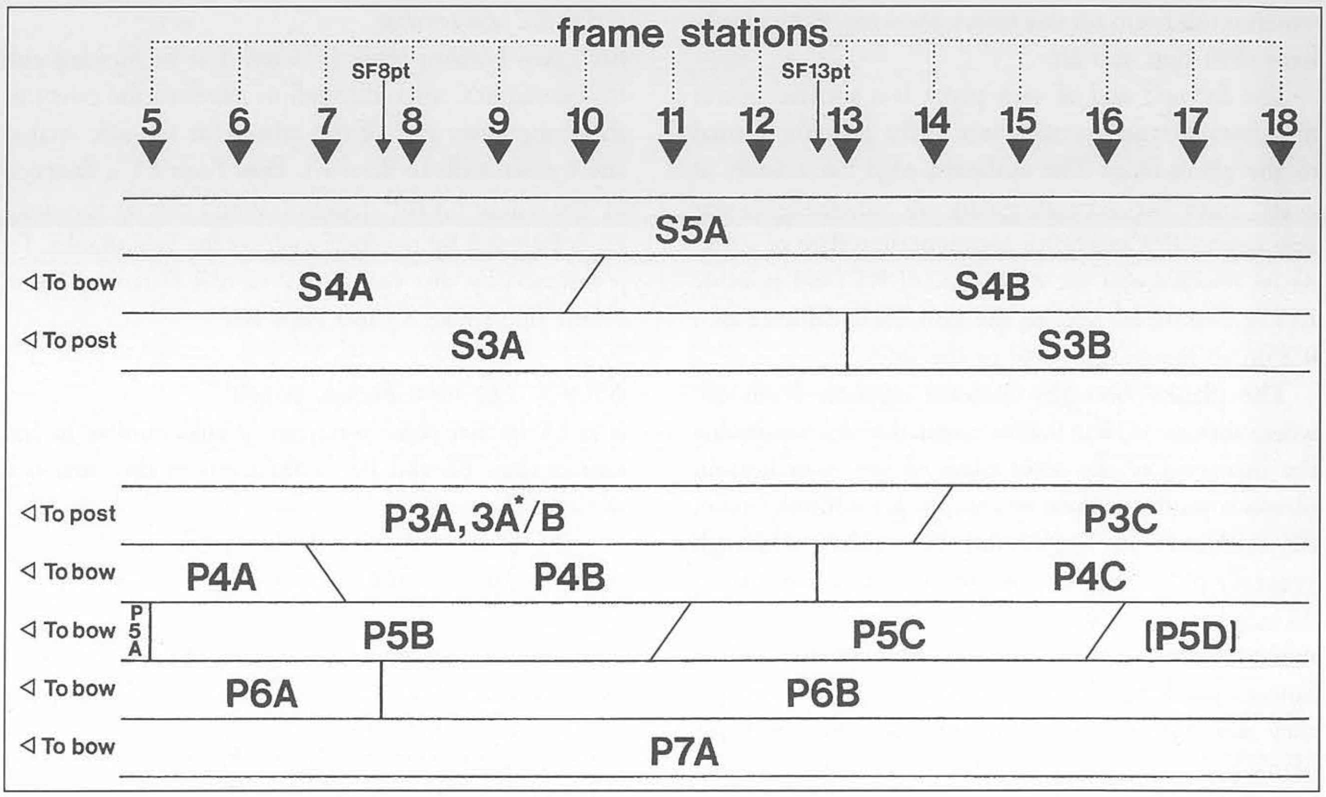


Figure 6.19 Diagram to show the position of known butt joints in the side planking, viewed from inside the boat.

are bevelled to fit into the stem post rabbet and shaped to match the angle of the stem post, here rising at 20 to 25° to the run of strake P3. The lower edge of P3A has an inner bevel where it fits against bow bottom plank BP. The upper edge of this strake appears to be normal to the plank faces where it fits into P3B; the lower edge has an outer bevel of *c* 10° where it fits against the outer bottom plank P2. Plank P3A and fragment P3A* together appear to be a repair set into the lower edge of P3B close to the post. This hypothesis needs to be investigated during the reassembly of the hull.

Planks P3B and P3C meet at floor F14 in a butt which is cut at an angle down and towards the stern. On the measured drawings the butt end of P3C is shown as 6mm thicker than P3B. There may have been an anamolous recording or it may be that this was a real discrepancy that was allowed for in the shaping of floor F14: this should be checked when the boat is reassembled.

6.3.4.4.2 Strake P4

Strake P4 is some 9.6m in length and survives from near the stem post to the vicinity of F17. It is broken at both ends. Plank P4A, is 4.13m long and is in a similar, two-state condition to plank P3B, with 'ghosts' of framing from F4 to F7Pt. Plank P4B is 3.22m long and in a reasonable condition, while plank P4C (2.25m long) is in a similar state to plank P3C.

This strake is *c* 0.165m broad near the bow, increasing to 0.24 to 0.255m over the midships region, where it is near parallel-sided and decreasing to *c* 0.2m as it approaches the stern.

The cross section is rectangular and plank thickness ranges from *c* 24mm forward, 30 to 35mm near amidships, to *c* 25 mm towards the stern.

The lower edge of plank P4A near the post appears to have a bevel, otherwise this edge is normal to the plank faces. The upper edge has an inner bevel of *c* 10°. Planks P4A and P4B meet at half-frame F7Pt in a butt that is angled down and forward; planks P4B and P4C have a vertical butt at SF13Pt. The problem of fastening this latter butt when side timber SF13Pt was not itself fastened to strake 3 is discussed elsewhere (see section 9.3.4). The drawings of the planks butted at F7Pt and at SF13Pt show that P4B is 8mm thicker than P4A and 12mm thicker than P4C. It has not yet proved possible to determine whether these were anomalous measurements or whether plank P4B was a repair.

6.3.4.4.3 Strake P5

This strake is *c* 7.76m in length and survives from near the stem post, where it is broken, to floor F16 where there was formerly a butt joint with a now missing plank P5D. The remains of plank P5A (1.7m long) are very fragmentary and the inner face cannot yet be recorded. Plank P5B (3.31m long) is in a better condition, but nevertheless the forward part of its inner face remains to be recorded. The inner face of plank P5C (measuring 2.75m in length) has similarly not been recorded and a large part of the upper edge aft is missing.

The breadth of this strake increases quickly from *c* 0.145m near the bow to a more parallel-sided length, with breadths between 0.255 and 0.275m decreasing to 0.260m at F16. The cross section is rectangular. Plank thickness increases from *c* 16mm forward to 22 to 25mm near amidships decreasing to *c* 20mm towards the stern.

The upper edge of this strake has a slight bevel over its middle length. Planks P5A and P5B meet at half-frame F5Pt in a vertical butt, planks P5B and P5C meet at floor F11, and plank P5C meets the missing P5D at floor F16 in butts which are angled down and aft.

6.3.4.4.4 Strake P6

Approximately 4.24m of strake P6 has survived, extending from near the stem post to aft of F10Pt. Both ends are broken. The whole of plank P6A (3.5m in length) is fragmented, much is missing, and the forward part of the inner face cannot yet be recorded. Plank P6B (1.74m long), though broken, is in a slightly better condition and the 'ghost' of SF9Pt is visible on the inner face. Further aft part of the upper edge of this plank is missing and the inner face here cannot be recorded until its conservation is completed.

The breadth of this strake near the bow is *c* 0.255m increasing to 0.27 to 0.3m towards amidships. A slight decrease in breadth begins as it nears F10Pt. The cross section is rectangular, and plank thickness increases from 20mm at the bow to 24mm. The upper edge of this strake has a probable bevel over its central lengths. Planks P6A and P6B meet at side timber SF8Pt in a vertical butt.

6.3.4.4.5 Strake P7

Elements of strake P7, the top strake, survive from the bow region to aft of SF9Pt, a length of *c* 4m. Two fastening holes near the top of half-frame F10Pt show that this strake originally extended at least as far as that station, making a minimum length of *c* 4.6m. The remains are fragmented and much is missing, but the growth rates, the breadths, and the general nature of the four main fragments are very similar, suggesting that they all came from plank P7A.

These fragments have breadths within the range 0.23 to 0.25m, with an apparent minimum near F7Pt. The cross section of the plank is rectangular and its thickness *c* 25mm.

6.3.4.4.6 Planks within strakes (Fig 6.19)

Given that the short plank P3A with fragment P3A* is a repair or insert, eleven planks or parts of planks survived on the port side. Plank P3C was fashioned across the diameter of its parent log, with the pith central along the length of this plank. P6A was worked across the pith at a slight angle. The remaining planks were converted tangentially, of which five were fashioned close to the pith, but P5A, P5C, P6B, and P7A were some distance away. Planks were generally fastened to the framing with the face outboard that had been closest to the pith of the parent log, but three planks (P4A, P5B, and P6B) had this face inboard. Three planks (P3B, P3C, and P4B) were positioned with the end that had been lowest in the parent tree (nearest the butt end) towards the bow of the boat: P4C, P5C, P6B, and P7A may have been positioned similarly. On the other hand plank P4A had its butt end aft and P5A, P5B, and P6A may have been similar.

Of the six planks that survived complete or near complete, plank P3B is the longest at *c* 7m. It probably would have weighed *c* 30kg. The others, P3C, P4A, P4B, P5B, and P5C have lengths in the range 4.13 to 2.05m and probable had weights, which because of varying thickness do not necessarily match lengths, ranging from 13 to 21kg.

6.3.4.4.7 Fastening pattern (Fig 6.3)

The rule for fastening the port planking to the framing appears to be two nails to every floor, half-frame and side timber with the following exceptions:

- insubstantial timbers such as floor F1 and side timbers SF1, SF 2, SF 3, and SF4, where there is generally room for only one nail;
- at the upper end of floors F3, F6, F14, and F15 and half-frame F5Pt and at the upper or lower end of substantial side timbers SF6.5 Pt and SF9Pt, where there is room only for one nail;
- at the lower ends of substantial side timbers SF8Pt and SF13Pt and the upper ends of floors F4 and F13 which only take against a strake and are not fastened to it.

There are a number of deviations from this deduced pattern:

- strake P3 is fastened to floor F4 by only one nail; this seems to be a mistake; however, strake S3 is similar;
- strake P3 is fastened to floor F9 by only one nail; however, this strake is at its narrowest at this station and it was probably decided that there was insufficient space for two nails;
- strake P3 is fastened to half-frame F15Pt by only one nail; this is probably a mistake;
- strakes P3 and P4 are each fastened to floor F15 by only one nail; this may be because this floor was probably added to the hull as a reinforcement sometime after construction;
- planks P4B and P4C share one nail in the butt joint at side timber SF13Pt; this was probably a mistake;
- strake P5 is fastened by only one nail to half-frame F7Pt; this was probably a mistake.

In addition nail holes in the stem post rabbet show that the forward ends of all port-side strakes were spiked to the post. There are corresponding holes in P3A (one) and in P3A* (two).

6.3.4.4.8 Repairs

The possible mismatch in thickness between P4B and its neighbours P4A and P4C may be because P4B was a replacement plank. The short and narrow plank P3A, with the fragment P3A*, was also probably a replacement fitted into a broken part of the forward end of P3B and fastened to the post and to side frame SF2Pt. A longitudinal split *c* 100mm long in the outer face of P6A near its after end has had caulking forced into it to prevent leakage.

6.3.4.4.9 Signs of use (Fig 6.20)

A sub-rectangular hole (50 × 30mm), with wear on its upper forward corner, has been cut through plank P7A near its top edge. This hole appears to be in line with or close to an angular groove on the after face of side timber SF6.5Pt (section 6.3.3.4.9) and may have been a lead for rigging.

6.3.4.4.10 Builders' marks?

A shallow mark was scribed across the inner face of plank P3B at the forward edge of floor F8 adjacent to side timber SF8Pt and across the inner face of P4C at the forward edge of floor F13 adjacent to side timber SF13Pt (see below 7.1.2).

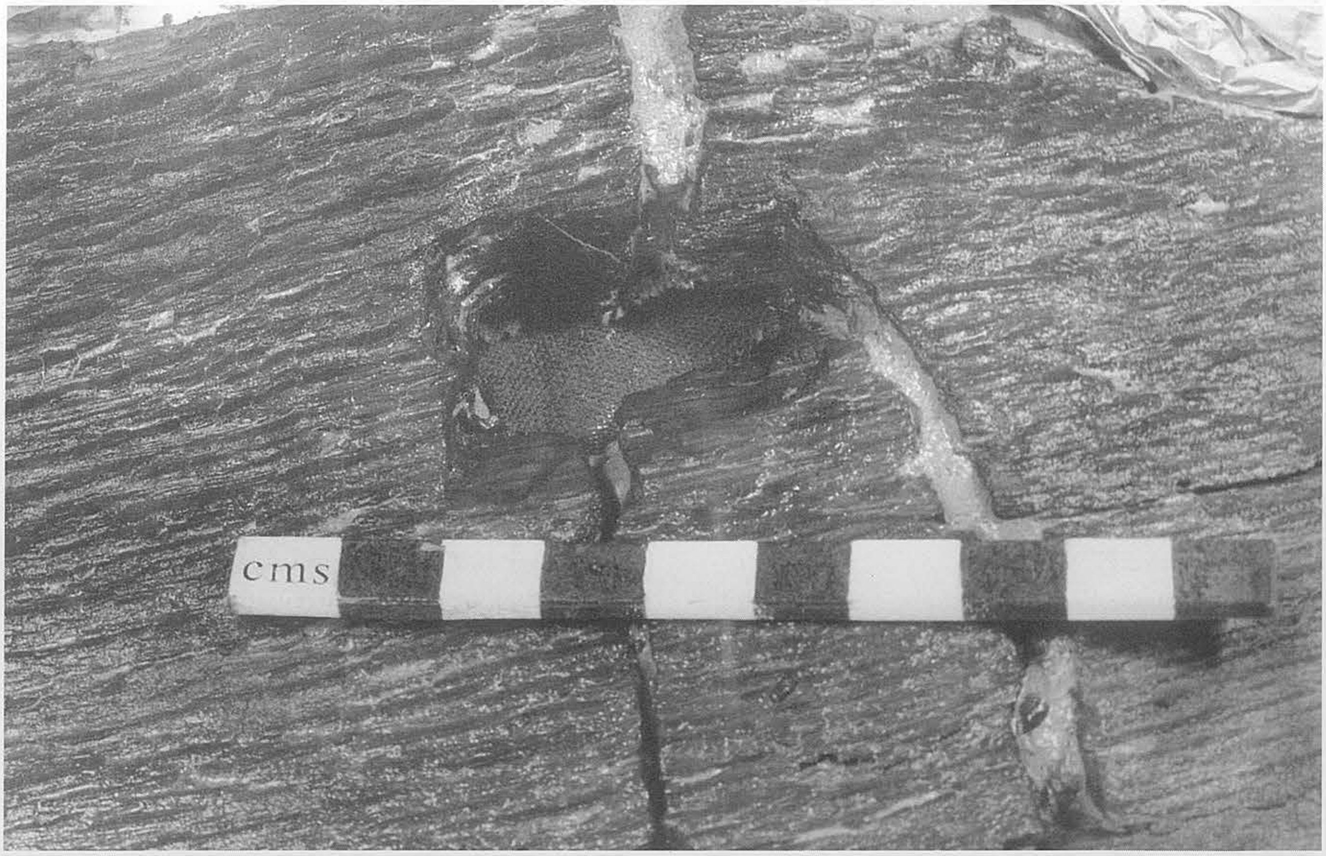


Figure 6.20 The sub-rectangular hole through plank P7A.

6.3.4.5 The starboard-side strakes (Fig 6.19 and see Figs A2.55–A2.59)

Elements of three starboard-side strakes (S3 to S5) have survived. Individual planks within each strake from the bow (southern end) are S3A (5127), S3B (5126), S4A (5137), S4B (5128), and S5A (5139).

All three strakes are fragmentary and fragmented and, because of their fragile nature, it has not yet proved possible to record their inner faces. The condition of the plank edges is such that any bevels cannot be recognised.

6.3.4.5.1 Strake S3

Approximately 8m of S3, the lowest side strake, survives. It extends from forward of bow floor F1 to the vicinity of floor F15. Both ends are broken. Plank S3A is *c* 6.92m in length and S3B, *c* 1.05m. These two planks are butted at floor F13; whether this butt is angled or not is impossible to judge.

Like P3 the lower edge of S3 is curved longitudinally and the plank tapers in breadth from *c* 0.24m, near the ends of the boat, to *c* 0.2m near the midships station. The cross section is generally rectangular. Plank thickness increases from *c* 20mm forward to *c* 23mm near amidships.

6.3.4.5.2 Strake S4

Strake S4 survives for *c* 6m, extending from near bow floor F2 to the vicinity of floor F14. Both ends are now broken. The six units that appear to form plank S4A are fragmented and there are gaps between units. It may be that there was a butt joint in one of these gaps, since some units have their pith-facing face inboard and some outboard. The variation in orientation may, however, be because this plank was converted across the pith of its parent log (as were P6A and S3A). Furthermore the growth rates of all the units are very similar, knots are about the same size and frequency, and the implied original length of something over 3.68m would match the corresponding port plank P4A. Until these remains are reassembled, they are, therefore, best thought of as one plank. Plank S4B is now *c* 2.26m in length. The butt between these two planks at half-frame F10St is angled down and towards the bow.

This strake appears to be *c* 0.15m broad forward, increasing to 0.22 to 0.24m. The cross section is generally rectangular. Plank thickness increases from *c* 20mm near the bow to 25mm or more near amidships. The drawings of the two planks butted at F10St show S4B to be 5–10mm thicker than S4A; it has not yet proved possible to determine whether this was an anomalous measurement.

6.3.4.5.3 Strake S5

Only *c* 3.5m of strake S5 survives, extending from the vicinity of floor F6 to near floor F12. Both ends are broken. The four units that form this strake seem likely to be fragments of one plank since they have similar growth rates, similar knots, and similar alignment of faces. This strake appears to be *c* 0.155m broad, with a thickness increasing from 20mm forward to *c* 28mm.

6.3.4.5.4 Planking within strakes

Parts of only five planks survive on the starboard side and not one is complete, although S3A is nearly so. This plank of *c* 7m was originally probably the longest. Apart from S5A, the length of which is indeterminate, the other surviving planks cannot have been longer than plank S4A which was a little over 4m in length. Plank S3A probably weighed *c* 27 kg; it is not possible to estimate the original weight of the others.

Plank S3A was fashioned at a slight angle across the pith of its parent log; plank S4A may have been similar. Planks S4B and S5A were fashioned tangentially some distance from the pith and they were fastened to the framing with their pith-facing face outboard. Planks S3A and S5A were positioned with their butt end forward.

6.3.4.5.5 Fastening pattern (Fig 6.3)

The remains of the starboard planking are fragmentary and fragmented, but the fastening rule seems to be the same as for the port side: two nails to every framing timber except where there is only room for one on insubstantial timbers, at the upper ends of certain floors, and the lower ends of certain side timbers. Most of the deviations from this pattern can be explained by missing parts of frames or planks but the one that cannot is on strake S3 that, like P3, is fastened to floor F4 by only one nail: this may be a mistake.

6.3.4.6 The planking pattern

6.3.4.6.1 Conversion

Most of the surviving side planks were converted tangentially from their parent log. Six of them (P3A, P3B, P4A, P4B, P4C, and P5B) are close to the pith – in this they are similar to the plank-keel, the outer bottom planks, and bow bottom plank BS. Another six are from some distance away (P5A, P5C, P6B, P7A, S4B, and S5A). Planks P6A and S3A, and possibly S4A, were, like bow bottom plank BP, worked across the pith at a slight angle, while P3C was fashioned across the diameter of its parent log, with the pith central along this plank's length.

Like plank-keel S1 and outer bottom plank P2, the majority of surviving planks were positioned in the boat with their butt end forward (P3B, P3C, P4B, S3A, and S5A and possibly P4C, P5C, P6B, P7A and S4A). Plank P4A and possibly P5A, P5B, and P6A had their butt end aft like P1 and S2.

Planks P3A, P4A, P5B, and P6B had their pith-facing face inboard, like bow bottom plank BP. The great majority (P3B, P4B, P4C, P5A, P5C, P6A, P7A, S4B, and S5A), like the plank-keel, the outer bottom planks, and BS, had their pith-facing face outboard.

6.3.4.6.2 Plank lengths

Excluding the short plank P3A with fragment P3A*, which may well be a repair, 16 planks or parts of planks have survived out of a probable total of 34. Of those that survive, only 4 are complete (P3C, P4B, P5B, and P5C), while 6 are nearly complete. On the port side alone, however, 11 out of, say, 17 planks or parts of planks survive (*c* 65%). In terms of length, *c* 37m survives out of total plank run of *c* 55m (67%). It seems possible, therefore, to draw some cautious conclusions about the lengths of plank used and intended to be used in this boat (Table 6.5).

The pattern suggested by the surviving data is:

lowest side strakes (P/S3): 1 very long; 1 medium in each strake.

second side strakes (P/S4): 1 long; 1 medium, and 1 short in each strake.

third side strakes (P/S5): 4 short in each strake.

fourth side strakes (P/S6): 1 medium; plus? in each strake.

fifth side strakes (P/S7): 1 very long; plus? in each strake.

where:	very long	= 5+m
	long	= 4–4.99m
	medium	= 3–3.99m
	short	= less than 3m.

Two deductions may be made from this data. First it seems possible that planks from each half of a single log may have been positioned in corresponding strakes, one to port and one to starboard: dendrochronological examination has neither confirmed nor confounded this hypothesis. Secondly the fact that the planks are generally shorter aft than forward probably means that this boat was fuller aft.

6.3.4.6.3 Shift of butts (Fig 6.19)

In the surviving planking there are two butt joints to starboard and eight to port. The rough analysis of plank lengths shown in Table 6.5 indicates that the requirement to stagger plank butts (so that they are not close together) probably influenced the choice of some of the plank lengths. This is generally borne out by the surviving butt positions. Butts in adjoining strakes are separated longitudinally by two to four frame stations (ie 1 to 2m) except for the butts in strake P3 at F14 and in P4 at SF13Pt that are separated by only one frame station (ie *c* 0.6m). Five of these butts (P3B/C, P4A/B, P5B/C, P5C/D and S4A/B) were clearly angled so that fastenings could be slightly staggered; the others seem to have been vertical.

6.3.4.6.4 Plank thickness

In general terms strakes P3 and P4 appear to be thicker than the other port strakes, but this does not appear to be the case to starboard. On the other hand the strakes on both sides increase in thickness from *c* 20mm near the bow to *c* 25–30 mm near the centre of the boat.

6.3.4.6.5 Plank bevels

Because of the degraded state of most of the plank edges it is difficult to be certain about bevels, especially on the starboard side. It seems clear, however, that the forward end of each strake was bevelled to fit into the post rabbet, as well as being shaped to the angle of the rising post. The lower edge of P3 appears to be slightly bevelled where it takes against the bevels on

Table 6.5 Estimated lengths of side planking

side strake	*bow*				*stern*
P/S3	7m				3m
P/S4	4 to 5m		3 to 4m		2 to 3m
P/S5	2 to 4m	3 to 4m		2 to 3m	2 to 3m
P/S6	3 to 4m		Over 2m	?	?
P/S7	Over 5m			?	?

Note: This table is based mainly on data from the port side strakes, but includes data from the starboard side where it has survived.

the outboard edges of bow bottom plank BP and outer bottom plank P2. The second to fourth port strakes (P4 to 6) seem to have a more distinctive bevel along their upper edges so that the next higher strake will lie at the appropriate angle in the curved sides.

6.3.4.6.6 Plank fastenings

The hood ends of each strake were spiked to the post – it is not clear how many nails were used for each plank. The general rule for fastening side planking to framing timbers seems to have been to use two nails to each timber except:

- where there was room for only one nail: at the upper ends of some floors (F3, F6, F11, F14, and F15); at the upper or lower ends of some half-frames (F5Pt and St, 7Pt and 12 Pt and St); along the length of some insubstantial timbers such as bow floor F1 and some of the side timbers; and at the lower ends of some of the more substantial side timbers (SF4Pt(F) and SF9Pt);
- where the ends of some framing timbers were merely shaped to take against a plank and there appears to have been insufficient room for any nails: at the upper ends of some floors (F4, F8, F9, and F13); the upper or lower ends of some half-frames (F5Pt and F15 Pt and St); and the lower ends of some side-frames (SF3Pt(M), SF6.5Pt, SF8Pt, and SF13Pt).

In certain cases, when only one nail has been used where there is clearly room for two, it seems likely that a mistake was made:

strakes P3 and S3 were fastened by one nail each to floor F4;

strake P3 was fastened by one nail to half-frame F15Pt;

strake P3 was fastened by one nail to floor F9;

strake P5 was fastened by only one nail to F7Pt.

Another mistake may have been made when strake P4 was fastened by three instead of four nails in a butt joint at SF13Pt. It may, however, have been impossible to get more than three nails into this slight timber.

Strakes P3 and P4 are also fastened by only one nail to floor F15. This may be because this timber was a reinforcement added to the hull sometime after it was built.

6.4 Propulsion, steering and bailing

6.4.1 Sailing

6.4.1.1 The mast-step timber (Fig 6.21)

The principal evidence for sail in the Barland's Farm boat is the mast-step timber. This timber, some 0.73m in length, has half-laps at each end (see Fig A2.60) that take against and overlap floor F6 forward and half-frames F7 Pt and St aft. The timber is fastened to each of these frames by a spike driven from above. There is a fourth spike, probably a repair, driven from inside the step at an angle into the forward edge of F7Pt.

The mast-step timber is generally rectangular in plan, overall 0.73m fore-and-aft × 0.18m athwartships, with a depth of 0.095m. It is suspended, as it were, from the framing, with a gap of *c* 25 mm between its lower face and the upper surface of the plank-keel.

The socket cut in the mast-step timber is *c* 60mm deep and generally rectangular in plan, being 125 mm alongships and *c* 115mm athwartships at the upper face and 115 × 90mm at the bottom. The sides and the forward end of the socket slope inwards from the top; the after end (partly F7Pt) is near vertical. The socket has been positioned aft of the centre of the mast-step timber against half-frame F7Pt, and a notch in that frame's upper forward edge completes the socket's after face.

The socket is also not central athwartships in the mast-step timber, but is *c* 15 mm to port of that timber's centreline. Relative to the middle line of the boat, the socket is biased some 10mm to port. The mast steps of Blackfriars 1 and St Peter Port 1 are also offset to port: the former is 127mm off the ship's middle line and the latter 50mm (Marsden 1994, 48; Rule and Monaghan 1993, 39). In the bottom of the St Peter Port mast step a second, smaller socket had been cut on that ship's middle line. It seems likely that in all three cases the socket was not cut until after the mast-step floor (or in the case of the Barland's Farm boat the mast-step timber) had been fastened in position. The slight residual bias to port in all three vessels was probably intentional: the mast was actually stepped on the vessel's middle line and held there by wedges or chocks on the port side of the mast step.

Figure 6.21 The mast-step timber straddling F6 (to the right) and F7Pt and St. The stern is to the left.

6.4.1.2 Wear marks

The plank-keel and the outer bottom planks are worn on their inner faces between half-frame F5St and floor F6 (Fig 6.9A). The plank-keel is most heavily worn – by *c* 22mm at the P2/P1 seam, increasing to *c* 30mm at P1/S1 and to 40mm at S1/S2. The wear on P2 varies from 7 to 13mm, while S2 has slight wear near its seam with S1. This is heavy wear for, at its worst, over half the thickness of the plank-keel had been worn away. Possible causes of this wear (see section 8.3.1.5) include human feet engaged in some recurrent activity in connection with the nearby mast, frequent bailing out at this station, or the shovelling out of some bulk cargo, as was found on the flat-bottomed 19th-century barge excavated from the River Usk at Tredunnoc, south-east Wales, but there the planking was pine (McGrail and Parry 1991). Of these the most likely cause is bailing. The plank-keel was also worn between F12St and F17 (Fig 6.9B), but not so heavily.

6.4.2 Oared propulsion

In a boat of this size oars would probably be worked through pivots near or on the top edge of the sides. There is no certain surviving evidence for this, but possibilities are considered further in Sections 8.1.2 and 8.3.2.

6.4.3 Steering arrangements

There is no direct evidence for the means by which this boat was steered, but the wear marks on the plank-keel P1 and S1 between F12St and F17 may have been caused by a steersman. This and other possibilities are considered in Sections 8.1.3 and 8.4.

6.4.4 Bailing out

The wear marks on the plank-keel and the outer bottom planks (see above) may have been made by a wooden bailer.

6.5 Conservation of the boat timbers, by J Spriggs

6.5.1 Summary of condition assessment

A condition assessment of the wood remains of the boat was undertaken in 1994 based on a survey of all the timber elements and the destructive and non-destructive testing of samples taken for the purpose (Panter and Spriggs 1994). The data collected lent substance to the readily observable physical state of the various components of the boat. The majority of wood is highly degraded and has little mechanical strength – the surviving cell wall structures are in a swollen state owing to the water they contain. Since such wood is very fragile and highly susceptible to any drying influences, it must be kept wet and handled carefully at all times.

As most of the planking from the sides of the boat was recovered in a highly fragmented state, the uppermost planking both on the port and starboard sides was lifted on fibreglass pallets to keep the fragments together (Hunter and Nayling 1997). The plank-keel (P1 and S1) and the outer bottom planks (P2 and S2) were found to be better preserved, with a proportion of relatively sound wood surviving as a core to each timber. The lower parts of the floor timbers were found to be similarly well preserved, but the condition deteriorated towards their upper ends, where the wood had become fragmentary in many cases.

The variability in condition of the wood elements suggested by the data is thought to be due to three principal factors: the suppression of bacterial activity due to the degree of waterlogging at different depths of burial; the characteristic zoning of deterioration typical of oak wood; and the inclusion of substantial areas of sapwood in many of the timbers.

6.5.2 A specification for conservation

Working on data collected during the assessment phase and having established the best conservation approach to the stabilisation of the wood (Panter and Spriggs 1994), it was possible to calculate the optimum grades and concentration of polyethylene glycol (PEG) polymers to use (Panter and Spriggs 1997). This indicated that the principal wood elements could conveniently be divided into two groups, each with different PEG requirements:

- group 1 (plank-keel and outer bottom planks) 12% PEG 200/25% PEG 4000;
- group 2 (all other elements) 5% PEG 200/25% PEG 4000.

These calculated results fitted with the known 'safe' proportions and concentrations of PEG that would not render the wood hygroscopic under normal condtions of display or storage after stabilization (Panter and Spriggs 1997). It was estimated that minimum immersion times in the PEG solutions should be 12 months and that the PEG increments should be not more than 5% at one time.

6.5.3 Conservation procedure

For physical protection stout boxes were built with dimensions that would allow for stacking during transport and storage. The boxes were constructed of wood battening and Correx plastic sheet, with non-corroding brass screw fittings so that the boxes could withstand immersion in the PEG tanks (Hunter and Nayling 1997). After cleaning and drying they could be used again to store and transport the finished timbers.

6.5.3.1 Tanking

Two treatment tanks were prepared, one measuring *c* 2.4 × 1.2 × 1.2m, the other *c* 3 × 1.8 × 1m. These were constructed from heavy-duty PVC pool liner supported on a scaffolding framework, with an underlay of polystyrene sheet 25mm thick. Each tank was equipped with a 'Silver Dolphin' copper/silver ion disinfection unit coupled to a circulation pump (Vere-Stevens *et al* 1999).

On arrival the timbers (on 81 separate pallets) were divided into Groups 1 and 2 (as in the condition survey) and the timbers of each batch were unwrapped from their wet packaging (plastic foam rubber and polythene), their numbers registered, and each one checked for remaining surface dirt. All appeared very clean apart from some silt lodged in cracks and crevices in some floor timbers. It was decided to deal with any further cleaning after freeze-drying. The timbers (still in their boxes) were stacked carefully into the tanks, each fastened to the next with battening to prevent shifting of the load as the tanks were filled with water. The tanks were filled with water up to a predetermined working level and treatment commenced. As well as the timbers on pallets, there were also a large number of fragments, wood samples, and other small items that were assessed as requiring a similar treatment to Group 2 (ie 5% PEG 200/25% PEG 4000) but for a shorter period of time. Designated Group 3, these were treated in smaller containers separately from the larger timbers, the treatment period being 15 months.

PEG additions to all three groups were made at intervals of between two weeks and a month and the concentration rise monitored using a hand-held refractometer. Circulation and disinfection of the solutions in Group 1 and 2 tanks was via 'Silver Dolphin' submersible units over the 31- to 34-month tank treatment periods. Adesol® (broad spectrum) biocide was used to control infection in the Group 3 container.

6.5.3.2 Freeze-drying

A newly constructed freeze-drying unit built to order by 'Frozen in Time' (Pickering, North Yorkshire) was employed to remove the remaining water safely from the wood structure (Fig 6.22). The chamber measures 4m long × 1.5m in diameter and is fitted with two removable cassettes that can hold up to ten trays onto which the wood was loaded external to the chamber. The cassettes were then manoeuvred up to the chamber on mobile trolleys and rolled inside on tracks. The Barland's Farm boat timbers were the first major groups of wood to be freeze-dried with this new equipment.

After removing the timbers from their pallets, they were quickly rinsed under running water to remove any sediment and surplus wax. They were then loaded onto the freeze-drier shelves that were positioned onto the loading cassettes. When the cassettes were full, they were pushed into the freeze-drier. Three sample planks were selected to monitor for temperature via needle probes inserted into broken ends or saw-cuts where samples for dendrochronology had been taken.

Once loaded, the chillers on the drier chamber were switched on and the load frozen down to between –25° and –30°C over a four-day period. The vacuum was then applied and the temperatures, vacuum, and ice collected in the condenser were all monitored and recorded regularly as drying commenced. The process was terminated when little or no ice continued to form in the condenser and when the object temperatures rose well above freezing point. The wood took between four and seven weeks to freeze-dry in three separate batches. In each run the minimum vacuum achieved was 0.030 and 0.015 bar respectively. The operating temperature of the condenser was between –50° and –60°C.

6.5.3.3 Surface treatment and joining of elements and fragments

After freeze-drying the wood batches were left in the freeze-drier chamber for a few days to acclimatise to room conditions before further work began. As each piece was removed, any surplus bloom of PEG was removed with soft brushes. Any deposits that could not be removed in this way were warmed with a hot air blower and dabbed away with absorbent paper as they melted.

As the cleaning proceeded, notes were made as to the level of fragmentation of each timber and which pieces should be joined together at this stage (Fig 6.23). Adhesion of broken elements was successfully carried out using 'Plamuur C'© epoxy adhesive/filler (Spriggs 1990) as earlier employed on the Viking 'Jorvik' timbers and other projects. Some very small fragments and splinters which became loosened during the surface cleaning process were re-adhered into position using HMG© (cellulose nitrate) adhesive.

Many of the wood elements (both planks and frames)

Figure 6.22
Boat timbers being loaded into a 4m-long freeze-drying chamber at York Archaeological Wood Centre. (Photograph by York Archaeological Trust)

Figure 6.23 Fragmented planking being reassembled after conservation using an epoxy adhesive and a variety of braces and clamps. (Photograph by York Archaeological Trust)

contained the remains of nail heads and shanks running through their thickness. Many of the nail heads and the ends of shanks where the nail heads were missing produced bright orange powdery oxidization products after freeze-drying. To ameliorate this effect, the affected areas were brushed lightly with a glass bristle brush and painted with 20% (wt/vol) tannic acid solution in water. This rendered the corroded area a dark grey/black colour that, although mainly cosmetic, will also have imparted some pacification against future corrosion.

After conservation all the wood elements were packed back into their pallets with ample bubble-wrap and tissue paper to provide protection during transport and storage at Newport Museum.

6.5.3.4 General comments on success of treatments

In general it was felt that the conservation treatment was reasonably successful. Good physical protection to the fragile wood had been provided during conservation and little damage was caused to any of the fragile elements during the various moves and transfers between tanks, freeze-dryer, and pallets. Much of the wood had a noticeably red hue to the surfaces after freeze-drying, due to the diffusion of iron oxides from the boat nails. Leaching out of iron corrosion products into the PEG solutions was noticeable and will also have contributed to the surface colour.

Despite at least 31 months' immersion in PEG solutions, it was noted that there had been some lateral shrinkage across several of the more substantial, tangentially sawn plank-keel (P1and S1) and the outer bottom planks (P2 and S2). The existence of this will need to be taken into account during any future reconstruction of the vessel. Generally though, the dimensional stability of the frames and planking and preservation and appearance of surface detail was considered perfectly satisfactory.

7

Boatbuilding techniques

7.1 Evidence

Builders' marks and tool marks found by examination of the worked surfaces of boat timbers, inspection of fastenings, and investigation of the 'internal stratigraphy' of a boat can all throw light on the building techniques used and on the sequence of construction. Examination of the structure of the timbers, knots and their emergent angle, the flow of the grain, the presence of sapwood or even bark, and especially the cross section can reveal facts about the parent trees and the conditions under which they were grown. Such examinations can also indicate how the limbs were converted into usable boat timbers (McGrail 1998, 37–43).

When recording the Barland's Farm boat timbers, Richard Brunning noted such marks and features on the measured drawings he compiled. Fair versions of his drawings are in Appendix 2. The direct evidence for building techniques is limited because of the degraded state of most of the fastenings, the fragmentary nature of many timbers, and because of in-use wear on the bottom planking. Nevertheless, much has been learnt, and more will be learned, and some of the hypotheses advanced in this book reinforced or refuted, when the hull timbers are reassembled for display.

7.1.1 Tool marks and tools, by R Brunning

Detailed information about woodworking can often be preserved in the form of marks left by tools in the surfaces of timbers. In the present case such information is severely limited by the generally poor condition of timber surfaces, mainly caused by wear during the active life of the vessel. Some tool marks do survive, however, notably where plank surfaces have been protected by framing timbers or the post.

The saw was used both along and across the grain to cut out the major timbers from their parent log or limb. The poor survival of saw marks on planks makes it hard to be certain of the precise method used. Where they can be recognised over a long length of plank, however (as on the outer faces of planks in strakes P5 and P4), it is clear that the saw was travelling consistently straight across the near-diameter of the log, ie the breadth of these tangentially converted planks. This suggests that, when sawing planks from logs, a double trestle or pit saw was used rather than a single trestle (see-saw) method. The few examples of angled saw marks are probably related to difficulties encountered with large knots. On one element of the plank-keel (P1) there is a slight step between two sets of saw marks, while there are traces of axes being used to cut through knots. Axes were also probably used to remove branches at an earlier stage in the conversion process.

Axe and adze marks are otherwise rarely preserved on the planking, but the surviving evidence suggests that, after they had been sawn to shape, planks were finished where necessary with axe or adze. 'Jam curves' left in the wood where the cutting blades came to a stop show that a range of axes or adzes were used. Most, if not all, 'jam curves' do not represent the full blade width, but the largest indicated blade was 70mm. Blade shapes varied from dead flat to moderately curved.

Axes were also used to square off those side timbers that were clearly fashioned from small branches. Larger framing timbers were initially sawn to shape and then finished off with an axe. For example, the port end of floor F2 was cut with axe blows from three directions.

The blind holes worked in the upper face of the plank-keel close to the seam between P1 and S1 had curved bottom profiles indicating that they had been made with a spoon auger of *c* 10mm diameter.

Housings for the posts that were worked in the ends of the plank-keel (P1 and S1) were made by first cutting across the grain with a chisel and then axing or adzing out the wood along the grain. The formation of the mast step was somewhat more complex. Holes *c* 20mm in diameter were augered at each corner. Then a chisel was used (possibly in conjunction with a hammer) to cut across the grain between the two forward holes and the two after holes. The wood was subsequently split away along the grain.

The limber holes in the outer faces of floors were first marked out by saw cuts across the grain to the required depth. The wood was then chiselled out using a narrow blade only 7mm wide, for example, on F15Pt and F12St and 10mm on F16. At times saw cuts evidently went too deep and grooves, 3 to 7mm wide were left in the upper corners of some limber holes.

Treenails through which fastening nails were subsequently driven were worked to shape using knives. An auger of diameter *c* 12mm was used to bore holes through the framing timbers to receive the treenails. Some at least of the scribed lines described below were probably cut with a knife. Tools used when fastening timbers together are described in section 7.4.

7.1.2 Tool marks or builders' marks?

There are feint marks 1 to 2mm deep across the outer faces of many of the framing timbers (Fig 6.12). These lines run more or less at right-angles to the run of these timbers (ie near parallel to the run of the planking) and they appear to lie where the plank seams would be. All floors (except F1, F15, and F16), all half-frames (except F5St, 15Pt, and 15St), and possibly one of the surviving side timbers (SF8Pt) have one or more of such marks. The degraded nature of some of the surviving framing and the fact that several timbers did not survive to be excavated mean that originally there were probably more of these marks. Details of the surviving lines are given in the catalogue entries for the framing and summarised in Table 7.1. Examples are: bow floor F2, near seams S2/3, P3/4, P4/5, and possibly P2/3; floor F6, near seams S2/3, P2/3, P4/5, and possibly S3/4 and P3/4; side timber SF8Pt, possibly near seam P2/3; half-frame F10St, possibly near seam S2/3.

These marks are not caused by the lower or upper edge of a plank digging into the frame – examples of that type of mark may be seen on F15. The marks under discussion must have been made before the planking was fastened to these frames, possibly by knife or by saw.

If these were tool marks left by a saw, they could be the remains of cuts made by a boatbuilder into the edges of oversize timbers to indicate the outline shape of the outer face of frames. The subsequent removal of wood in between these marks, by chisel, axe, or

Table 7.1 Marks on outer faces of framing timbers

	plank seams						
frame	P2/3	P3/4	P4/5	P5/6	P6/7	S2/3	S3/4
F1							
F2	?	1	1			1	
F3		1	1				
F4	1	1	1			?	1
F5Pt					?		
F5St							
F6	1	?	1			1	?
F7Pt	?		1	1			
F7St						1	
SF8Pt	?						
F8	1	1					
F9	1	1	1			1	1
F10Pt		1	1				
F10St						?	
F11	1		?			1	
F12Pt	?	1	?				
F12St						1	
F13	1					1	
F14						1	
F15Pt							
F15St							
F16							

Code 1 = A mark ? = Possible mark

Table 7.2 Comparison of plank breadths (mm) indicated by direct measure (p) and by marks on framing (f)

	F2		F3		F4		F6		F7Pt		F8		F9		F10Pt	
	f	p	f	p	f	p	f	p	f	p	f	p	f	p	f	p
P3	24	25	19	25	25	25	23	21			19	18	17	17		
P4	18	19?	17	17	18	19	21?	22					23	26	23	25
P5									26	26						
S3					15	23?	13?	20?								

adze, would have allowed the sawyer to change saw angle as he cut along the curving line, as suggested by Richard Brunning.

They may, on the other hand, have been builders' marks, ie knife scribings marking where plank seams should be. They would then be part of the design process, the means by which the builder determined the shape of individual strakes.

These marks, therefore, were either guides to the shape of frames or guides to the shape of planking. As they were on the outer faces of the framing, they were not seen on site and were first noted during post-excavation recording. An interpretation of their function was first sought using measurements from the 1:5 scale drawings of frames and associated planking. This investigation indicated (within the accuracy obtainable by such a method) that most of these marks were generally in line with a plank seam. This observation received support (within the accuracy of (this time) a 1:10 scale) when the 'as found' model (Fig 6.4) was assembled. After conservation the distances between marks on the same framing timber were recorded and compared with actual plank breadths at those stations. The results are tabulated in Table 7.2.

The data in Table 7.2 suggests that for the better-preserved port side of the boat at least, there is some correlation between plank breadths and the spacing of marks on framing, ie these marks could have been guides to plank shape. If on the other hand these marks had been left at the end of a saw cut during frame shaping, it would be expected that far more of them would have been obliterated as the frames were fashioned to size and then faired. Vestigial remains of such frame-shaping saw cuts might also have been expected on the inner faces of frames. The fact that such marks have not been noted where they might be expected if they had been guides to plank shapes (ie on the post) may be due to differential wear during the boat's life and to the vagaries of degradation and survival.

On balance it is considered that these were probably builders' marks made during the process of 'designing' the plank shapes. This hypothesis will be investigated further when the planking is fitted to the framing as the boat is prepared for display.

7.1.3 Builders' marks

Builders' marks have been found on both inner and outer faces of the boat's timbers. Blind holes *c* 12mm in diameter had been bored by a spoon auger 6–10mm deep into the inner face of the plank-keel close to the seam P1/S1 (Fig 6.8 and section 6.3.1.3). They are in a fore-and-aft line; from floor F16 to frame F7St they lie on P1; forward of F8 they are mainly in the seam, with the two foremost holes, aft of floor F4, on S2. The plank-keel (P1 and S1 together) is not quite rectangular in plan, being *c* 0.55m broad forward (at F5St) and *c* 0.52m broad aft (at F16). Since P1 and S1 are not precise mirror images of each other, the seam P1/S1 is at a slight angle to the centreline of this skewed trapezium. The holes mark the near centreline of both the plank-keel and the boat's bottom (ie plank-keel and outer bottom planks together).

These holes are irregularly spaced. Overall there is a mean spacing of 150mm with a range from 50 to 290mm. Some shorter runs of holes are spaced at 68mm ± 18mm; others at 100mm ± 35mm; while yet others have a wider spacing with more variability. No holes are visible at stations F4, F6, F7Pt and St, F8, F13, and F17. The inboard edges of P1 and S1 are, however, much damaged in the vicinity of station 7 and it is now impossible to be certain that holes were not once present. Although there is some damage at station 8, it seems likely that there never was a blind hole there.

These builders' marks have the following implications for the sequence of building this boat:

- the holes were bored after P1 and S1 had been brought together;
- they were bored after frames F4, F6, F13, and F17 (and probably F8) had been fastened in position and possibly after F7Pt and St had also been positioned;

- it seems likely that a temporary (chalk or charcoal?) centreline was drawn before any frames were fitted;
- the intermittent, permanent centreline of blind holes was probably used to set further frames in position relative to the boat's middle line and to check that the outer bottom planks had been fashioned so that the boat's bottom was symmetrical about that line.

Shallow marks 60 to 70mm in length had been scribed across the inner face of strake P3, where F8 and SF8Pt overlap, and strake P4, where F13 and F13Pt overlap. These seem unlikely to be builders' marks and may have been caused when cleaning out 'gunge'.

There are grooves *c* 2mm deep across the outer faces of plank-keel P1 and S1 and outer bottom plank S2. These grooves are in line with the forward edge of floor F6 and aft of the area of wear on the inner faces of these planks. No such groove has been noted on outer bottom plank P2. These are difficult to interpret as builders' marks. They were possibly caused by a trestle when the planks edges were being sawn. A link with the worn area of planking on the inner plank faces or even with the nearby mast seems remote.

7.1.4 Examination of the timbers

Examination of the timbers especially the cross section from the wood science viewpoint and for dendrochronological purposes has revealed much about the choice of trees and of individual limbs. For example, the timbers were all oak (*Quercus* sp) and generally speaking individual parent timbers were clearly chosen to match the particular job in hand. It has also shown how this raw material was converted into planks and frames. For example, the majority if not all of the timbers were sawn from their parent tree – there is no evidence for splitting oaks along the rays to produce planking as was done in northern Europe in later centuries (McGrail 1998, 28–34).

7.2 Selection of trees

It has not yet proved possible to determine the trees' ages on felling. Nor has it proved possible, because of short runs of tree rings, to demonstrate dendrochronologically that certain timbers came from the same parent tree. Thus comprehensive statements about tree selection cannot be made. Nor can precise estimates be made of the number of trees used, since, for example, some of the planking sawn from close to the pith could have come from the same tree as planks sawn at some distance from the pith, while further planks could have come from the other half of the same bole, as appears to have been the case with the two elements of the plank-keel (P1 and S1 – see section 6.3.1) and also the outer bottom planks (P2 and S2 – see section 6.3.4.1). Similarly some of the crooks used for framing could have been sawn in half lengthwise to make two floors (F4 and F17?), half-frames (F15Pt and St; F10Pt and St), and even the two posts. Nevertheless something can be learned about the oaks from which this boat was built.

7.2.1 Planking

The oaks selected for the plank-keel, the bottom planking, and the side strakes had growth rates less than 4.6mm per year; thirteen out of twenty planks had growth rates of less than 3mm per year. There are three distinct groups of trees:

1 this group includes the plank-keel, the outer bottom planks, and longer side planks P3B, S3A, and P7A. The boles of the parent trees of these planks were more than 5m long (some, at least, were more than 7m), with straight grain and girths in the range 1.38 to 1.85m (diameters 0.44 to 0.59m.). They had moderate growth rates of 2 to 3 mm per year; and their branches were generally of moderate size or less. The two plank-keel planks had two large knots at their upper ends indicating the beginning of their parent tree's canopy;

2 this group includes most of the shorter side planks. These boles were less than 5m long, generally straight grained, with small, occasionally medium-sized branches. They had girths in the range 1.1 to 1.41m (0.35 to 0.45m diameter), and variable growth rates of 1.7 to 4.6mm/year. The two bow bottom planks *c* 1.5m in length form a distinctive sub-group here, differing from the others in having large to medium branches and also variable grain which makes it impossible to estimate limb size. They may have come from the upper end of much taller trees;

3 three other planks, P5C, P6A, and P6B came from trees 3 to 4m tall, with some small branches; they had large girths of 2.2, 1.57, and

1.7m (diameters 0.7, 0.5, and 0.54m) and fast growth rates of 4.33 to 4.6mm per year.

7.2.2 Post
The post was fashioned from a natural crook with subsidiary branches. The crook had a maximum girth of 2.37m (diameter 0.75m) and a growth rate of 2.5mm per year.

7.2.3 Bow floors
The bow floors were from crooks that had had subsidiary branches. The main limbs had girths of 0.79 to 1.35m (0.25–0.43m diameter), with growth rates from 2.1 to 4.1mm per year.

7.2.4 Main floors
The main floors came from crooks formed at the junction of a branch with a main bole or limb. F13 was unusual here as its parent bole or main limb also had a natural curve, while the other boles were straight. All crooks had had mostly small or medium subsidiary branches, but F11's parent crook formerly divided into two larger branches, one of which became the starboard arm of this floor while the other was removed. Large branches had also to be removed from both ends of F14. The main limbs had girths in the range 0.82 to 1.63m (0.26–0.52m diameter) with six in the range 0.91 to 1.1m (0.29–0.35m diameter). Seven out of nine had growth rates of 3.3 to 4.3mm per year; the others were less.

7.2.5 Side timbers
The side timbers were converted either by minimal shaping from roundwood (eight examples) of girths ranging from 0.31 to 0.5m (0.1–0.16m diameter) or from segments (eight examples) of oak limbs (some of them possibly boles) which had had girths of 0.72 to 2.83m (0.23–0.9m diameter). All parent branches, limbs, and boles had had side branches; ten out of sixteen had growth rates of less than 3mm per year.

7.2.6 Half-frames
The half-frames were fashioned from natural crooks, with the exception that F5St may have come from a single curved limb. The parent boles or limbs seem to fall into two groups: six half-frames from oaks of relatively great girth (1.41 to 2.17m and 0.45–0.69m diameter), with fast growth rates of 5 to 7mm per year; and four from less substantial limbs (0.6 to 1.26m girth and 0.19–0.4m diameter) of slower growth (2.7 to 3.7mm per year).

7.2.7 Choice of individual trees
Trees suitable for planks had primarily to be straight grained. For the plank-keels and other long planks, tall oaks of medium growth rate and medium girth were chosen. More variability in size and growth rate was acceptable for shorter planks. Long planks running the length of the boat are very suitable for the bottom of a flat-bottomed boat. Provided they can be made to accept any bending required, long planks are also an advantage in the side planking, since they minimise the number of butt joints that not only weaken the structure, but are also a potential sources of leaks. Slow-grown oak is relatively easy to work; fast-grown oak with its wide rings and dense late wood is stronger (Rendle 1971, 12–13).

Trees selected for framing timbers had to have good crooks. For floors and the post, such trees could be of some size (although a significant number were relatively slender) and of medium growth rate. Timbers used for those side timbers that were not just branches seem to have been mainly 'offcuts' from medium- to large-girth oaks of slowish growth. Trees for half-frames were either relatively slender and of medium growth rate or of medium size and faster growth. In general terms when selecting timber for frames the crooked nature of a tree outweighed other characteristics.

7.3 Conversion into boat timbers

The conclusions drawn in this section are based on Richard Brunning's observations when recording the boat timbers (Section 6.1 and Appendix 2).

7.3.1 Plank-keel (Fig 7.1)
The elements of the plank-keel were fashioned tangentially from half logs (possibly halves of the same bole) retaining some of the taper of their parent trees. The grain flows along their length. Some sapwood was left on at the edges in their lower parts (aft in P1; forward in S1); more was left on towards their upper ends where heartwood is narrowest.

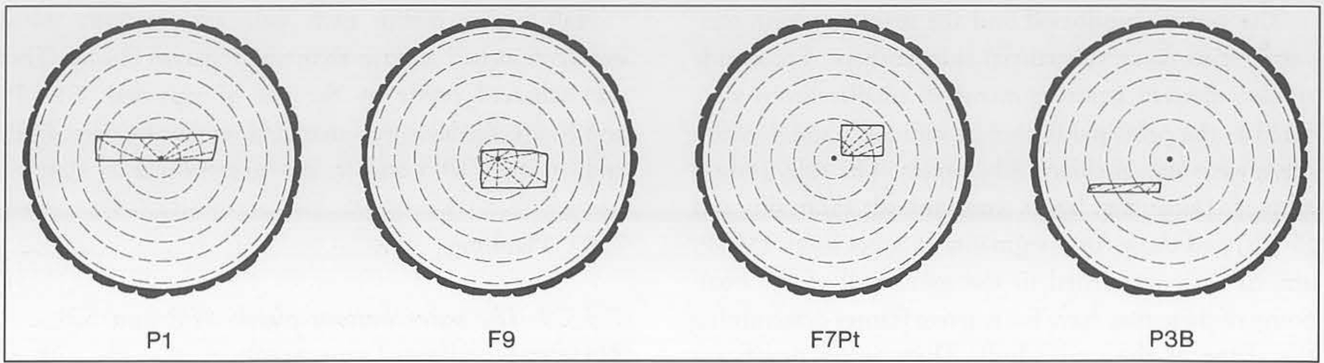


Figure 7.1 Diagram to illustrate the orientation of selected timbers in their parent logs. These trees were of medium growth rate. Based on timber recording by R. Brunning (Appendix 2). Not to scale.

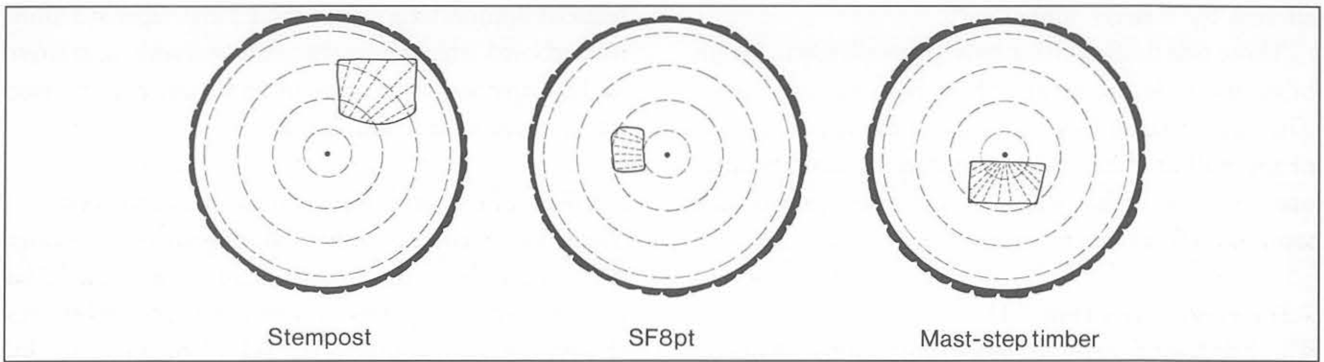


Figure 7.2 Diagram to illustrate the orientation of selected timbers in their parent logs. These were relatively fast-grown trees. Based on timber recording by R. Brunning (Appendix 2). Not to scale.

7.3.2 Post (Fig 7.2)

The post was fashioned from an oak crook, possibly through the half-log stage. It is possible that the missing stern post could have been fashioned from the same log. It is not clear whether the horizontal or the upper, curved portion was formed from the main limb. The grain generally follows the curve of the surviving part of the post but with some short grain. Sapwood was left on in places on all faces.

7.3.3 Bow floors

The bow floors were made from crooks – F1 and F2 from roundwood, F3 from a half log. The grain follows or nearly follows one of the curves in each timber, but there is some short grain on all of them. Floor F2 (the more substantial timber) is all heartwood, while the others have some sapwood.

7.3.4 Main floors (Fig 7.1)

The floors are fashioned from crooks. F4 may have been converted through the half-log stage (with F17 from the other half of the same crook); the others from whole logs. Eight of the nine floors were fashioned so that the main limb element of their parent crook formed one arm and the horizontal portion, while the branch became the other arm. In most cases this resulted in short grain in one arm (F9, F11, F14, and possibly F15) or both (F4, F6, and F8). Unlike the other seven, floor F13 had little if any short grain in either of its arms: the main limb part of its parent crook must have had a natural curve. F13 was fitted in the boat so that its arm made from a branch was to port. The others had theirs to starboard.

Unusually for this boat, floor F16 was fashioned so that the branch part of its parent crook formed one arm and the horizontal portion, the other arm (fitted here to starboard) coming from the main limb. The grain generally flows along the port arm and the horizontal part of F16, but it is confused in the starboard arm and there is short grain.

7.3.5 Side timbers (Fig 7.2)

All the examples of smaller roundwood were converted into slight side timbers in the bow, at station 2, and as auxiliaries at stations 3 and 4. These were undoubtedly passive framing, fashioned to match the planking rather than to determine the shape of the hull.

The larger roundwood and the segments were converted into more substantial side timbers. Those side timbers derived from segments of smaller limbs were fitted as the principal timber at stations 3 and 4 where there were also auxiliary side-frames. The side timbers derived from the larger roundwood (SF6.5Pt and SF9Pt) and those from segments of larger limbs (SF8Pt and SF9St) were fitted in the main hull of the boat. Some of these may have been active frames determining the shape of the upper hull. There is no significant difference in size between the side timbers in these two groups. It seems likely, therefore,that SF8Pt and SF9St were converted from offcuts from large limbs primarily selected for a larger timber.

Those side timbers that survived completely in length or nearly so do not seem to have been natural crooks. They were shaped longitudinally to the required curve of the hull at their station resulting in short grain at one or both ends. Many of the side timbers had sapwood left on several faces.

7.3.6 Half-frames (Fig 7.1)

The half-frames were fashioned from crooks. Most of them could have been through the half-log stage. It seems likely that the pairs F10Pt and St and F15Pt and St were each converted from the same parent crook. Of those half-frames in which limb and branch could be identified, most had their horizontal part fashioned from the branch and their arm from the main bole. F12St was the exception, having its arm from the branch, as was common in the medieval Scandinavian tradition (Crumlin-Pedersen pers comm). All half-frames have had sapwood left on, while F7St additionally has some bark at the junction of its after and inner faces. The grain generally flows along the length of F5Pt and St, but in most other timbers there is short grain around the curve and generally in the rising arm. F15Pt and St both have spiral grain.

Half-frames within each pair are generally more evenly matched in size than their parent limbs. This was achieved partly by the use of sapwood. F12 Pt and St are the least well matched, while the pairs F5Pt and St and F10Pt and St are most similar in size.

7.3.7 Planking

7.3.7.1 The outer bottom planks (P2 and S2)

These were fashioned tangentially close to the pith of their parent bole. It is possible that they were converted from halves of the same tree. They both have some short grain towards their ends where their breadth is reduced approaching the posts. P2 has sapwood along its outboard edge where the plank breadth is greatest. S2 has sapwood at its forward end (upper in the tree) where there is least heartwood.

7.3.7.2 The bow bottom planks (BP and BS)

These were generally fashioned tangentially, although BP crosses the pith towards its forward end. Both planks have short grain forward where they have been shaped upwards to match the rise of the post. BP has sapwood on both edges.

7.3.7.3 The side planks (Fig 7.1)

With four exceptions these were fashioned tangentially from their parent boles. Six were close to the pith and six some distance away. Plank P3C was worked across the diameter of its parent bole, with the pith central along its length. Planks P6A and S3A, and possibly S4A, were worked at a slight angle to the pith along their length. Sapwood was removed from all side planks except for a little on P5C and P7A. The grain generally flows along the length of these planks except for P3C (slightly wavy), P4A (somewhat spiral towards one end), and P5B (slightly wavy and cross grained at one end).

7.4 The fastenings

The iron nails are badly corroded, some explosively. Nevertheless the general method of fastening the planking to the framing is clear. The nails were driven from outboard through the planking, through a treenail previously inserted in the framing timber and then clenched inboard by turning the emerging point of the nail through 180° back into the inner face of the frame (Fig 7.3). This is the method used in Blackfriars 1 (Marsden 1994, 50–4) and in St Peter Port 1 (Rule and Monaghan 1993, 17) and it has been recognised as one of the diagnostic characteristics of the Romano-Celtic boat and shipbuilding tradition (McGrail 1995).

This technique (Fig 7.4) of clenching a nail by 'hooking' was earlier used in Mediterranean ships of the 1st millennium BC, for example, in the 4th-century BC Kyrenia ship (Steffy 1994, 42–59). In those plank-first vessels, however, bronze nails were used to fasten framing to planking, rather than iron nails to fasten planking to the framing of frame-first Romano-Celtic vessels. Subsequently this type of iron fastening was

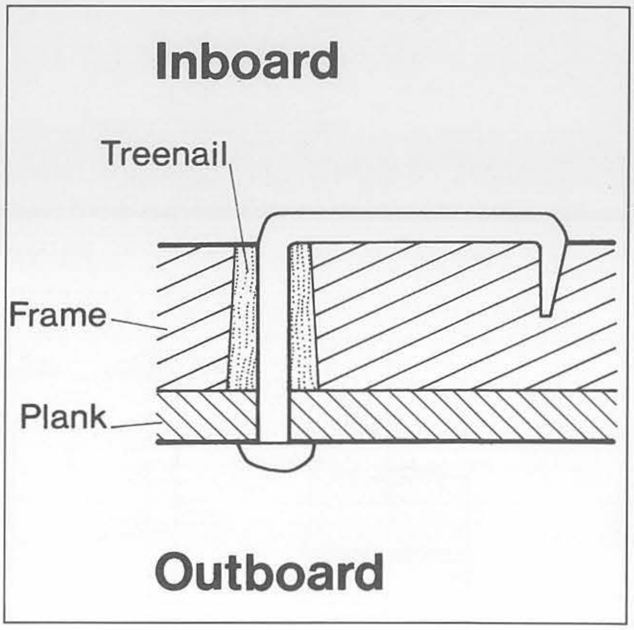


Figure 7.3
Diagram to show how the Barland's Farm planking was fastened to the framing.

used in medieval north-west Europe to fasten together the side planking of the seagoing cargo ship known as the cog (Ellmers 1994). The clinker planking of some 20th-century British boats was also fastened together by hooked iron nails (McKee 1972, 25; McGrail and Parry 1991). The reverse-clinker planking of the Orissan *patia*, a fishing boat of the Bay of Bengal, is similarly fastened (Blue *et al* 1997).

In the instances of fastening planking together given above, the nail is driven directly through the planks and not through a treenail. The main ancient example known to date of plank-fastening nails driven through treenails (as in the Barland's Farm boat) is the *c* 10th-century AD clinker-built Graveney boat (Fenwick 1978, 221–4), but here the nails are clenched in the Nordic way by deforming the tip over a rove. Clenching a nail by hooking, like clenching by deforming the tip, has the advantage that there is a positive grip on the timber at both ends of the nail, unlike the effect of using a spike.

7.4.1 Nails

Radiographs of some of the Barland's Farm boat nails show them to have a domed head 11 to 12mm deep and 32 to 38mm diameter. They have a rectangular shank except close to the head where they are circular and of *c* 10mm diameter. The St Peter Port and Blackfriars nail heads were hollow, but the Barland's Farm nails do not appear to have been.

Although no measurable complete nail has survived, it is still possible to get some idea of nail lengths. Blind holes left in the inner faces of the framing by the hooked tips of nails are 12 to 20mm deep. Using 15mm as an average length of hidden tip, it is possible to estimate some nail lengths, since the lengths of certain nails exposed on the inner faces of frames can be measured and the thickness of planking and frame is known. Floor F9, for example, has fourteen nails with measurable lengths on its inboard face (Fig 7.5 and see Fig A2.10). Nails fastening side planking to this floor are estimated to range in length from 97 to 157mm; outer bottom planking to F9, from 124 to 144mm; and F9 to plank-keel, 128 to 163mm. Individual nails in other timbers are longer. For example, a nail used as a spike to fasten the mast-step timber to F7Pt pierces that half-frame but does not penetrate the underlying plank-keel P1. This nail was, therefore, 192 to 217mm in length. Other examples of long nails are: P4 to F15 (200mm); P4 to SF9Pt (200mm); F15 to P1 (204mm); P4 to F9 (215mm); F9 to P1 (235mm); F11 to P1 (260mm).

The examples are too few and the available data insufficiently precise to use any statistical analysis on this group of nails. It seems clear, however, that they were not made to a uniform size and possibly not even to two or three standard sizes. In general terms, nails seem to have ranged in length from *c* 100 to over 250mm.

There would have been *c* 450 nails in the original boat. It has not proved possible to weigh any of the Barland's Farm nails, but if it is assumed that they weighed as much as a Blackfriars 1 nail in proportion to length, this outfit of nails would have weighed *c* 80kg.

There is no sign in the limited data for the Barland's Farm nails of the rule of thumb quoted by McKee

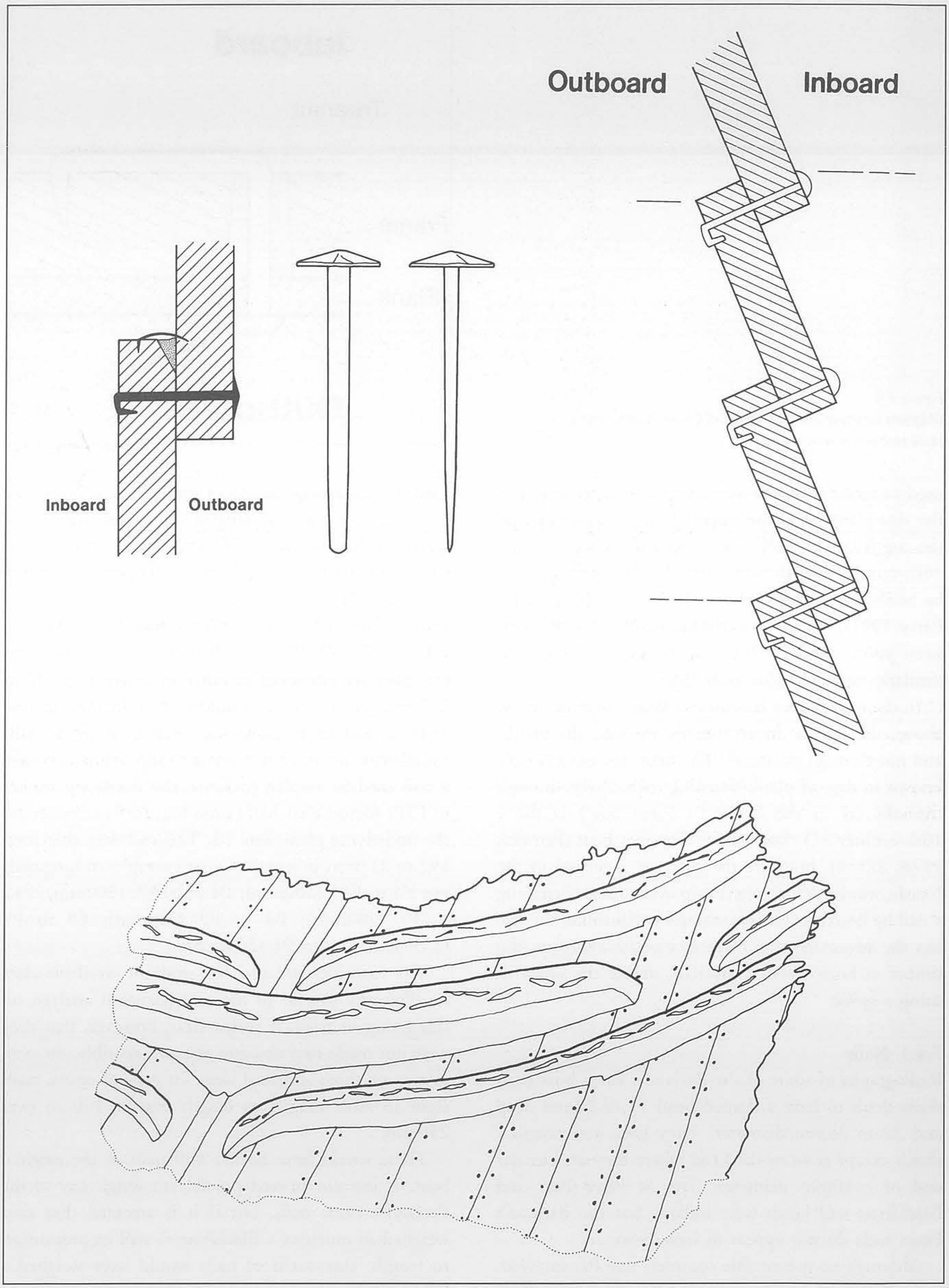


Figure 7.4 Diagram showing the use of hooked nails: in Indian reverse-clinker planking (upper right); in Cog clinker planking (upper left); and to fasten framing to planking in the 4th-century BC Kyrenia ship.

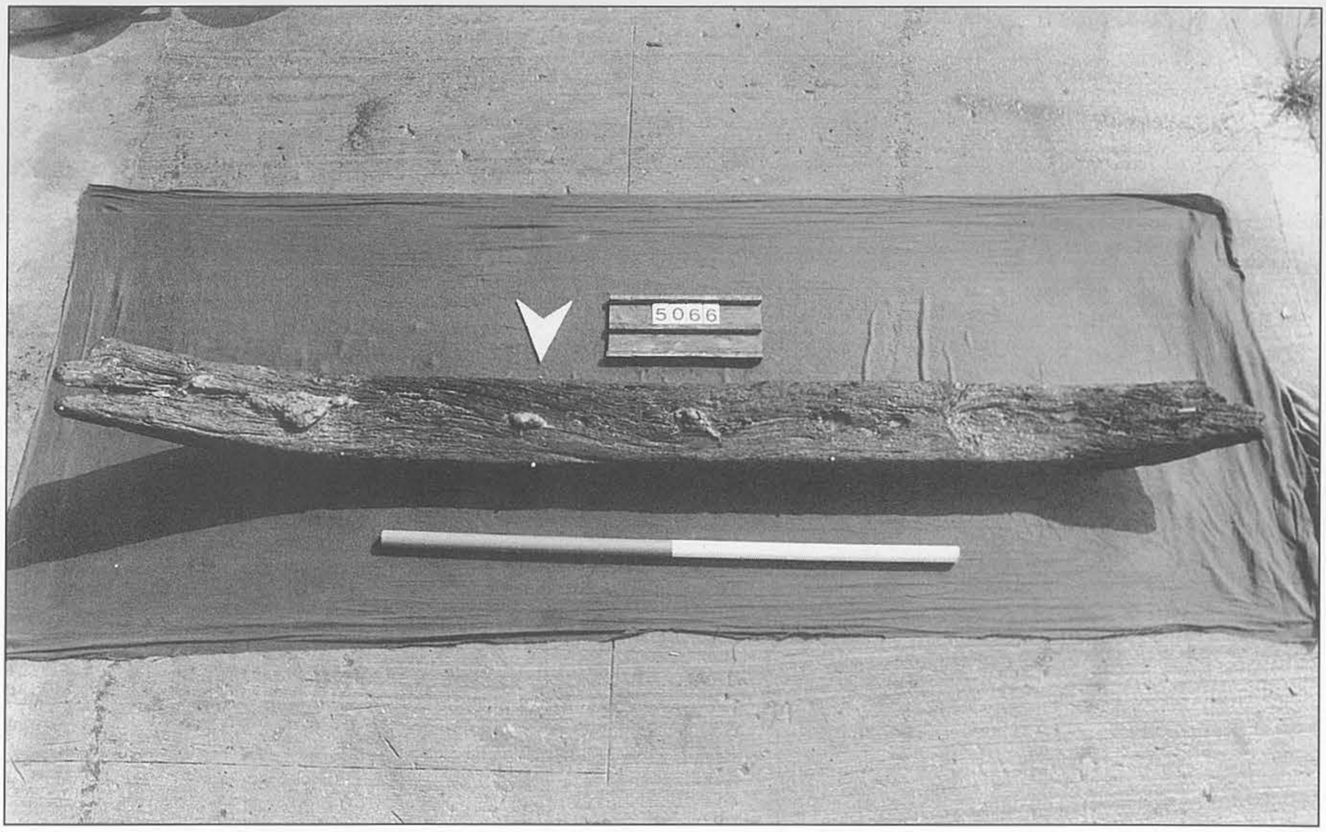


Figure 7.5 The inboard face of floor F9 showing the remains of hooked nails. Port is to the left.

(1972, 25) that ensures that the length of turned nail exposed equals the length re-entering the timber. On the contrary, there is no observable uniformity and lengths of exposed nail range from 35 to 100mm while the length of tip within the frame seems to range from *c* 12 to *c* 20mm. There is, however, a degree of regularity in the direction the nails were turned. Most were turned towards the middle line of the boat, but angled towards the bow or the stern by up to 50°. By crossing the run of the grain of the frame in this way, the grip of the nail was maximised. In this respect they are similar to the nails in Blackfriars 1 and St Peter Port 1, but without those vessels' evident herring-bone near uniformity (Marsden 1994, 51, fig 38; Rule and Monaghan 1993, 17, fig 12).

The non-uniformity of the Barland's Farm nail pattern may be illustrated by considering floor F9 (Fig 7.5 and see Fig A2.10). The nails fastening this floor to the plank-keel were all turned towards the middle line, three angled aft, one forward. The nails fastening the outer bottom planks to this floor were similarly turned, but two were angled aft, one forward and one along the grain. The nails fastening the side strakes (P3 and 4) were also turned towards the middle line and all angled forward. One of the nails fastening S3 was turned towards the middle line but along the grain, the other (the higher nail) was turned away from the middle line and angled aft, while the nail fastening S4 was parallel to the higher nail in S3. Some of the apparent anomalies here could be due to the nails fastening strakes S3 (partly) and S4 to this floor being clenched by a man standing outboard and leaning over the planking into the boat, while the other strakes had their nails clenched from inboard. Insufficient nails survive in good condition for this hypothesis to be investigated on strakes at other stations.

7.4.1.1 Nail holes

Measurable empty nail holes in the framing range in diameter from 12 to 16mm; for a group of 21 holes the range is 13.5 to 15.4, with a mean of 14.4 ± 0.9mm. Although one plank (P3B) has split along a line of holes bored along the grain near the upper edge between stations 5 and 8, most neighbouring nails appear to have been positioned on different grain lines. Distances in from the plank edge generally vary from *c* 45 to 80mm, although some are as close as 20mm. Nailheads on the plank-keel of the St Peter Port ship (Rule and Monaghan 1993, 28) were countersunk into the plank-keel. This technique does not appear to have been used in the Barland's Farm boat.

Only two timbers (floors F4 and F13) are broad enough (siding) to have the two rows of fastenings that are general in the St Peter Port and Blackfriars 1 ships. The single line of nails along the length of the other Barland's Farm framing timbers is generally down the centre of the timber, with the occasional nail slightly forward or aft. There was evidently not the same concern about splitting these relatively massive frames along a line of grain. Furthermore the cushioning effect of the inserted treenails would have minimized any tendency to split.

7.4.2 Treenails (Fig 7.6)

Treenails were found lining all those nail holes in the framing timbers that were examined in detail. Four of the six treenail remains that could be botanically identified (Table 3.6.5) were from framing timbers and were up to 72mm in length and had diameters of 13 to 17mm. Two were hazel (*Corylus avellana*) and two willow/poplar (*Salix/Populus*). Two others (123 and 196) appear to have been associated with planking. One was of oak with P6A and one of willow/poplar with P4C. Another treenail (167) removed from a fastening hole in half-frame F12Pt had collapsed into an elliptical cross section and was tapered along its length of 39mm from 11mm outboard to 6mm inboard.

Some fastening nails had been driven at an angle across their associated treenail and it might be deduced from this that holes were generally not bored through treenails before the fastening nails were driven. It is much more likely that these were individual mistakes and that holes were generally bored through treenails before nails were driven, as seems to have been the case in the Blackfriars 1 ship (Marsden 1994, 51). In addition to the cushioning effect described above, the principal advantage of driving nails through treenails is that the compressed treenail ensures a watertight fit and militates against the nail working loose due to stresses imposed in a seaway. Furthermore it seems likely that the same fastening holes in the framing could be reused when a plank had to be replaced – the only action needed would be to drive out the nail, clean out the hole in the frame, and replace the treenail, probably with a slightly bigger one.

7.4.3 Caulking (Fig 6.18 and Table 3.3.4)

Layers of caulking material were found between all adjacent planking in the hull (including the elements of the plank-keel), within all butt joints, between the post and the bottom planking, and the post and the side planking. Caulking was found within the hollow of nail heads and wrapped around nail shafts in the St Peter Port and Blackfriars ships, but it was not so used in the Barland's Farm boat as far as can be ascertained. The Barland's Farm caulking consisted of macerated and twisted hazel (*Corylus avellana*) and/or willow (*Salix* sp) probably bound together with a resin or tar, although no traces were found (Evershead pers comm). It was held in place by small iron nails *c* 28mm in length, with heads of *c* 11mm diameter and near-rectangular shanks. This caulking was not driven between the planking after the planks had been fastened to the framing – as is done in frame-first building today – but nailed in position (along plank edges, inside the post housing, and so on) before two timbers were

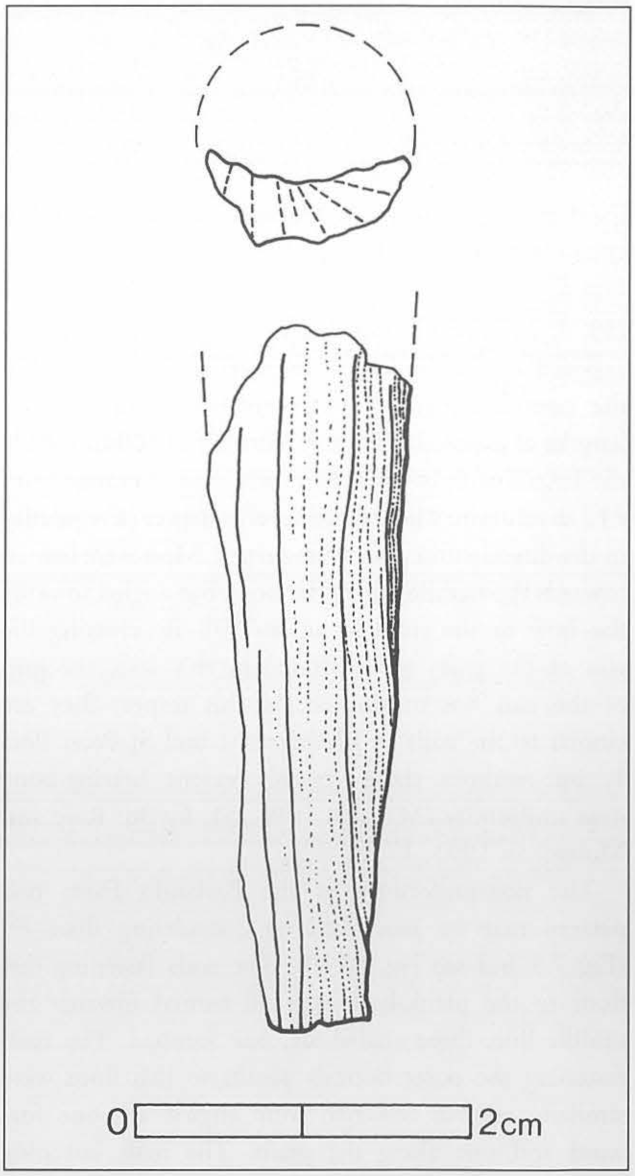


Figure 7.6 A treenail from half-frame F12Pt.

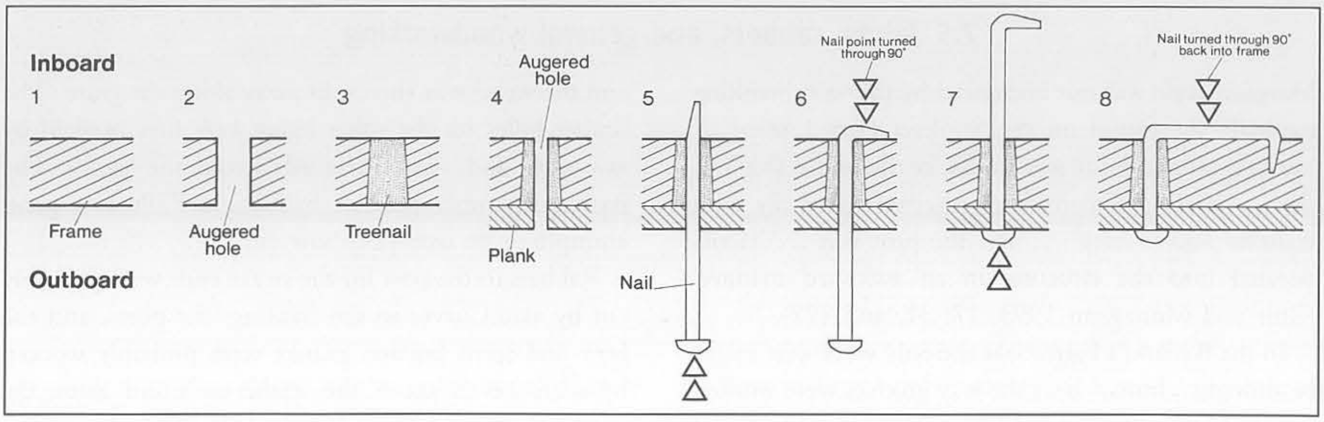


Figure 7.7 Diagram to show the sequence of fastening the Barlands' Farm planking to the framing,

brought together in the hull structure (Marsden 1994, 40, 189–90).

7.4.4 Fastening sequence (Fig 7.7)

Using evidence from the St Peter Port and Blackfriars ships where necessary, the method of fastening a Barland's Farm plank in position can be described as follows (the sequence for other timbers – stem to plank-keel, floor to plank-keel, side-frame to planking – would have been similar):

- appropriate bevel worked along upper edge of plank already fastened to next strake below;
- next plank fashioned to required shape, test-fitted (bowsing in to required curve by levers where necessary) and trimmed by axe/adze to a precise fit; plank refitted and when satisfactory removed;
- hammer used to nail caulking to plank ends and edges;
- holes bored by auger from inboard through frames;
- treenails (dried?) driven by mallet from outboard, narrow end first, into holes in framing;
- plank firmly positioned;
- holes bored through treenails and plank from inboard;
- nails of appropriate length selected (caulking possibly added to nails); each nail driven from outboard by a hammer (possibly against a wooden or metal dolly shaped to the nail head, as suggested by Marsden (1994, 53–4)) through hole in plank and through treenail in frame;
- when the nail has emerged some 12 to 20mm from the inboard face of the frame, the nail tip is turned through 90° to lie along the face of the timber, pointing towards the middle line of the boat at an angle of *c* 40° to the grain;
- the nail is driven home fully;
- holding a dolly against the head, a hammer is used to turn the inboard section of the nail through a further 90° in the same direction as before, so that the point re-enters the frame and the nail shank becomes flush with the inner face of the frame.

McKee (1972, 25) has described an 'even more professional way' of hooking a nail. After the nail has emerged from the frame's inner face, the dolly is placed at an angle to it so that, as the nail is driven home, it 'is successively bent over into a hoop with every hammer blow'. As the dolly is brought upright this hoop will be driven into the timber, 'pulling the parts being joined very firmly together'. This technique is 'harder to master but quicker and more effective' than the method illustrated in Figure 7.7. It may have been used in the Barland's Farm boat.

7.5 Joints, rabbets, and general woodworking

Margaret Rule was not impressed by the woodworking methods she found on the St Peter Port 1 ship: ... 'no carpentered joint was found in the entire ship' ... the ... 'method of construction seems outwardly both wasteful and clumsy' ... and the post was ... 'incorporated into the structure in an awkward manner' (Rule and Monaghan 1993, 17, 31, and 127).

In the Barland's Farm boat the only work that might be thought 'clumsy' is in the way grooves were worked across the bow bottom planks to take bow floors F2 and F3. Otherwise this boat has been built in a competent manner and there are at least two joints that may be considered 'carpentered'. The outer rabbet at the lower end of the post and the recess worked in the forward end of the plank-keel form a half-lap scarf; the inner rabbet at the same end of the post, together with the notch worked in the outer face of floor F4, form a double-notch joint directly above that scarf. Two nails driven through these two joints (Fig 6.10) and clenched on the inner face of F4, together with a third nail through post and floor, firmly locked together the plank-keel and the post to form the backbone of this boat.

The mast-step timber (Fig 6.21) was fastened to the framing in two simple lap joints (see Fig A2.60). The mast step itself was first marked out with auger holes at each corner, chisel cuts were made across the grain, and the wood was then split away along the grain. The limber holes on the other hand were first marked by saw cuts and then chiselled across the grain. The starboard limber hole of half-frame F7Pt is a good example of an over-deep saw cut.

Rabbets in the post for the strake ends were probably cut by axe. Curves in the framing, the posts, and the bow and stern bottom planks were probably worked by adze; bevels across the strake ends and along the upper edges of planks were probably finished by knife. The planking and framing were first sawn to shape and then where necessary trimmed by axe or adze and their edges chamfered to conform to the curvature of the hull. The finished timbers and planks were smooth though multifaceted in places (see section 7.1.1). At least five of the nine identifiable plank butts within the strakes were worked at an angle so that each plank at the butt could take two nails and there was less chance of splitting the frame (Fig 6.19). Some 450 holes would have been bored through plank and frame by auger, at positions determined by rules of thumb from which there were only minor deviations. Four hundred and fifty and more nails were made, driven, and clench fastened.

It is evident throughout this boat that the standard of craftmanship was entirely appropriate to the job in hand – the building of a working boat.

7.6 Repairs and replacements

7.6.1 Additional framing

That there are three main framing timbers at station 15 (Fig 6.17), when there are only one or two elsewhere in the boat, strongly suggests that one (or possibly two) of the three was added sometime after the boat was built to reinforce the framing in that part of the boat. The spacing of the main groups of framing and the sequence of half-frames interspaced among the main floors (Tables 6.2–6.4) indicate that the second and third timbers (from forward) at station 15 were the original timbers there and that these were a pair of half-frames (F15 Pt and St). This implies that the forward timber in this group (F15) was a reinforcement. Although only parts of F15Pt and St have survived, nail holes in the planking confirm (F15Pt) or are compatible with (F15St) the theory that they were originally half-frames. Similarly the nail pattern is compatible with F15 as a floor.

Side timbers SF3Pt and 4Pt were both reinforced by subsidiary timbers, two at station 3 and one at station 4.

7.6.2 Extra and replacement nails

The mast-step timber was originally fastened by one spike each to floor F6 and half-frames F7 Pt and St. A fourth spike appears to have been driven at an angle from within the step itself into F7 Pt, presumably as a result of the timber working during the boat's life.

An extra nail seems to have been driven as a spike through lowest side strake S3 into the end of F10Pt to reinforce the two clenched nails already fastening that strake to the adjacent half-frame F10St.

One of the two nails fastening outer bottom plank P2 to half-frame F15St had been driven from inboard through the half-frame near its lower end, through the outer bottom plank, and clenched by turning the tip through 90° so that it pointed aft along the outer face of the plank. As there was clearly room for two nails to be used here, the turned (ie not hooked) nail was probably a replacement rather than a reinforcement. The use of treenails within nail holes through the framing makes it relatively safe to reuse existing holes for replacement nails. This may have been done as a 'quick fix' during building. Alternatively it could have been done later in the boat's life, perhaps around the time floor F15 was added to the hull.

One of the two nail holes through which strake P5 was fastened to half-frame F12Pt has two channels within the frame, the lower channel plugged. This appears to have been a replacement nail that for some reason could not be driven through the original hole.

7.6.3 Repairs to planking

The short length of planking P3A and the fragment P3A* appear to be a repair to the forward end of the much longer plank P3B. This could have been needed during building or at any time in the boat's life.

The apparent mismatch in thickness between plank P4B and its neighbours P4A and P4C suggests that this 3.22m-long plank may have been a repair to strake P4. In a frame-first boat such as Barland's Farm, replacing part of a damaged strake is simpler than in an edge-fastened, plank-first boat such as the Magor Pill boat (Nayling 1998).

A short split in the outer face of plank P6A between stations 7 and 8 had been filled with caulking.

7.6.4 Repairs to framing

A small oak wedge had been driven from forward between floor F4 and the underlying planking near seam S2/S3. This was probably a temporary measure to tighten fastenings that had worked loose.

There are two evidently secondary features that are difficult to explain other than as a repair or as a 'mistake'. A treenail has been driven diagonally from the inner face of plank-keel S1 between stations 5 and 6 into the seam with outer bottom plank S2 where its end was shaped to match the edge of S1. There is no sign of this treenail on the corresponding edge of S2. The treenail was probably used to plug an unwanted fastening hole.There is a blind augered hole in the after face of half-frame F7Pt in the vicinity of strake P5.

7.7 Distinctive features of this boat

7.7.1 Structural features

The Barland's Farm boat has many of the characteristic features of the Romano-Celtic tradition as that style of shipbuilding is now perceived (McGrail 1995, 140):

1 *Framing*: her framing is relatively massive and closely spaced and consists of:

a pairs of half-frames and

b floors with side timbers.

Individual timbers at each station overlap one another, but are not fastened together.

2 *Planking*: her planking is flush-laid, edge to edge, but is not fastened together.

3 *Fastenings*: the relatively large iron nails fastening planking to framing are driven through treenails and clenched by characteristically hooking the emergent tip back into the inboard face of the frame. The distinctive caulking consists of macerated wood (probably blended with tar or resin) which is nailed to the edges of planks before they are fastened in position.

4 *Building sequence*: taken together, features 2 and 3 mean that the Barland's Farm boat was 'frame-based'; her shape was determined by the framing. A significant part of her framing (sufficient to define hull shape) was erected (not necessarily all at the same time) before her planking was fashioned and fitted.

5 *Propulsion*: her sailing mast was stepped about one-third the waterline length from the bow.

Apart from flatness in the floors that gives her a flat bottom internally, with her plank-keel and her posts this boat is structurally similar to the two ships Blackfriars 1 (Marsden 1994, 33–95) and St Peter Port 1 (Rule and Monaghan 1993, 13–28 and 127–9). She also bears some resemblance to the little that is known of the New Guy's House boat (Marsden 1994, 97–104). Like these three vessels, the Barland's Farm boat also has several other features in common with the keel-less and post-less Rhineland 'barges' and canal boats of this tradition, with their entirely flat bottoms (McGrail 1995, 142–3). These similarities are further considered in Chapter 9.

7.7.2 Apparent irregularities

To 21st-century eyes there are a number of irregularities in the framework of this boat:

- the frames do not lie precisely at right-angles to the fore-and-aft line;
- no two main floors have the same moulded and sided dimensions and, although all except F8 appear to extend from third side strake to third side strake, some merely touch that strake, while others fully overlap it; furthermore, the cross section of some floors, especially F4, vary markedly along their horizontal element;
- the half-frames, while not as individually variable as the floors, are not homogeneous as a group and certain of them differ significantly from the other member of their pair;
- although almost all the main side timbers extend from the lowest to the highest side strake, they begin and end at different points on those strakes, while the length of their overlap with associated floor timbers is not standardised;
- the sequence of half-frames and floors with side timbers is not entirely regular, even allowing that floor F15 was an afterthought;
- furthermore the mast step appears to be off-centre.

Taken together, these features give the inside of the boat a somewhat irregular appearance (Figs 6.2 and 8.1). Non-standardised timber sizes and an irregular framing pattern have, however, little if any influence on the shape, the structural strength, and the performance of this boat. Her builders evidently not only matched their resources to the particular job in hand, but also made best use of the timber available to them without compromising the performance of this boat in her particular role and operational environment.

7.7.3 Selection of timber

All timber that survived was of oak (*Quercus* sp). This may have been due to the excavation of an unrepresentative sample of timbers. On the other hand it may well be that the boat was indeed entirely built of oak and there are sound reasons for such a choice. Oak is in the second of five groups when classified for durability: it takes nails readily and has very good bending properties, yet is hard and strong. This strength is particularly marked in the line of the grain (Farmer 1972, 146–8).

When grown in forest conditions oaks form a long clear bole which is ideal for conversion into long runs of straight-grained, virtually knot-free timber very suitable for planking: see the Barland's Farm plank-keel (P1 and S1), the outer bottom planks (P2 and S2), and side planks (S3A, P3B, and possibly P7A. Other, shorter planks in this boat may also have come from such trees.

More isolated oaks on the other hand carry lower branches and the bole is not only relatively shorter but may also have some spiral grain. The branches of such oaks can be suitable for the curved timbers needed in a boat's framing, since the strength of these crooks lies along their grain. There can, however, be a diminution in strength where smaller branches form knots in these crooks. These properties are not restricted to branches in isolated oaks, however. They may also be found in the curvaceous branches that eventually grow on those forest trees that win the competitive race to survive. Natural crooks were clearly selected for the Barland's Farm floor timbers, but only in the case of F13 was it possible to get a crook with the required double curve. Other floors have short grain and hence reduced strength in at least one arm. The curves needed for the half-frames were only matched approximately by the crooks selected, and in general there is more short grain in these strength members than is thought desirable today. The side timbers were not converted from crooks and hence all had some short grain.

Quickly grown oaks (as isolated oaks generally are today) contain a large proportion of dense late wood. Hence their timber is stronger than that of today's slowly grown (often forest) oaks, which is light in weight and soft and, therefore, easier to work (Rendle 1971, 12–13). If 'slow grown' is defined as a radial growth rate of less than 2mm per year and 'fast grown' as greater than 3mm per year, we see that little slow grown oak was used in the Barland's Farm boat (section 7.2). The planking was chosen mostly from oaks of medium growth rate as was the post. The floors and the framing on the other hand came from medium- to fast-grown trees. The rate of growth of individual trees is, however, determined not only by the presence or absence of competing trees, but also by type of soil, aspect, rainfall, and a number of other factors. None of the Barland's Farm timbers need, therefore, to have come from isolated oaks, as are known today, but all probably came from a forest environment (possibly from the edges) where there was competition from other trees. Indeed planking and framing may have been converted from the same trees.

7.7.4 Use of sapwood

Sapwood that conducts sap and stores food is less resistant to decay caused by insect and fungus attack than heartwood that is naturally durable. Nowadays, therefore, sapwood is entirely removed from oak limbs destined to be used in boats or it is treated with preservatives. The strength of sapwood and heartwood is, however, practically the same. Where oak is unlikely to be exposed to conditions favouring decay, there is little to be gained by removing the sapwood (Rendle 1971, 11). A well-ventilated, open boat, such as that from Barland's Farm, is less likely to be susceptible to rots and fungal attacks than are modern decked boats (McGrail 1974, 41 and 1998, 28). The fact that sapwood was left on some of the Barland's Farm boat's timbers does not necessarily mean the her boatbuilders were skimping their work and storing up trouble for the future.

Some sapwood has been found on almost every excavated ancient boat built of oak that has been thoroughly examined (McGrail 1998, 28). The Barland's Farm boat is no exception to this rule since the side strakes have little sapwood, but there is relatively much more on most of the framing elements and towards the ends of the plank-keel. This sapwood has invariably been left on where an extra 12mm or so beyond the available heartwood was needed to give the shape required for a particular timber.

7.7.5 Conversion of oaks

7.7.5.1 Use of saws

Of the tools deduced to have been used to build the Barland's Farm boat (section 7.1.1), the saw is the only one for which there is no evidence in pre-Roman boatbuilding in Britain. The saw(s) used to convert the parent logs of the Barland's Farm plank-keel and the outer bottom planks into usable planking must have been large ones used in the saw-pit mode, though not necessarily over a pit. Similar saws would have had to be used to saw lengthwise the parent log of the two posts and that of the paired half-frames at station 10 and 15, as is thought to have happened. Use of a saw in this way means that trees can be converted into useful timbers more economically than if they are split. As this is particularly true of planking, it seems likely that four and more broad planks could readily have been converted from across the breadth of one large oak.

Although such tangential planks can be split from oaks, the easiest way to convert an oak into useful planks (used widely in medieval north-west Europe) is to split it radially because the alignment of the large rays assists the cleaving process (McGrail 1974, 42–3; 1998, 32). A radially cloven plank follows the natural run of the grain. This results in a stronger board than one in which the grain slopes from one plank face to the other (short grain), as can readily happen with sawn planks (see, for example, P6A and S3A in the Barland's Farm boat). On the other hand sawing rather than splitting ensures a more economical conversion of a log, and the planks are broader and have a standard thickness. Unless the parent log is very straight-grained, however, and maintains something like its butt diameter to a great height, there will be short grain which can lead to splits across the planking.

Planking sawn tangentially has other disadvantages in comparison to radial splits (McGrail 1974, 43–4; 1998, 28–32). A knot in a tangentially sawn log will appear in many planks (rather than in one or two); and knots are inherently weakening. When drying out from the green condition, planks sawn in this manner shrink more in breadth and are more liable to warp, check, and split than cloven planking.

These are all potentially serious weaknesses in a boat. Nevertheless, providing straight-grained, relatively knot-free oaks are used and sawing done carefully, as seems to have been the case in the Barland's Farm boat, the economic advantages to be gained by use of the saw are great and can outweigh the potential disadvantages.

7.7.5.2 Seasoned or unseasoned timber?

Control or avoidance of the drying-out process can also reduce (if not nullify) some of the disadvantages of tangentially sawn planking. After felling, an oak begins to dry from its 'green' condition. If this drying is not avoided in some way the timber begins to shrink differentially causing stresses that lead to distortion and splitting (McGrail 1998, 27–8). A second effect of this drying is that oak becomes increasingly difficult to work and to bend.

On these two counts (avoidance of shrinkage and retention of easy working properties), early builders of open boats are presumed to have converted and worked their timber soon after it was felled, ie in the green state, and there is ethnographic evidence for such practices (McGrail 1974, 39–41). The danger of rot in such unseasoned timber is minimal in an open, well-ventilated boat.

It seems likely (but cannot be demonstrated) that the Barland's Farm boat was built of green rather than seasoned timber. On completion the timbers of her immersed hull would have been stabilised at a relatively high moisture content in the boat's natural element – the sea. Her upper works would soon be covered by salt deposited from the spray, and being hygroscopic, that salt would have acted as a buffer to environmental changes and kept her timber at a relatively high moisture content. When hauled out of the water for the winter, stowage in an open-sided boathouse near the foreshore and a protective coat of tar or resin would have minimised any tendency for her timbers to dry out.

8

RECONSTRUCTION OF THE BOAT

8.1 Theory and methods

The theoretical reconstruction of the form and structure of an excavated boat together with her propulsion outfit and steering arrangements is a crucial stage in the assessment of performance (Coates *et al* 1995). Such reconstructions must be firmly based on the excavated evidence and be compatible with the 'technological environment' of the appropriate time and place (McGrail 1997b, 313–74) if they are to serve as a basis for an authentic, full-scale, experimental reconstruction (colloquially 'replica') and for valid predictions of stability, speed, cargo capacity, and the like.

8.1.1 The hull

The direct evidence for the Barland's Farm hull is encapsulated in the 1:10 'as found' model (Fig 6.4). The technological environment for reconstruction of those parts of the hull and those fittings that were not excavated is that of late Roman Britain, Ireland, Gaul, and adjacent coasts and rivers. Such evidence may be found in the Barland's Farm remains themselves, in the Blackfriars 1 ship and the Guy's House boat, both of which were probably built in Britain (Marsden 1994), in the St Peter Port 1 wreck from Guernsey waters which is considered by her excavators to have been built on the Continent (Rule and Monaghan 1993), and in the Romano-Celtic 'barges' excavated from continental rivers (McGrail 1995). Evidence for tools and techniques used in the building of Romano-British non-boat wooden structures may also be considered.

Hypothetical reconstruction may be in the form of a scale model or a scale drawing. Models have been used in the reconstruction of the prehistoric Brigg 'raft' (McGrail 1985), by Steffy (1994) in his work on early Mediterranean vessels, and by Crumlin-Pederson (1986, 99) in projects concerning medieval boats and ships of the Nordic tradition. Scale drawings were used to reconstruct the medieval Graveney boat (McKee 1978) and the prehistoric Hasholme logboat (McGrail 1988); models were subsequently built from these drawings. This latter method was the one chosen for the Barland's Farm boat.

The 'as found' model (Fig 6.4) was dismantled and reassembled a number of times until (with one exception – half-frame F10Pt) it seemed to conform best to the other evidence available, especially the photogrammetric plans and on-site photographs. The model was then glued together and a measured drawing compiled using offsets. This drawing consists of a plan, a long section seen from the starboard beam, and twelve transverse sections (Fig 8.1). At half the scale of the model, the original measured drawing is a 1:20 representation of the boat 'as found'. Overall this drawing measures 0.65 × 0.5m, a more manageable size than if a 1:10 scale had been used.

The elements of the boat fitted together well on this drawing, the planking runs were fair, and the individual drawings in three planes could be readily harmonised. It was, therefore, decided to use this drawing as a basis for a reconstruction of the hull.

8.1.2 Propulsion

The direct evidence for propulsion by sail is the mast-step timber fitted about one-third the length of the waterline from the bow of the Barland's Farm boat. Such a position is ideal for a towing mast, however. and the possibility that the Barland's Farm boat was a barge towed from canal or river bank cannot be ruled out without further enquiry.

There have been no finds of rigging, yards, or sails and only one mast and one mast beam that can be attributed to Romano-Celtic vessels. It is, therefore, necessary to look elsewhere for guidance – for example, earlier to the Graeco-Roman tradition of the Mediterranean and later to the Nordic tradition of northern Europe. Generally speaking ships' masts in these two traditions had their heel set into a socket in a mast-step timber of one sort or another, with further support at crossbeam/deck level. The mast was further braced by stays running from near the masthead forward and aft and shrouds to the sides. This could be a model for the reconstruction of the sailing outfit of the Barland's Farm boat. Such a comprehensive outfit of standing rigging is not essential, however, if some limitations on performance can be accepted. For example, it is possible to sail certain boats on rivers and in coastal waters using a cantilever mast without standing rigging, providing the heel is in a step and there is further support at crossbeam/thwart level (McGrail 1998, 224). Such a rig would generally limit the sail area and it could only be used for running and reaching rather than beating to windward when stresses are greatest. The question that must, therefore, be asked is whether the Barland's Farm boat was designed to have such restrictions on her performance and on the environmental conditions in which she could be used under sail.

There is no direct evidence for methods of propulsion other than sailing in the Barland's Farm boat, but boats of this size can be propelled by oar, by poles in the shallows, and even by paddle. The use of pole and paddle generally leaves no archaeologically visible evidence (McGrail 1998, 204–7).

Oars need to be worked through a pivot. In a boat of Barland's Farm size this would probably be near or on the top edge of the sides, whether the oarsman sat or stood to row (McGrail 1998, 207–16). Oar pivots can be very simple indeed – merely a grommet through a hole in the side planking, as found in Indian Bay of Bengal boats today (Blue *et al* 1997). Wear marks on the planking may indicate where an oar was pivoted or where an oarsman had frequently stood.

8.1.3 Steering

Sailing boats of Barland's Farm size may be steered by several means (McGrail 1998, 239–51): by trimming the sail; by a steering oar used over the stern or quarter; by side rudder on the quarter; by median rudder at the stern

Steering by sail, although practicable within certain limits, is unlikely to have been the only method in the Barland's Farm boat. The possible use of steering oar or rudder needs therefore to be investigated.

8.2 The hull

Examination of the remains, the 1:5 drawings of each timber, and the 1:10 model (Figs 6.4, 8.1) revealed two important features about the original boat's general shape: she had had a post at the stern rather than a transom; and she had had a flat bottom with a plank-keel, but without rocker. During the recording of the timbers, it had become clear that P7 was the top strake; this placed an upper bound on the height of most of the hull. The other design parameters that had to be determined were the original length of the boat, the original height of the posts, and the form of the stern and the upper bow.

Using the 'as found' 1:20 drawing (Fig 8.1) compiled from the 1:10 model (Fig 6.4), these four problems were tackled. This was not a simple process since any alteration or extension of the boat in one particular plane (plan, longitudinal section, or transverse section) meant that consequential adjustments had to be made to the drawings in the other planes. Furthermore these secondary alterations had to be compatible with the boat's form as already depicted in those two planes. Any single alteration thus led to an iteration of adjustments until the lines of the boat were fair in all three dimensions.

The curves in profile of the surviving post and strake P5 (Fig 8.1) were projected forward and upwards until they met, thereby delineating the middle section of the post. The run of the surviving lengths of the upper strakes was then extended, with a rising sheerline in the bows forward of F3, until these strakes met a further extension of the run of the post. This construction gave a forward limit to the boat, with a minimum height for the post, and determined the sheerline forward and the shape of the upper bows.

During the compilation of the descriptions of each timber (see Appendix 2) it had become clear that, although the after half of this boat was generally similar in shape to the forward half, it was not its mirror image. While the bottom of the boat (plank-keel and outer bottom planks together) was symmetrical about its own mid-point, frames aft had a slightly greater overall breadth than those in near-corresponding stations forward. Furthermore shorter lengths of planking were used towards the stern. These two features suggested that the boat had been fuller aft than forward. The run of the plank seams on the 'as found' model (Fig 6.4) which are readily appreciated on the 1:20 drawing (Fig 8.1), was such that the planking aft curved upwards from a point closer to the plank-keel mid-point than did the forward planking. This also indicated a stern that was fuller than the bows.

It was considered that the *maximum* possible overall

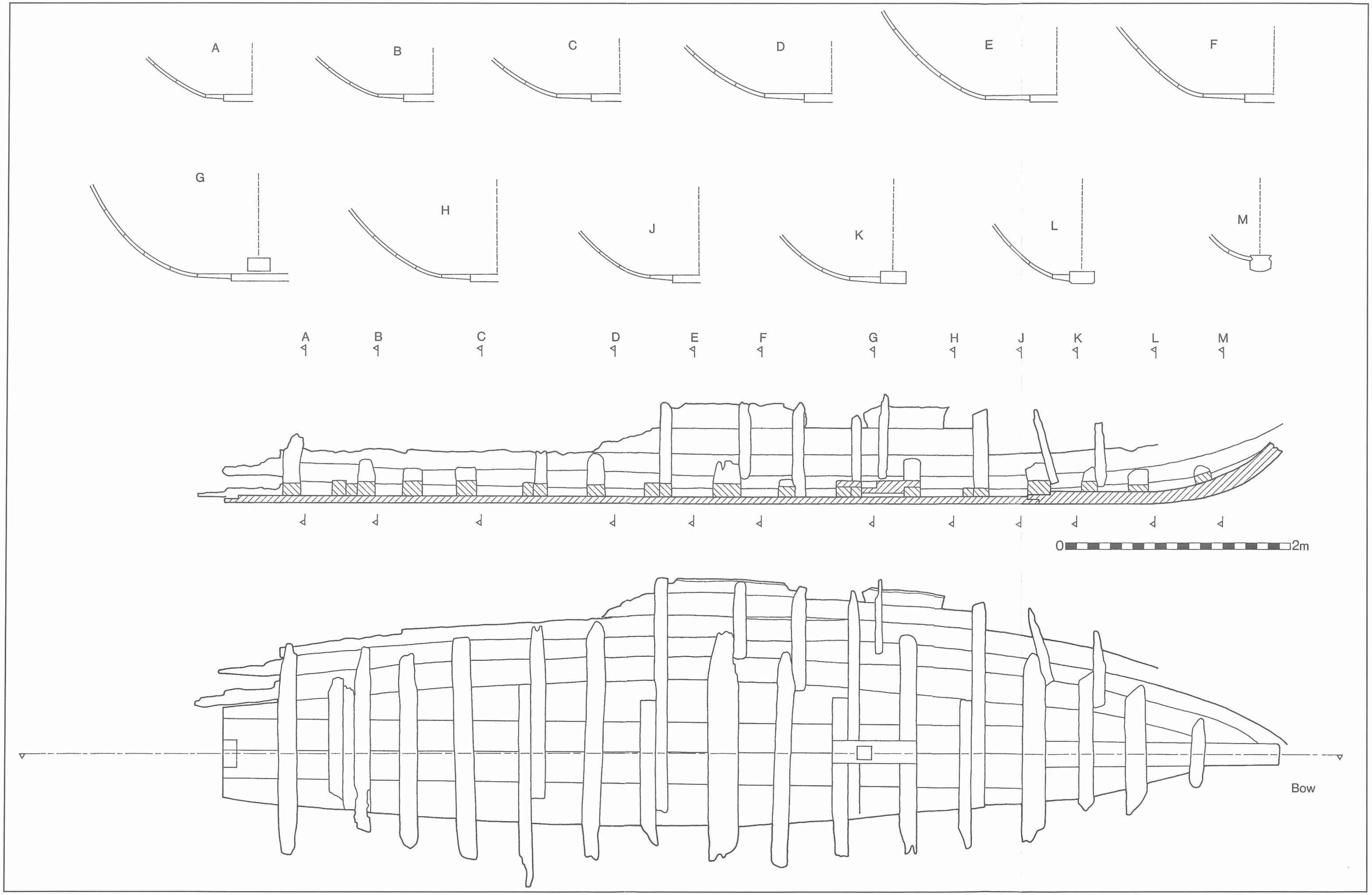


Figure 8.1 Measured drawing of the 'as found' model of the boat (see also Fig 6.4).

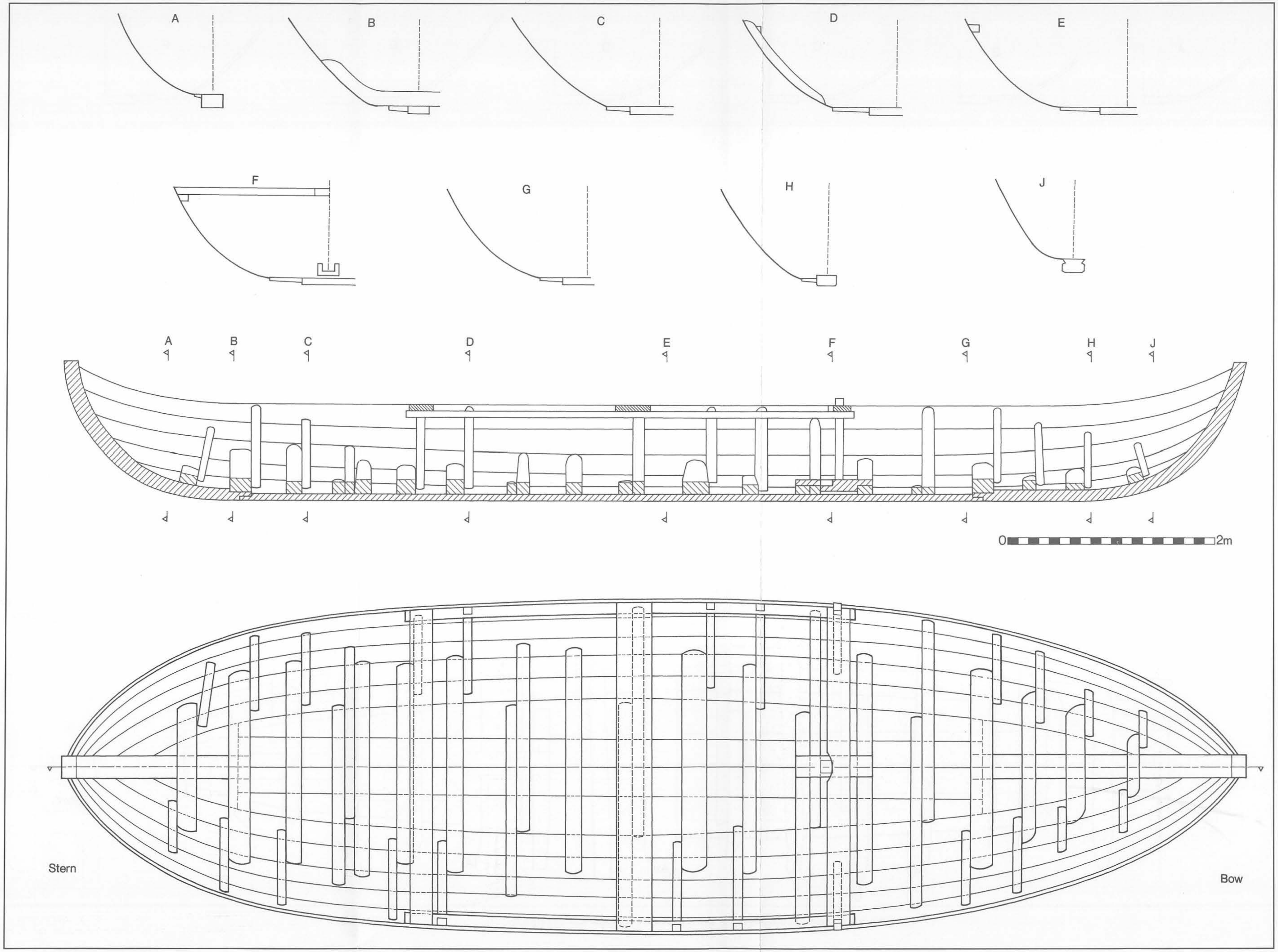


Figure 8.2
Reconstruction drawing of the boat's hull based on the 1:10 model of the boat 'as found' (Figs. 6.4 and 8.1). The hypothetical elements can be recognised by comparing this drawing with Fig 8.1. This reconstruction incorporates the secondary floor F15, but not the auxiliary side timbers at stations F3 and F4. Reconstruction drawings of the propulsion outfit and the steering arrangements are in Figs 8.9, 8.12, 8.20, and 8.21.

length of the boat would be if she were to be fitted with a stern post similar in length to the stem post. This would make the plank-keel's mid-point coincide with the longitudinal mid-point of the boat and give an overall length of *c* 12.2m. The *minimum* length appeared to be when the horizontal arm of this post was eliminated so that the stern post began to curve upwards immediately aft of its scarf with the plank-keel. This would mean an overall length of *c* 11.4m. By trial extensions of the 'as found' drawing in these two ways, it was found that the minimum solution better fitted the known run of planking aft. It also gave a fuller stern, one that it was practicable to plank with short planks similar in length to those which had survived aft.

Furthermore these hull curves aft could be achieved with planks no broader than those already used in the boat, providing that short lengths of stern bottom planks were fitted which had somewhat more up-curvature than did the bow bottom planks. This was considered practicable since curves in planks BP and BS had been achieved by hewing rather than bending.

When reconstructed in this manner (Figs 8.2 and 8.3) the bow and stern are generally similar but not exactly the same shape, while the mid-point of the boat's overall length lies between floor F9 and half-frame F10Pt, some 0.4m forward of the plank-keel's mid-point between half-frame F10St and floor F11. When the reconstruction drawing (Fig 8.2) is compared with the 'as found' drawing (Fig 8.1), it can be seen that the hull has been reconstructed by natural extensions of the plank runs and the curves of post and frames.

There is some latitude in the overall length of the boat but not much, as the existing plank runs are difficult to harmonise with a boat much longer than 11.4m overall. The other indeterminate parameter is the height of the posts. Either or both posts could be extended beyond that shown in Figure 8.2 to give both a greater sheer and a more curvaceous shape at bow and stern. The minimum solution is preferred in this matter, however, as it is for overall length.

In the light of the information at present available, it is considered that Figure 8.2 is a valid reconstruction

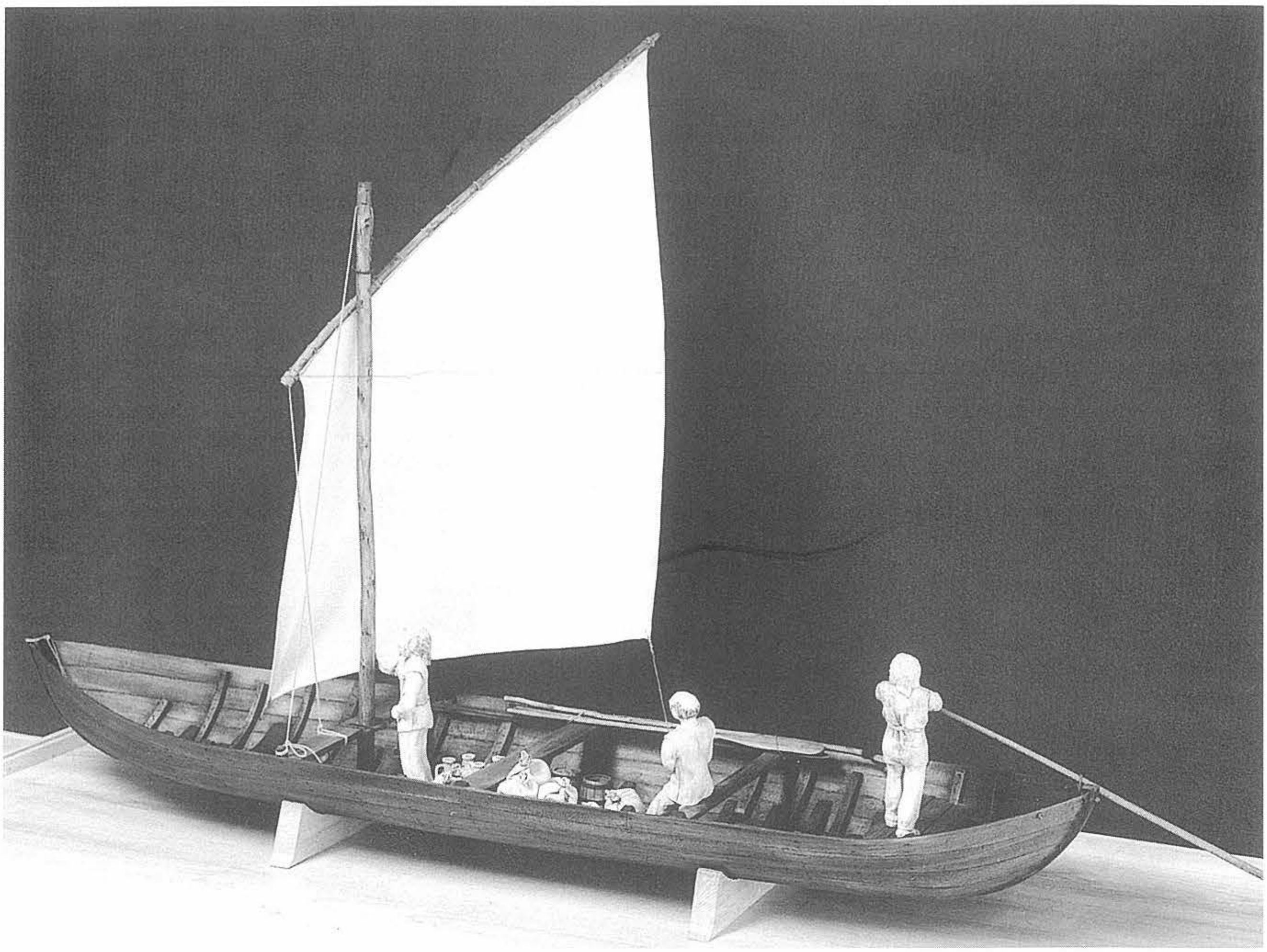


Figure 8.3 Photograph of the reconstruction model.

of the minimum version of the hull of the Barland's Farm boat. Based on the incomplete hull that was excavated, the drawing has been completed with the minimum of assumptions. Figure 8.2 can be used with confidence to deduce the general order of performance of the original boat.

In addition to the shape of the reconstructed hull, there are also structural considerations. In the reconstruction drawing, the missing strakes and parts of strakes are planked-up in a manner compatible with the existing pattern of butts (Fig 6.19). The incomplete framing timbers are extended to the best estimate of their original length and side timbers are added to complete the pattern deduced (section 6.3.3.6). The position of floor F17 is known – over the scarf between plank-keel and stern post – and it is reconstructed as a replica of F4 with associated side timbers. Another floor (F18) is needed some 0.56m (the mean frame spacing) aft of F17 and this is reconstructed with side timbers to fit the hull shape at this station.

Although plank boats without crossbeams are known (McGrail 1998, 142), estuary and seagoing boats need them to hold the sides of the boat at a fixed distance apart and thus, with the framing, increase the boat's resistance to hogging and sagging stresses experienced in a seaway.

Crossbeams also frequently have secondary functions such as mast supports and thwarts for oarsmen. The upperworks of the St Peter Port 1 ship (Rule and Monaghan 1993) did not survive and the reconstruction of the vessel has not yet been attempted. Marsden (1994) on the other hand has reconstructed the Blackfriars 1 ship. As a fragment of a knee was excavated with this ship, knees have been used in Marsden's reconstruction drawing to support crossbeams, either directly or on a beam shelf (Marsden 1994, 64–5).

No crossbeams, knees, or shelves were excavated with the Barland's Farm boat and there are no clear indications on the upper surviving strakes (limited in extent as they are) that beams were once fastened to them directly or indirectly.

There are, however, suggestions that a beam shelf could have been fitted near the heads of the framing timbers from F5Pt to F10Pt. On this minimal evidence it is postulated that crossbeams were once fitted at stations 6.5, 10, and 14 supported by a beam shelf along the port and starboard sides that may have been intermittent. In the reconstruction these beams have been fitted high on the frames, but at such a height that a man may sit on them with his feet on bottom boards (section 6.3.3.5). Much, if not all, of the cargo was probably carried in this midships section of the boat, between stations 7 and 14, and on structural grounds such beams are a necessity. In addition the crossbeam at station 6.5 could conveniently act as a mast beam.

Data for the reconstructed hull is tabulated in Table 8.1. Using definitions given by McKee (1983, 81), the overall hull shape of the reconstructed Barland's Farm boat may be described as:

- neither 'beamy' ($\leq$ 2.6) nor 'narrow' ($\geq$3.75) in relation to length, but in between;
- a 'shallow' ($\geq$ 3) transverse section in relation to breadth, rather than 'deep' ($\leq$ 2);
- a 'firm' midships sectional area rather than 'full' (0.85 and greater) or 'easy' (0.70 or less).

It should be emphasised that this reconstruction is the result of a theoretical study based on the surviving remains. As such it can give only an indication of probable performance. Correspondingly the reconstruction drawing (Fig 8.2) is an archaeological reconstruction and not a blueprint for a full-scale

Table 8.1 Hull data for the reconstructed boat

	overall	*at 60% water-line*
L × B × D	11.40 × 3.16 × 090m	10.8 × 2.8 × 0.54m
height at posts	1.30m	1.30m
mast-step position	4.05/11.40 = 0.36	3.6/10.8 = 0.33
L/B	3.6	3.9
B/D	3.50	5.2
L/D	12.67	20
midships coefficient	0.80	–

Notes
1 The significance of the ratios and coefficients is considered below (section 8.6).
2 At 60% water-line the draft is 60% the height of sides amidships.
3 The mast-step position is given as % of the length of the boat measured from the bow. At 50% water-line this would be 32% (see section 8.6.13).

'replica'. An authentic full-scale reconstruction (replica) could only be designed as a result of a rigorous evaluation and detailed criticism of the evidence by a group of specialists, as recommended by Coates *et al* (1995; see also McGrail forthcoming).

8.3 Propulsion

The principal evidence for propulsion in the Barland's Farm boat is the mast-step timber on the centreline of the boat at station 6.5 (as described in section 6.4). The mast step worked in this timber is *c* 60mm deep, 125 to 115mm in the fore-and-aft line, and 115 to 90mm athwartships. It would be suitable for a mast of *c* 90mm diameter at its heel, or *c* 60mm sided if squared. Like the mast steps of the Blackfriars and St Peter Port ships (these are two to three times the size of the Barland's Farm boat) and other vessels of the

Figure 8.4
A Zwammerdam barge during excavation. (Photograph by Seán McGrail)

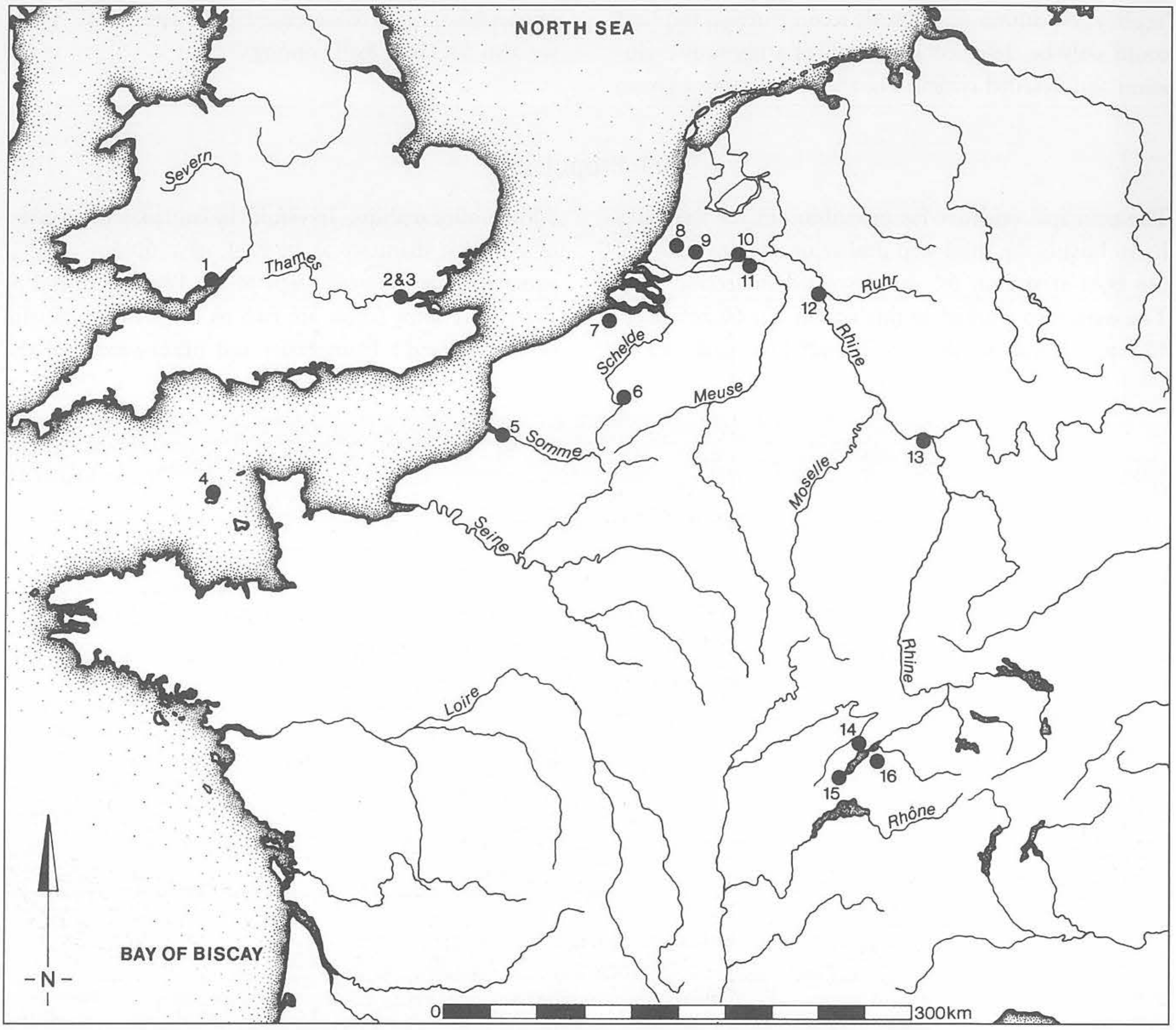


Figure 8.5 Map showing the distribution of Romano-Celtic boats and ships: 1 Barland's Farm; 2 Blackfriars; 3 New Guy's House; 4 St Peter Port; 5 Abbeville; 6 Pommeroeul; 7 Bruges; 8 Zwammerdam; 9 Woerden; 10 Kapel Avezaath; 11 Druten; 12 Xanten; 13 Mainz; 14 Bevaix; 15 Yverden; 16 Avenches.

Romano-Celtic tradition (McGrail 1998, 218, table 12.5), the Barland's Farm step is positioned approximately one-third the waterline length from the bow. In relation to the overall length of the boat, it is 36% from forward. In relation to the 60% waterline it is 35% and at 32% for the 50% waterline (see section 8.6.13). This position is suitable for a mast with a fore-and-aft sail on a seagoing vessel or for a towing mast on a canal or river barge (McGrail 1998, 216–18).

A towing mast stepped on the middle line and between 20% and 40% of the waterline length from the bow ensures that when the vessel is towed from a river or canal bank it remains parallel to the near bank (Rawson and Tupper 1976, 511; McKee 1983, fig 104). The majority of the Romano-Celtic vessels recognised to date are of a lidless box shape, flat-bottomed, keel-less, without stems, and of barge-like proportions (Fig 8.4). Furthermore they were found near the River Rhine or its tributaries (Fig 8.5) (Marsden 1994, fig 146, table 16). The mast in these river and canal boats was primarily a *towing* mast, although in fair winds it may well have been practicable to hoist a sail.

The ships from St Peter Port and Blackfriars on the other hand, although having a number of attributes in common with these barges (McGrail 1995) are, unlike them, full-bodied in form and have posts and a plank-keel (Fig 8.6). For these and other reasons, it is clear that these two vessels were seagoing ships with sailing masts. The Barland's Farm boat has posts and a plank-keel and, although she has flat outer bottom planks,

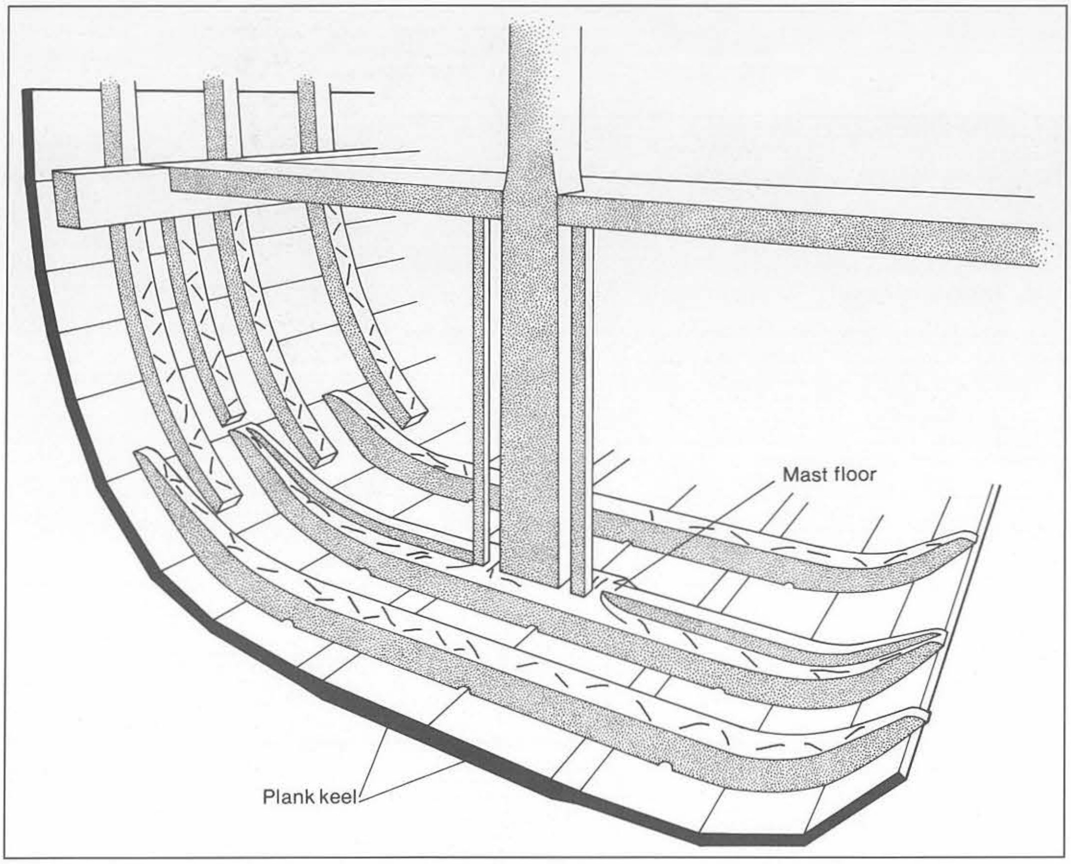


Figure 8.6a (*left*) Diagram to show the structure of the hull of Blackfriars 1 in the region of the mast. Note the two-unit plank-keel and the mast floor timber with a strengthening medial ridge (after Marsden 1994, fig 58.

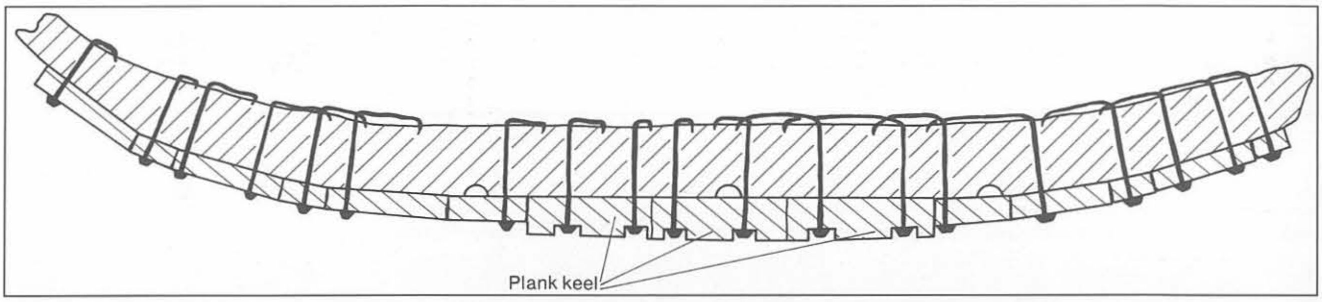


Figure 8.6b Cross section through the surviving hull of St Peter Port 1 at floor T42 showing the method of fastening the planking to the framing. Note that the heads of the nails fastening floor T42 to the three-unit plank-keel are countersunk (after Rule and Monaghan 1993, fig 12).

from the chine upwards her sides are as curvaceous as those of Blackfriars and St Peter Port. Moreover the Barland's Farm boat was found close to the Severn Estuary (Fig 1.1) and her shape and structure suggest that she was an estuary boat using the tidal flows to advantage to go up and down the rivers flowing into the Severn. She was also able to sail along and across the estuary in appropriate conditions. The Barland's Farm mast step was for a sailing mast which would probably have been supported higher up by a crossbeam with a metal fitting, possibly similar to that in the near-contemporary Romano-Celtic river and canal barge Zwammerdam 4 (Fig 8.7).

Figure 8.7 The mast beam of Zwammerdam 4. (Photograph by Seán McGrail)

8.3.1 Mast, sail, and rigging

8.3.1.1 The mast

The only mast excavated from early north-west Europe is the 2nd- to 3rd-century AD mast from Bruges (Marsden 1976) that had a maximum diameter of 0.16m and a length of *c* 9.3m. Marsden (1994, 67) has estimated the Bruges boat's maximum beam as 4.7m. Using the same ratio of mast length to beam, the mast of the Barland's Farm boat would be *c* 6m. Of the rules quoted by Marsden (1994, 67–9) in his estimation of the length of the Blackfriars 1 mast, most apply to ships with several masts. The only rule applicable to boats and small ships (and therefore possibly relevant here) is the traditional Vestland Norwegian rule (Andersen 1975, 90–6) that the mast from heel to halyard hole should equal the girth of the boat at that station. According to this rule the Barland's Farm halyard hole would be *c* 6.45m above the mast step.

8.3.1.2 The sail

Roberts (see Table 8.7) has shown that, for the Barland's Farm boat with her mast step so far forward, a fore-and-aft sail is more efficient than a square sail since it gives a better performance in a beam wind and steering is made easier as the rig is more balanced. Documentary and representational evidence for the use of fore-and-aft sails in north-west Europe is from a much later date (Moore 1970). Ellmers (1969, pl 16 and 1978, figs 3 and 5) has suggested, however, that boats depicted on a 2nd- to 3rd-century AD Rhineland mosaic and a gravestone have leather lug sails fitted with battens. It may be that the Celtic lug sail began to be used from the 2nd century AD, replacing or in addition to the square sail which appears to have been used on the vessel represented by the 1st-century BC gold model boat from Broighter in the north of Ireland and the 1st-century AD coins of Cunobelin excavated from Canterbury and Colchester, both of which have a mast near amidships (McGrail 1990, 36–9 and 43–4). Excavated evidence suggests that a mast stepped well forward is a characteristic of Romano-Celtic ships and boats. Taking this point into consideration, Roberts' analysis, and Ellmers' conjecture, it seems reasonable to suggest that the Barland's Farm boat may have had a lug sail; if so, this would be the earliest use in north-west Europe. Nevertheless the use of a square sail cannot be discounted.

Sails of linen and of wool are known to have been used in medieval north-west Europe (McGrail 1998, 222, 234, and 236) but Caesar (*De Bello Gallico* iii. 13) and Strabo (*Geographia* iv. 195) tell us that the seagoing ships of the Celtic Veneti had leather sails. Woollen and linen sails have been proven in use on full-scale reconstructions of ancient boats (Crumlin-Pedersen pers comm), but leather sails have not so far been tested.

There are a number of ways of estimating sail area. For example, the sail area/displacement coefficient may be used to estimate the maximum sail area appropriate to vessels within a particular (modern) class (McGrail 1998, 221–2). Using a sail area coefficient of 8 (that for Skuldelev 1) the Barland's Farm boat's sail area would be *c* 34 m^2.

A simplified version of this coefficient gives maximum sail area as proportional to (maximum beam)^2. Data published by Crumlin-Pederson for the small Viking Age vessels Skuldelev 1 and 3 (McGrail 1998, 222) suggest the approximate equation: sail area = 4 (maximum beam). This would give the Barland's Farm boat a sail area of 31m^2.

By calculating the wind pressure in a sail in a force 5 wind (fresh breeze) and considering the righting moments due to the hull and heeling moments due to the sail, Owain Roberts has calculated a sail area of 25m^2 (see section 8.6.6).

Of the three values, the minimum of 25m^2 is preferred. A single dipping lug sail has 25% to 33% of its area before the mast. Using the 25% measure, a lug sail of *c* 25m^2 on a 6m mast of maximum diameter 0.09m would appear on the Barland's Farm boat as in Fig 8.3. Alternatively, a square sail of similar area may have been used (see Fig 8.21).

8.3.1.3 Standing rigging

Shrouds are not always essential in a boat the size of the Barland's Farm boat with a mast that is not overlong (McKee 1983, 149–151; Leather 1989, 69). A single shroud used on the weather side, however, would be prudent and would allow a boat to sail closer to the wind. This with a backstay/halyard (see below) would probably be the minimum standing rigging for the Barland's Farm boat. Such a shroud might have been rigged from the masthead to protruding side timbers at station 6.5 port and starboard.

8.3.1.4 Running rigging

The minimum running rigging was probably a halyard led from the yard through a halyard hole high on the mast and then taken someway aft on the weather side to double as a backstay, a tack from the forward lower corner of the sail to floor F4, sheets from the after lower corner via a cleat to the helmsman or nearby, and a dipping line from the forward end of the yard to the mast beam. The yard would have been held to the mast by a traveller (*Manual of Seamanship* 1926, 266).

8.3.1.5 Evidence for sail use

Side timber SF6.5Pt, which is at the same station as the Barland's Farm boat's mast step, extends upwards beyond the top strake of planking (Table 6.1). Towards the top of this side timber a groove 10mm wide and angled downwards from outboard has been worked in the after face (Fig 6.15). The groove appears to be aligned with a sub-rectangular hole measuring 50 × 30mm through strake P7, *c* 40mm from its upper edge (Fig 6.20). There seem to be signs of wear on the upper forward corner of this hole. This wear and the groove in SF6.5Pt could have been caused by rigging, possibly a shroud. It is conceivable that the corresponding strake S7 and side timber SF6.5St had similar uses. Simple methods of attaching shrouds to a rope grommet through the planking are illustrated by Andersen and Andersen (1989). Alternatively a belaying pin may have been inserted in the hole through P7 and a shroud made fast to it Half-frame F10Pt and possibly others may have protruded above the top strakes and may similarly have been used as a kevel head (see section 6.3.3.5).

The plank-keel and outer bottom planks of the Barland's Farm boat are worn on their inner faces between half-frame F5St and floor F6 (Fig 6.9). The plank-keel is most heavily worn by *c* 22mm at the P2/P1 seam, increasing to *c* 30mm at P1/S1 and to 40mm at S1/S2. The wear on P2 varies from 7 to 13mm while S2 has slight wear near its seam with S1. This is relatively heavy wear – at its worst over half the thickness of the plank-keel has been worn away. It is conceivable that this wear was caused by human feet engaged in a recurrent activity in connection with the nearby mast (for example, dipping a lug sail), but such wear would more likely be alongside the mast and aft of it rather than forward. It seems more likely that bailing out bilge water would cause such a wear pattern or the shovelling out of some bulk cargo (as was found on the flat-bottomed 19th-century barge excavated from the River Usk at Tredunnoc, south-east Wales, but there the planking was pine (*Pinus* sp; see McGrail and Parry 1991). On balance it seems likely that these wear patterns were caused by use of a bailer.

8.3.2 Other means of propulsion

There is no direct evidence for other methods of propelling the Barland's Farm boat, but boats of this size can be propelled by oar, by poles in the shallows, and even by paddle. It seems very likely that the Barland's Farm boat was propelled by poles in shoal waters, but such use generally leaves no archaeologically visible evidence – as is the case here (McGrail 1998, 204–7). Models of three poles with forked terminals were found with the Broighter boat and similar metal terminals have been found in late Iron Age and Roman Age contexts in north-west Europe (McGrail 1998, 204–5). Poles *c* 3 to 4m in length would be suitable for the Barland's Farm boat.

Oars need to be worked through a pivot: in a boat of Barland's Farm size this would probably be near or on the top edge of the sides. There is, however, no clear evidence for such a pivot in those parts of the top strake (P7) that have survived. The earliest excavated oar pivots are the single grown crooks with a grommet on the Nydam boat (Åkerlund 1963; McGrail 1998, 214). The 5th-century BC Duurnberg model has simple U-shaped oarports cut in the top of the sides (McGrail 1998, fig 12.10). On the other hand the oars with the

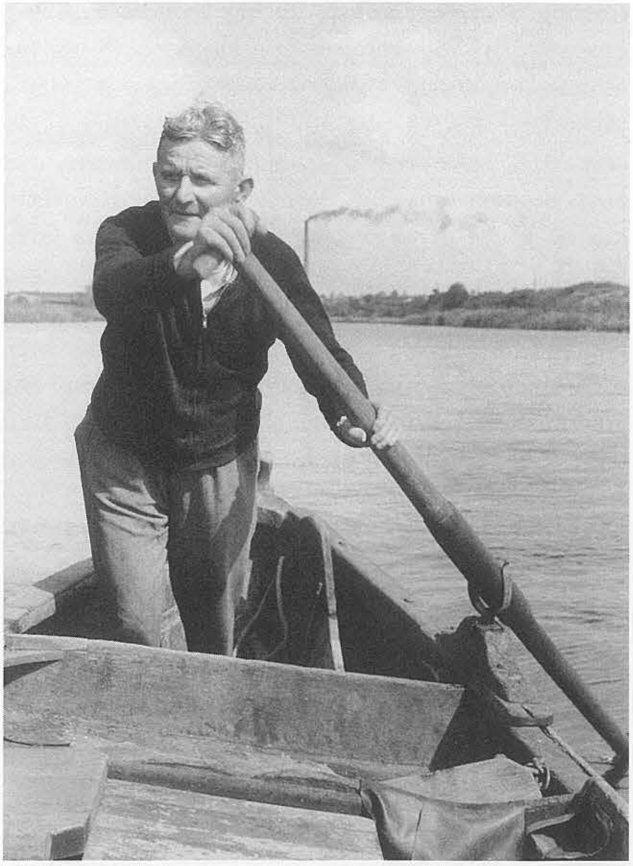


Figure 8.8 Stand-push rowing a kahn near Rostock. (Photograph by Wolfgang Rudolph)

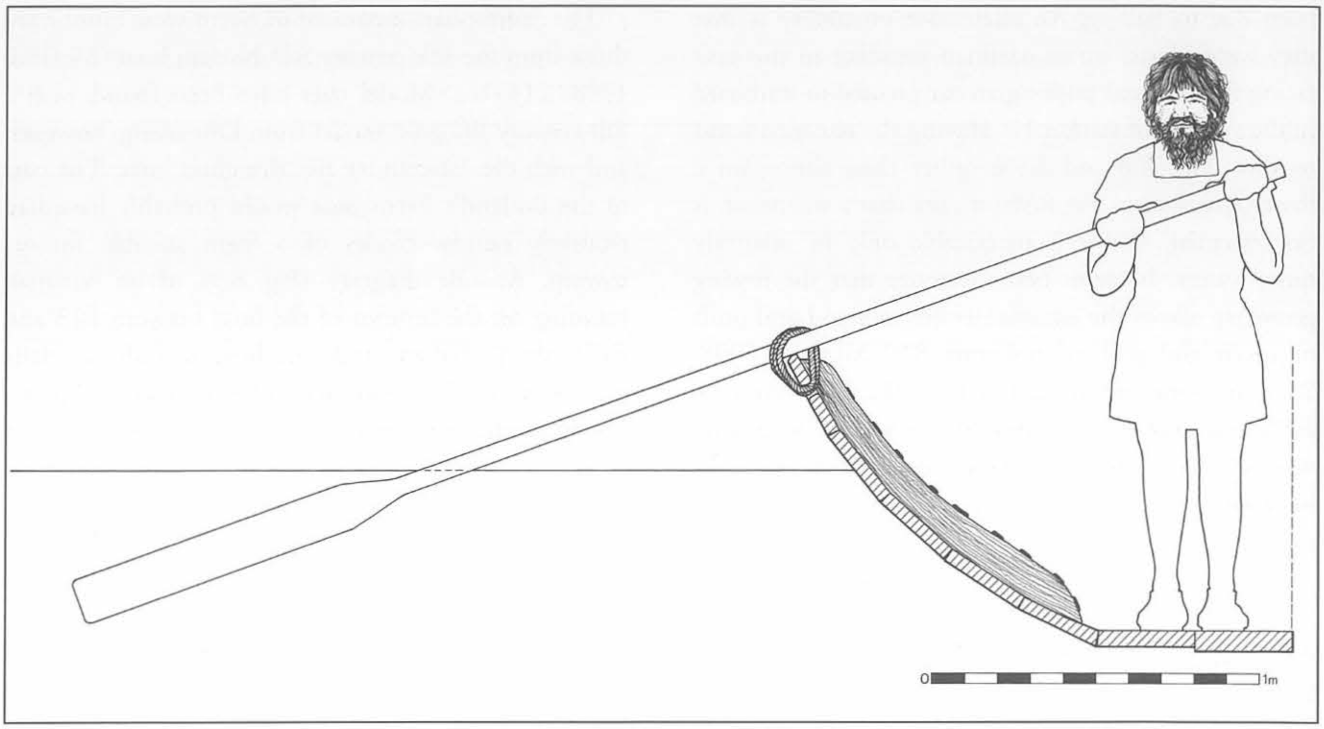


Figure 8.9a Diagram to show the rowing geometry of an oarsman standing to push an oar on the starboard side of the boat between half-frame F12St and floor F13.

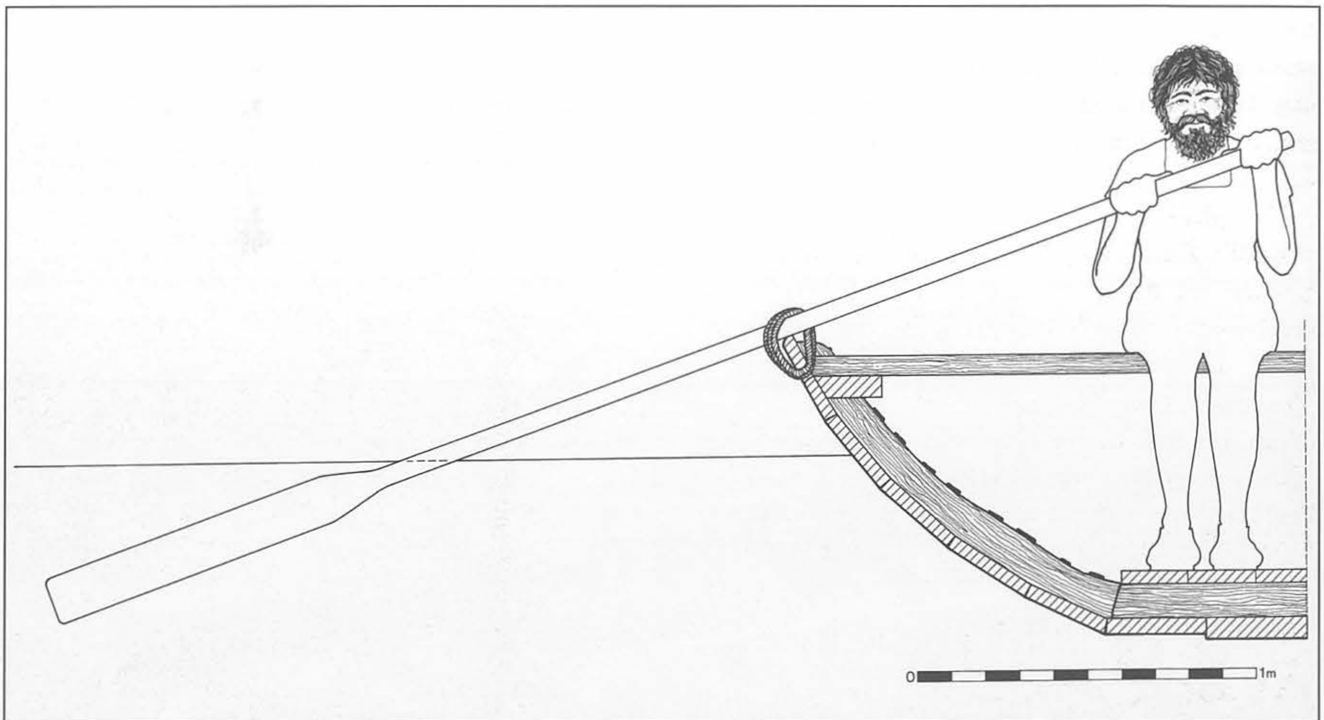


Figure 8.9b Diagram to show the rowing geometry of an oarsman sitting on the port side of a crossbeam at F10 and pulling an oar.

1st-century BC model boat from Broighter (McGrail 1998, figs 10.9 and 12.2) are evidently pivoted in rope grommets through a hole in the side planking. Such simple devices are used in many parts of the world today (for example, in Bay of Bengal boats; Blue *et al* 1997, 202). Grommets through a hole in the top strake or in an extended side timber may well have been used in the Barland's Farm boat.

The curved wear marks (Fig 6.9b) on the inner face of the plank-keel between F16 and F17 may also have been due to bailing. An alternative possibility is that they were caused by an oarsman standing to this task facing forward and pushing an oar pivoted to starboard in the vicinity of station 17. Having the oarsmen stand to row (Figs 8.8 and 8.9a) rather than sitting on a thwart/crossbeam (Fig 8.9b) means that a steersman is not essential, but it is practicable only in relatively quiet waters. It seems best to ensure that the rowing geometry allows the oarsman either to stand and push or to sit and pull as in Figure 8.9 (McGrail 1998, 207–16). One oar on each side of the boat, say near F5Pt and between F13 and F12St, would be all that was necessary for propulsion when the boat could not be sailed or poled.

The earliest oars excavated in north-west Europe are those from the 4th-century AD Nydam boat (McGrail 1998, 214–16). Model oars have been found with a 5th-century BC gold model from Durrnberg, however, and with the 1st-century BC Broighter boat. The oars of the Barland's Farm boat would probably have had relatively narrow blades of a form suitable for sea rowing. A scale diagram (Fig 8.9) of an oarsman standing on the bottom of the boat between F13 and F12St shows that an oar 3.55m long (including a blade of 0.80m) would be needed. The oar angle used is *c* 18° from the horizontal.

8.4 Steering

Although practicable within certain limits, steering by sail is unlikely to have been the only method in the Barland's Farm boat. The median rudder is unknown in north-west Europe until the late 12th century AD (McGrail 1998, 239–51). Steering oars have been found at Zwammerdam (Fig 8.10), Lake Neuchatel, and Bruges associated directly or indirectly with Romano-Celtic boats (McGrail 1998, table 12.8; de Weerd 1988, 174). They are also depicted on a 1st-century AD Rhineland monument to the Celt Blussus (McGrail 1998, fig 12.32) and on a 3rd-century AD altar to Nehellennia from Colinsplaat in the

Figure 8.10 The 5.15m-long composite steering oar from Zwammerdam. (Photograph by Seán McGrail)

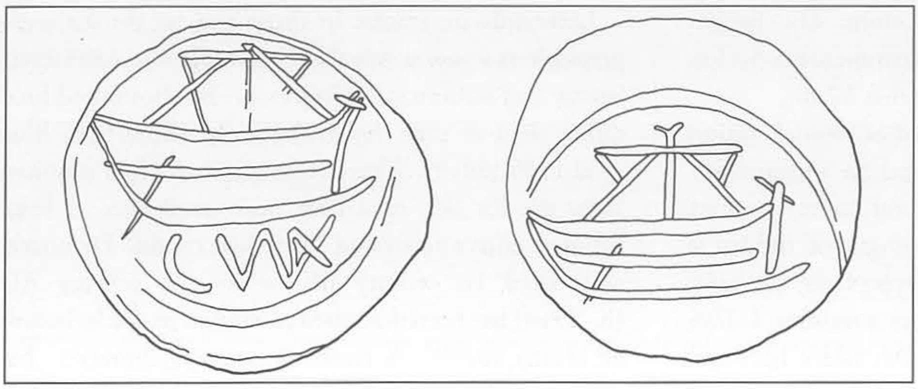


Figure 8.11
Drawing of two 1st-century AD coins of Cunobelin from Canterbury (left) and from Sheepen near Colchester.

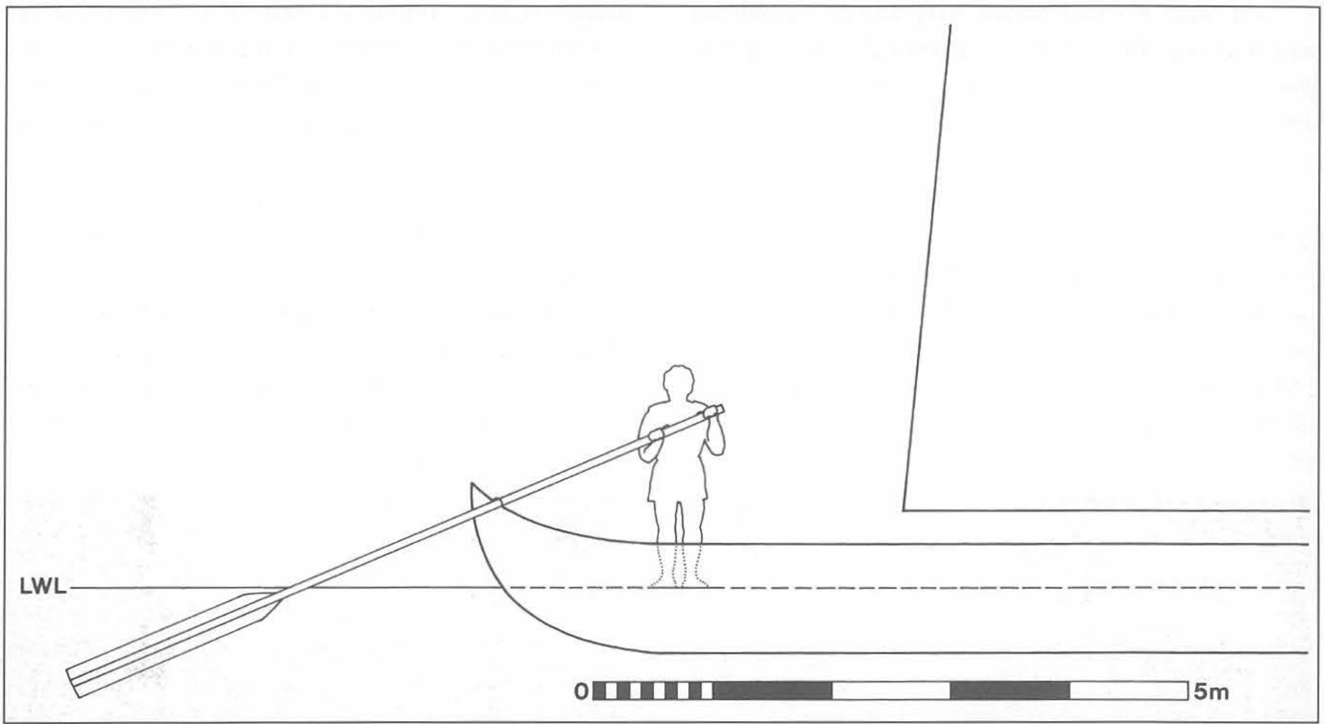


Figure 8.12 Diagram showing a steersman using a 6m-long steering oar at the stern of the Barland's Farm boat. Compare with the use of a side rudder in Figure 8.20.

Netherlands (Ellmers 1978, fig 15). The Broighter model boat of 1st-century BC Ireland also has a steering oar (McGrail 1998, fig 12.2); it is usually, and incorrectly, displayed as a side rudder.

The earliest known side or quarter rudders in north-west Europe are those fitted to the 4th-century AD Nydam boats (Rieck 1995). The 6th-century Sutton Hoo and Kvalsund 2 vessels also probably had side rudders. These vessels are all of the Nordic tradition. However, the sailing ships (Fig 8.11) depicted on the 1st-century AD coins of Cunobelin, the Celtic ruler of the Catuvellauni in easten England, have an angled line across their starboard quarter which may represent a side rudder (McGrail 1990, 43–4).

From the viewpoint of the technological 'environment', therefore, the Barland's Farm boat may have had either a side rudder on the starboard quarter or a steering oar over the stern. That part of the hull has not survived, but indirect evidence may be used to evaluate these possibilities. If the Barland's Farm boat had a steering oar astern worked through two grommets, one through a hole in the stern post and one through a hole in the nearby planking (as in the Bay of Bengal today), an oar of *c* 6m would have been needed and the steersman would have had to stand on raised decking some 0.5m above the bottom of the boat at around station 17 (Fig 8.12). If the steering oar had an overhead tiller, as depicted on the 1st-century AD Blussus boat (McGrail 1998, fig 12.32), a shorter oar could have been used and/or the steersman could have stood on the boat's bottom. The Bruges steering oar is *c* 4.45m overall, Zwammerdam 5.15m and Bevaix 10m (McGrail 1998, table 12.8).

With a side rudder 2m long fitted at around station 17, with pivots on the planking and an athwartships tiller, the steersman could have stood on the bottom of the boat (see Fig 8.20). This length of rudder is within the range of excavated examples from the early centuries AD. The Kvalsund rudder measures 1.27m and the Nydam 3.3m (McGrail 1998, tables 12.9 and 10).

Two other steering devices may also be considered to ensure a comprehensive investigation. The *guares* or *firrer* is a wooden blade fitted through the logs of a raft or on the quarter in a boat, so that it can be moved only in the vertical plane. Movement in this plane changes the area of the blade immersed and hence the turning force on the vessel is varied (McGrail 1998, 241). These devices have not yet been encountered archaeologically in north-west Europe and are only known to have been used on the sailing rafts of India, China, and South America and on small boats of the Steinhuder Meer near Hanover, Germany. On present evidence they are unlikely to have been used in the Barland's Farm boat.

Leeboards are similar in shape and act on the same principle as a *guares*, but their main role is to counteract leeway and achieve sail balance on a flat-bottomed boat rather than to turn the boat (Kemp 1888, 628; Blue *et al* 1998, 64–5). They are suspended when required from the lee side of a boat near amidships. A large wooden object recovered from Egernsund, Denmark, and dated 1st century BC to the 1st century AD (K–2514) has been described as 'similar to the leeboards of Dutch vessels'. A recent reappraisal, however, has identified this object as part of a logboat (Crumlin-Pederson pers comm). Leeboards are otherwise not known in north-west Europe until post-medieval times.

Guares and leeboards are simple devices, but they are unlikely to have been used in the Barland's Farm boat: side rudder or steering oar are more probable. Although the steering oar seems to be more firmly embedded than the side rudder in the Celtic maritime world as now known (McGrail 1998, 242–4), it seems not possible on present evidence to chose one rather than the other for this reconstruction. The underwater form of the Barland's Farm boat would not have had much resistance to leeway when under sail and her steering oar or side rudder would have needed a large immersed area to help counter drift downwind.

8.5 Mooring

Other than taking the ground on a falling tide ('beaching'), boats can be made fast to the sea or river bed in several ways (McGrail 1998, 251–7):

- by painter to a mooring post;
- by chain to a mooring spike;
- by line to a stone sinker;
- by chain or rope cable to a hook-shaped anchor.

The rope or chain element of all these devices has to be fastened to a strong point in the boat such as a hole through the stem post, a forward thwart, an extended frame (kevel head), or a specialised mooring bit. There may be a special fairlead through which the anchor cable passes outboard, but often the lead is direct over the top strake.

No mooring device was found with the Barland's Farm boat, nor could any timber be specifically associated with mooring but several of the (now missing) higher timbers in the bow could have been used.

In view of the abilities of the Celtic smith (Manning 1995) shown, not least, in the wealth of iron used in the Barland's Farm boat, it seems likely that she carried at least one iron, hook-shaped anchor and chain.

The 1st-century BC Broighter boat model has a small four-prong anchor known as a grapnel (McGrail 1998, fig 12.2). A 1st-century AD iron anchor (Fig 8.13) some 1.44m in length was found as part of a hoard in the hillfort at Bulbury, near Poole Harbour in Dorset (Cunliffe 1972). This was a basic anchor with an iron stock (not with the hoard) set at right-angles to the arms (McGrail 1998, fig 12.38). Today a similar anchor, but with shaped flukes, is known as the 'fisherman's anchor'. Over 6.5m of chain was attached to a ring through a hole in the Bulbury anchor shank: this was a forerunner and to it would have been fastened many fathoms of organic rope. Such an anchor, or perhaps something smaller, would have been appropriate for the Barland's Farm boat: she may also have carried one or two grapnels.

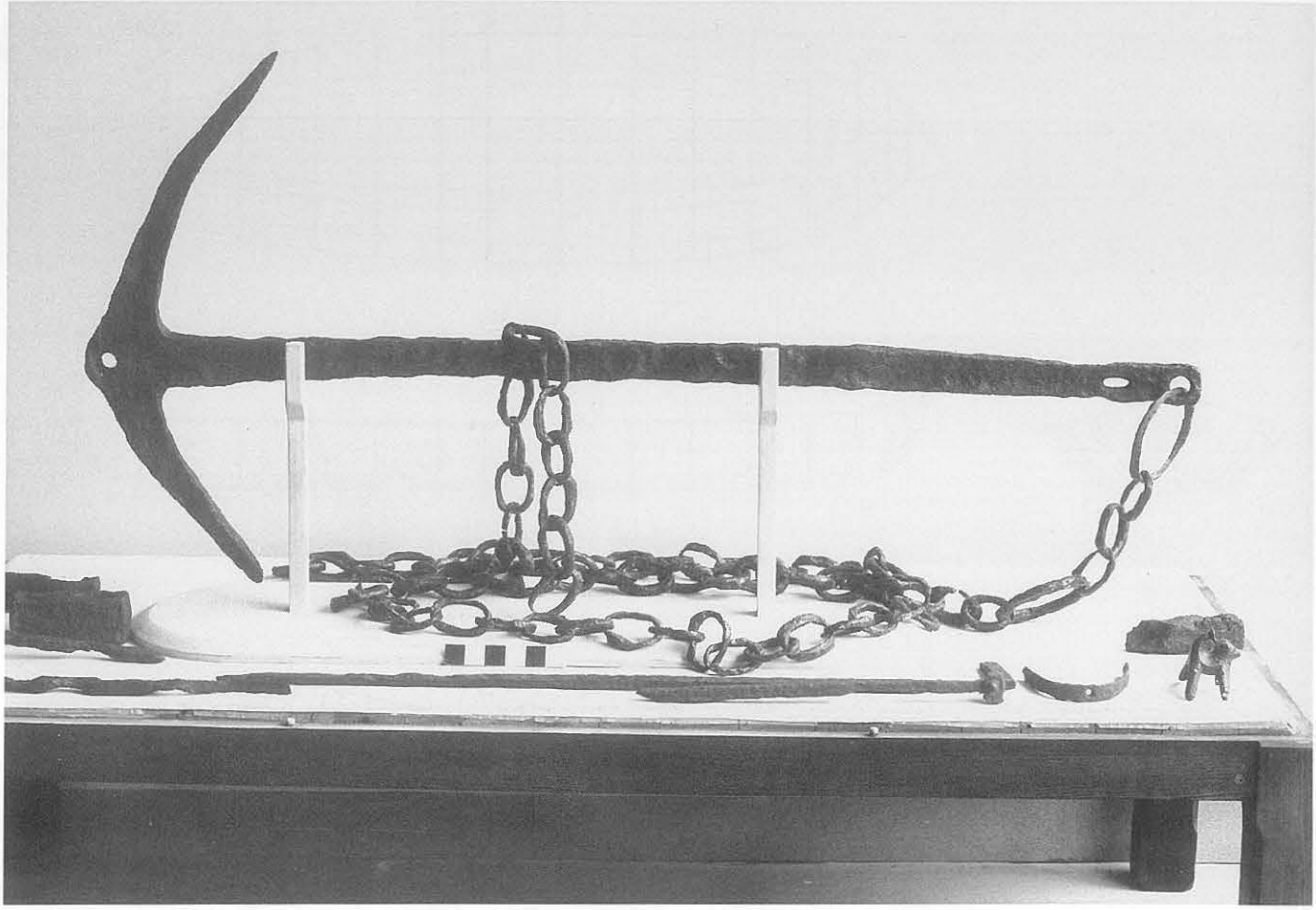


Figure 8.13 The mid-1st-century AD anchor and chain from Bulbury, Dorset. (Photograph by Dorchester Museum)

8.6 An assessment of handling characteristics, by O Roberts

8.6.1 Defining the hull

In order to make an assessment of the Barland's Farm boat, a set of lines which defined her three-dimensional shape was needed. By reference to the structural drawing (Fig 8.2) developed from the archaeological record by means of a scale model (Figs 6.4 and 8.1) a series of points on each constructional section was measured from both horizontal and vertical datum lines. The points were entered as coordinates in a ship design computer program called Hullform (Fig 8.14). Very little fairing was needed and the slight fullness towards the stern that was developed confirmed and agreed with that which had been interpreted from the remains.

Despite having a distinctive flat form in the central portion from stem to stern, the builder's efforts to blend the bottom and sides a little by putting some curvature into the topsides ensured that the lines define a hull shape which has clearly moved on somewhat from its flat-bottomed, hard chine origin. Performance, in terms of less hull drag, could have been improved further by a slight softening of the chine and the lessening of its eddy-making, energy-absorbing tendency. This evolvement has not lost those qualities of form that make the hull-type eminently suited to the marshy, shallow margins on each side of the Severn Estuary and the beginnings of the Bristol Channel, coupled with occasional forays up the smaller, tidal, drying rivers situated on each coast. As will be seen later, the hull floats in very little water when light or unloaded. The flaring sides ensure adequate buoyancy as cargo is loaded and in any choppy seas that might have been be encountered. Stability is increased usefully too, in a way not available to a slab-sided flat-bottomed shape of hull. The boat would have been easy to beach, probably as part of her loading pattern, a factor shown to have been considered by the slow curve given to her stem and stern profile. This would enable her to slide up a beach to a gradual stop even when heavily loaded. This is linked to the keel/stem scarfs that because of their construction are not solely dependent

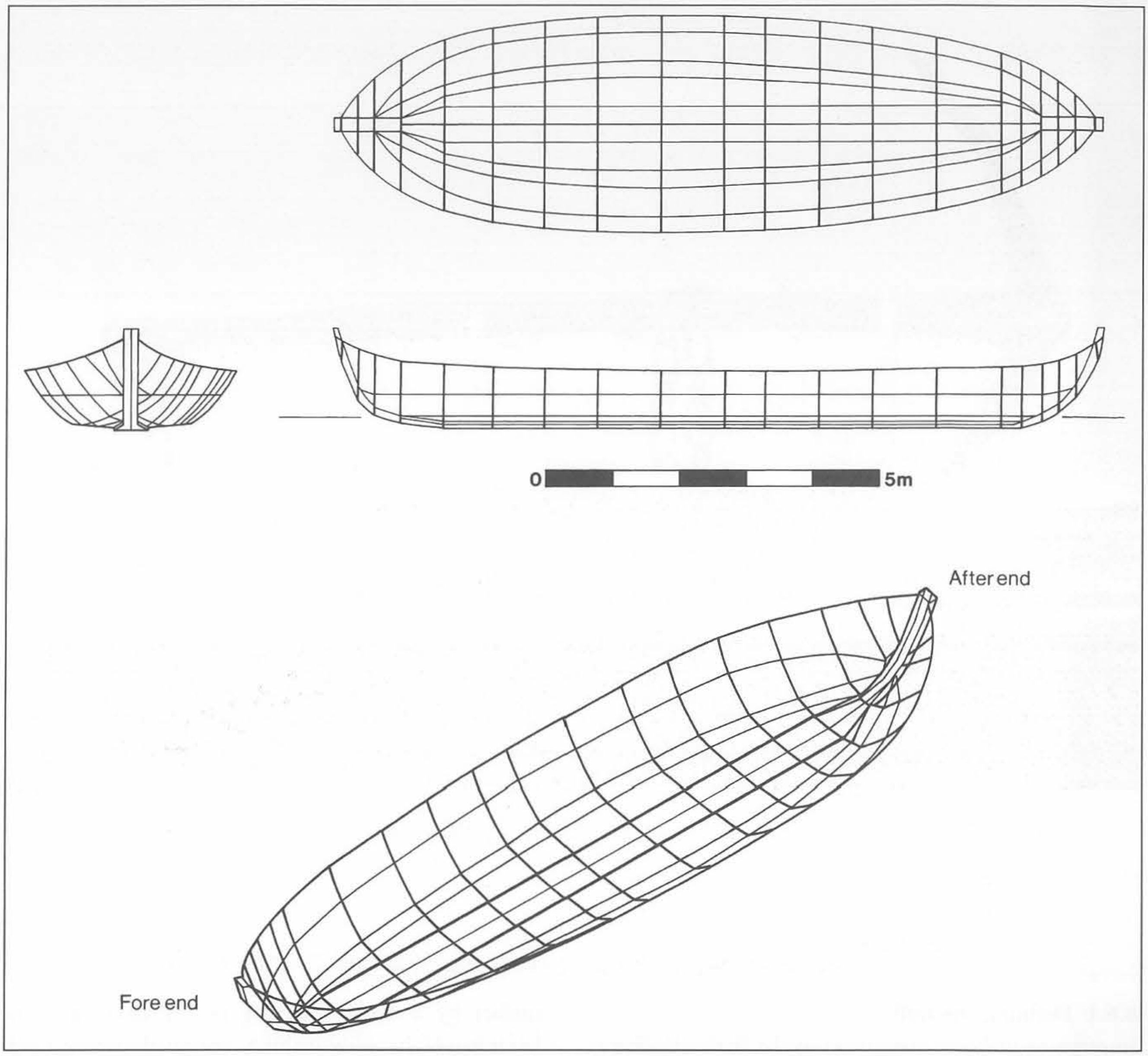


Figure 8.14 Lines of the boat produced by the Hullform computer program based on the reconstruction drawing in Figure 8.2. (Diagram by Owain Roberts)

on fastenings to transfer the stress of nudging up a beach to the keel and the rest of the hull. As will be seen later the hull is not deep and would not be drawing much water even when loaded. If a side rudder had been fitted there would, therefore, have been little difficulty in steering. A hull that is fuller aft usually has a tendency to turn towards the wind when heeled under sail. This may be one reason for the positioning of the mast step. While not seeming to be narrow in plan, the lines of the hull (Fig 8.14) indicate an easily driven form which may be neither able nor in any case need to carry much sail area.

The hull is shallow for its length and its beam with regard to the stresses it may suffer during a coasting voyage in average conditions or on being beached for loading or discharging cargo. In an area of high tidal range, this must have been a frequent situation. Much of the structural mass is low in the hull in the condition it was found, even at its bottom. This would cause the neutral axis to be very low. This would have a severe effect on longitudinal stiffness without the addition of several beams at sheer level as have been incorporated in the structural reconstruction.

The main dimensions of the hull derived from the lines are tabulated in Table 8.2. Because the flared shape influences the performance and loading characteristics, those for the length-water-line (LWL) and the beam (B) at the water-line are included for each draft (Dr). This has allowed extra columns of dimensional ratios to be included.

Table 8.2 Dimensional ratios

LOA *m*	*LWL* *m.*	*Bmax* *m*	*Bwl* *m.*	*D* *m.*	*Dr* *m.*	*%*	*L/Bm*	*Bm/D*	*L/D*	*L/Bw*	*Lw/Bw*	*Bw/D*	*Lw/D*
11.4	10.06	3.16	2.07	0.9	0.18		3.6	3.5	12.6	5.5	4.85	2.3	11.2
	10.65		2.6		0.45	50				4.4	4.1	2.9	11.8
	10.74		2.74		0.54	60				4.2	3.9	3.1	12
	10.93		2.99		0.72	80				3.8	3.7	3.3	12.2

Notes:
LOA = Length overall.
% = ratio (Draft/Height of Sides) expressed as a percentage.
D is depth of hull.
For other abbreviations see text.

Table 8.3 Weight assessment

bottom planks and posts		468 kg
floors		260 kg
half-frames		130 kg
side-timbers		109 kg
side strakes	10 × 60kg	600 kg
mast-step timber		7 kg
crossbeams	3 × 34kg	102 kg
beam shelves	2 × 23kg	46 kg
nails	450 × 178g	80 kg
mast larch pole		40 kg
yard		26 kg
rope ... standing and running rigging		34 kg
rudder oak	sg 0.9 2 × 0.1 × 0.3m	50 kg
sail 25 sq m canvas	18 oz/sq yd or RN flax no. 3 558g/sq m	14 kg
anchor	30kg and warp 52kg	82 kg
oars	2 × 12kg	24 kg
boat hook/quant		8 kg
Light weight – displacement without crew or cargo		2.080 tonnes

Those ratios derived from water-line dimensions are the true indicators of the narrowness of this hull, especially of its water-line plane in a light condition. Their seeming improvement with respect to stability, particularly those of the length-water-line to beam-water-line ratios (Lw/Bw) is directly related to an increase in draft. This will be considered later. The ratios of maximum beam-to-depth (Bm/D) and the length-to-depth (L/D) emphasise the general shallowness of the hull and suggest that particular structural problems had to be considered by the builder to ensure adequate hull strength. The solution must have included a few crossbeams at sheer level (as in the reconstruction) and, quite possibly, hanging knees and beam pillars.

8.6.2 Light displacement or empty weight

Having produced a satisfactory set of lines for the Barland's Farm boat, it was necessary to establish the weight of the hull, fittings, and equipment so that her displacement and hence her draft could be calculated. This was needed in the light or unloaded condition as a benchmark from which subsequent loadings and drafts would be assessed. The hull's remains were measured, converted to kilograms, and gave guidance to the weight of the reconstructed portion to which it was added to give the hull's bare weight. Rig, rudder, ground tackle, oars, and equipment were calculated or chosen after consultation (Molesworth 1899; McKerrell 1940; Martin and Irving 1935). Table 8.3 shows the major groupings of the weights included in the weight assessment.

More could be added to the list of equipment but the absolute minimum allows a close approximation to the original displacement and a sound base from which to make further calculations.

The light displacement was applied to the hull's lines held within the computer's design programme. Effectively the vessel was 'floated in sea water' at the light displacement and from that state it was possible to begin to extract the hydrostatics information that defined the parameters of her economic usefulness.

Subsequently the hull was loaded to the 50% waterline (ie where the draft was 50% of its moulded depth), then to 60%, and finally to 80% which might represent the condition if it were used as a lighter in quiet water. The graph of displacement against draft shows their relationship based on such loadings (Fig 8.15).

8.6.3 Stability

Stability is a valued attribute that enables a vessel to return without hesitation to an upright position after being heeled, for instance by a passing wave, the strength of the wind in her sail, or even the movement of crew to one side. A stable vessel is able to counter the heeling force in a manner that gives confidence and even hope to her crew, that if she is handled with skill and sound judgment she will enable them to complete voyages safely. The reference to skill and judgment imply that there are limits known to the crew members that must not be exceeded. The external forces of wind and wave clearly need managing, but an awareness of how the vessel will react to such heeling forces as a result of the way she has been loaded is absolutely essential for their safety before the vessel ever sets sail. Just as it is possible to handle the vessel successfully in various wind strengths and wave heights, so it is possible to load her with cargoes of various quantities and densities to suit the range of stability

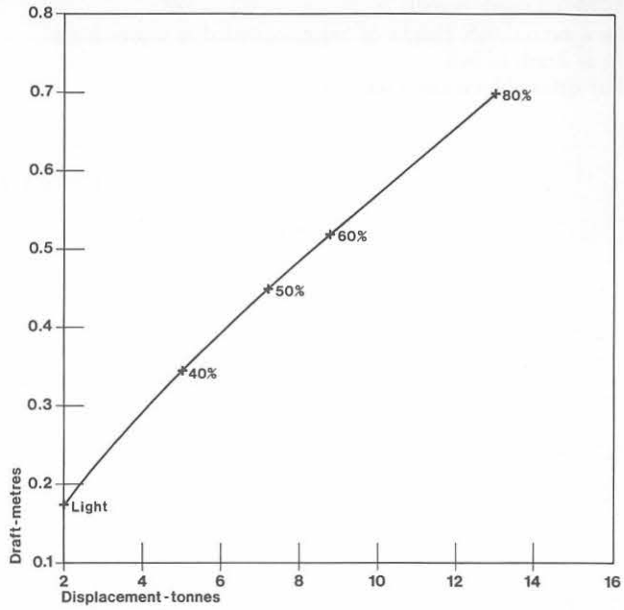


Figure 8.15 Graph of the boat's displacement at drafts as a percentage of height of sides. (Diagram by Owain Roberts)

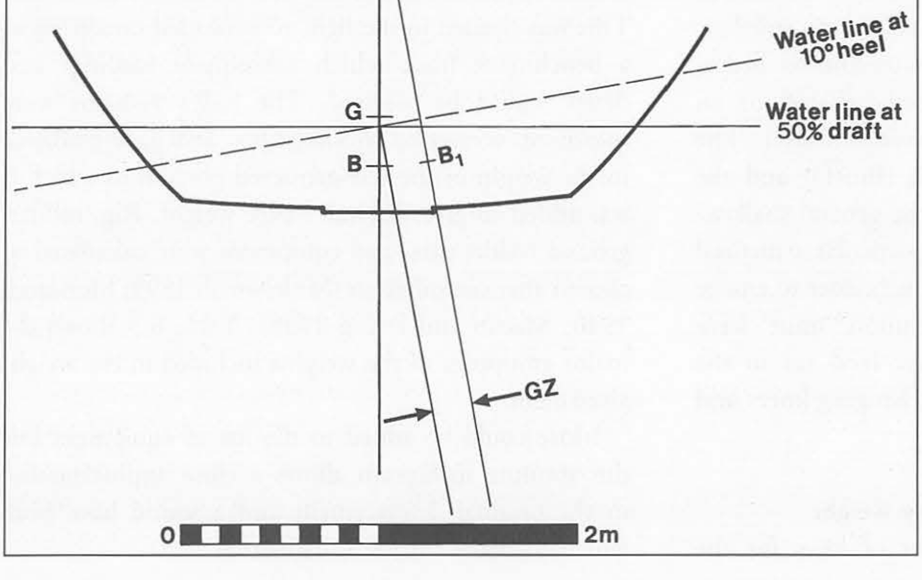


Figure 8.16
Diagram to illustrate transverse stability and the righting lever (GZ). (Diagram by Owain Roberts)

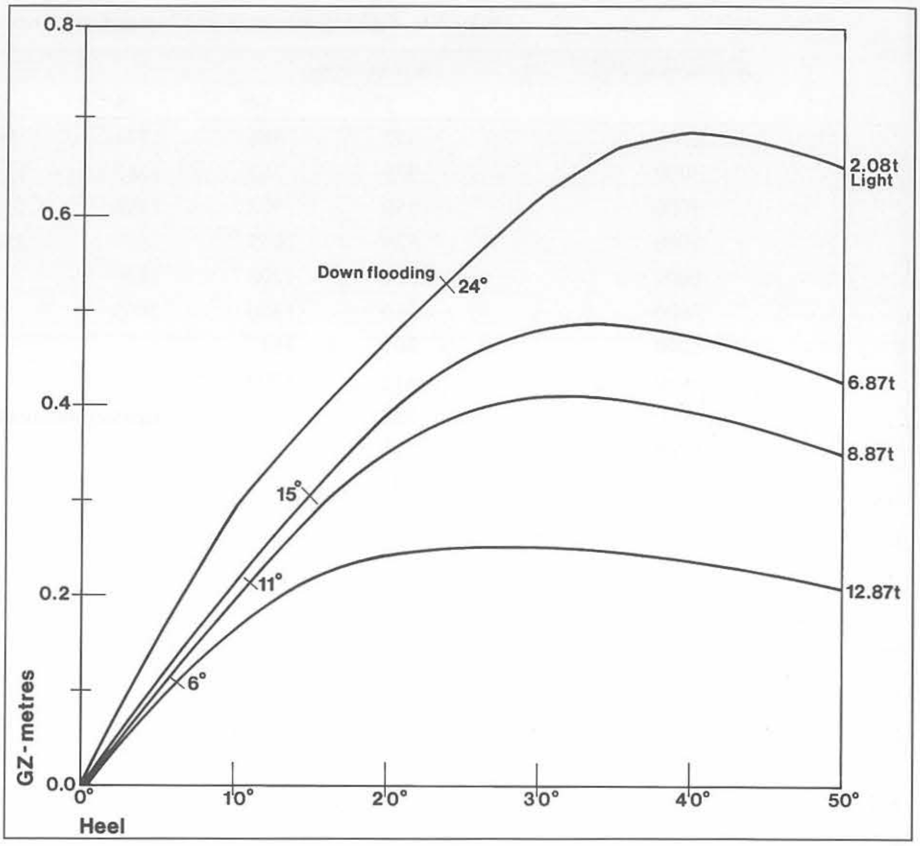


Figure 8.17
Curves of righting levers (GZ) at various angles of heel plotted at four displacements. corresponding to 80% waterline (lowest curve), 60%, 50%, and when empty (light). (Diagram by Owain Roberts)

acceptable for a particular voyage. In order to understand the hydrostatic, commercial, and environmental restraints within which the crew of the Barland's Farm boat had to apply their skill and judgment, it is necessary to establish the parameters of her stability.

8.6.4 Forces which affect stability

The link between draft and displacement has been demonstrated graphically (Fig 8.16). These relate to the body plan or cross section. Put simply a narrow hull will float deeply needing careful ballasting for stability, whereas a broad hull tends to be stable due to its form. The Barland's Farm boat is seen to be narrow at the bottom, but because of the flare of the topsides (the angle by which the sides lean outwards), she has sufficient heeled beam for stability. Slight curvature of the sides inwards near the bottom ensures a slightly flatter flare angle lower down. This makes the water-line beam wider than it would otherwise be. As the water-line beam increases, there is some indication that there is a faster increase in displacement per unit immersion. While this is to be expected with a hull of this form, the effect is blurred by topside curvature and the well-rounded stem and stern.

When the boat is floating upright (Fig 8.16), the centre of gravity (G) of her structure and the centre of buoyancy (B) of her immersed portion act at the middle line of the hull. In this shape of hull, G would be slightly above B unless a very dense cargo was being carried. This would be of extra advantage for ensuring her stability. By graphical methods G was established to be about 0.5m above the plank-keel for a range of cargoes when trimmed for sailing. On beginning to heel, B moves that way too (ie to leeward) because the shape of the hull's immersed portion changes and shifts in volume to the heeling side. G does not move in the hull because it is fixed by the structural weights and cargo and so continues to act vertically downwards. B acts vertically upwards in trying to resist the heeling force pressing down that side of the hull.

The horizontal distance between the two vertical forces acting through G and through the heeled position of B is the righting lever (GZ; Fig 8.16).

The GZ changes in length as the heel increases and this varies with the displacement of the vessel at the time. The graph curves of righting levers GZ (Fig 8.17) shows the curves for a range of displacements. On each curve is marked the angle of heel at which the sea begins to pour in over the leeward side (ie 'downflooding') when loaded to that displacement and to the remaining freeboard. Above that downflooding angle the increasing length of the GZ might seem academic, except that a good GZ is important at angles less than that of downflooding in order to counter the

Table 8.4 Righting moments in kilograms per metre

displacement (kg)	*heel in degrees*				
	5°	10°	15°	20°	25°
2000	312	584	774	947	1107
3000	379	762	1087	1345	
4000	450	908	1358	1739	
5000	524	1055	1599	2104	
6000	601	1208	1829		
7000	680	1366	2063		
8000	761	1527			
9000	844	1700			
10000	928		righting moments kg/m		
11000	1014				
12000	1101				
13000	1189				

draft as % of moulded depth	*80%*	*60%*	*50%*	*40%*	*light*
downflooding angle	6°	11°	15°	18°	24°

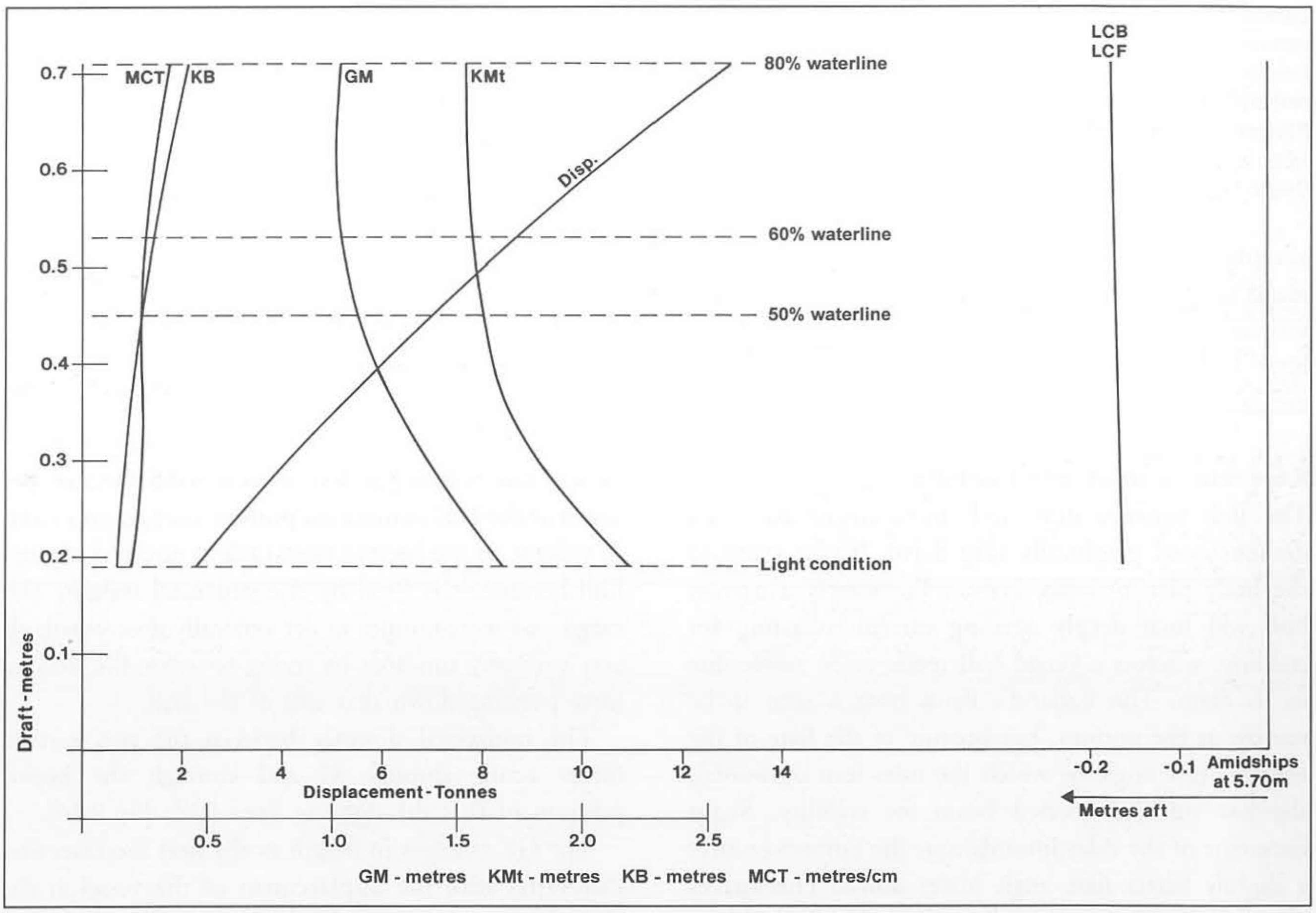


Figure 8.18 Hydrostatic curves for the Barlands boat. See also Figure 8.15.
MCT = Moment to change trim;
KB = Height of Centre of Buoyancy above the datum (K) (underside of keel);
GM = Distance Centre of Gravity to Centre of Buoyancy: the metacentric height;
KMt = Height of Metacentre (M) above the datum;
Disp = Displacement.
(Diagram by Owain Roberts)

effect of free water surface on stability, ie the water that has come aboard as spray and through the inevitable leaking.

By multiplying the length GZ by the displacement, the righting moment is obtained and that answer in kg/m is the true indicator of the available stability at the selected angle of heel. It makes it possible to calculate the sail area that could be set for a given wind strength to ensure that a sensible rig may be hypothesised for the reconstruction. Table 8.4 (righting moments) was calculated from the lines plan entered into the Hullform design programme.

From the righting moments table, it is evident that the best sailing trim for the Barland's Farm boat is when she is loaded to a draft which ranges from a little less than 40% to a little beyond 50% of the moulded depth or with displacements varying between 4 tonnes and 8 tonnes. In that trim she has a practical angle of heel coupled with the best righting moment when compared with those above and below those values. Without cargo or with a small or light cargo she would be perfectly capable of being sailed safely with due regard to the weather. Heavily loaded as a lighter, movement in quiet water would be safe as long as speed was low. Otherwise any wavelets could climb aboard. Sailing while deeply laden would not be attempted, except perhaps in a gentle following breeze.

8.6.5 Hydrostatic curves

Much of the hydrostatic information made available by calculations based on the lines plan may be combined on one graph (Fig 8.18) which becomes a useful hydrostatic picture of the Barland's Farm boat and a tool by which comparison may be made with other finds of archaeological wrecks.

8.6.6 Sail-carrying power

The source of power available to a sailing vessel is the very force that is trying to capsize her. The better able she is to resist the capsizing force then the more sail she may set and the better her speed on passage. This stiffness as it is called enables a vessel active in strong tidal waters to sail further on a favourable tide and to make up against a foul tide with only a small crew, given sufficient wind.

Using information derived from the lines plan developed in the design programme, the sail-carrying power of the Barland's Farm boat has been calculated by the following standard formulae:

A To find pressure of wind in the sails (Howard-Williams 1976).

Pressure in a sail = 0.004 × velocity^2 × area (answer in pounds per square foot)

If area entered is 1 square foot then varying the velocity (in mph) allows the pressure in one square foot of sail to be found for a chosen wind velocity. It is convenient to retain imperial units since wind speeds in mph directly relating to the Beaufort Wind Scale may be used.

To metricate: lb/sq ft × 0.4536 × 10.7639 sq ft = pressure in kg/sq m. This may be used in subsequent formulae for sail-carrying power.

B To find the sail-carrying power which makes use of the heeling wind forces (Phillips-Birt 1972).

Since righting moments = heeling moments at a steady angle of heel, then the sail area for particular heel angles, various displacements, and wind pressures may be calculated by the following formula:

$$GZ \times \Delta = H \times P \times A \times \text{Cos}^2\,\theta$$

where: GZ is righting lever in metres;
Δ is displacement in tonnes;
H is centre of effort of sail in metres;
A is sail area in square metres;
θ is angle of heel;
P is sail pressure in kg/m^2 at required wind speed from formula A.

This formula appears in slightly different forms elsewhere but differences are minor.

Examples of some of the calculations include:

Question 1

What pressure is in a unit of sail at 20mph wind velocity?

Calculation

Pressure in one square foot = 0.004 × 20^2 × 1

Answer

Pressure = 1.6 lb/sq ft and 7.8 kg/sq m at 20mph.

Question 2

What sail area is set when displacement is 2.1 tonnes, wind of 20mph, safe heel 11°, GZ is 0.3m, height of sail C of E is 4m?

Calculation

0.3m × 2100kg = 4m × 7.8kg/sq m × area × cos^2 11°

Answer

Area = 21sq m.

Question 3
What strength of wind would cause maximum heel of 24° at the same displacement with a sail of 21sq m, GZ 0.55, height of C of E is 4m?
Calculation a
0.55m × 2100kg = 4m × pressure × 21sq m × $\cos^2 24°$
Answer a
Pressure = 16.5 kg/sq m or 3.4 lb/sq ft
Calculation b
3.4 lb/sq ft = 0.004 × velocity^2
Answer b
Velocity = 29mph wind strength.

As the height of the centre of effort of the sail area would change very little, it was kept constant for these and the following results. In the calculations the maximum heel angle was considered to be the downflooding angle. The safe heeling angle was considered to be half of this, so that variations in wind strength or wave height would be countered by the available freeboard and extra stability on increased heel or immersion. Results were obtained for three states of displacement within the vessel's likely operational range, sail area being varied with heel angle and wind strength. These are produced in Table 8.5 for comparisons to be made.

The Barland's Farm boat is able to carry more sail as displacement increases but still has only a small wind force margin between safe heel and maximum heel at the sail areas shown. An increase or gust of 8 or 9mph (and much more) above the wind speed at the safe heel angle is a common feature of good sailing breezes. Except for the lightest displacement, the sail areas found are likely to need reducing with regularity. Yet the smallest area of $21m^2$ would be insufficient when sailing at the heavier displacements.

Based on further results shown in the lower section of Table 8.5, it is believed that a sail area of $25m^2$ would provide good working sail for most conditions, while a reef could be tied in when sailing lightly loaded.

A wind of velocity 20mph is at the lower end of force 5 on the Beaufort Wind Scale (ie just above 17 knots) so that it is believed that the Barland's Farm boat could have made passages in such winds, though not by choice. Force 5 (ie wind speeds from 17 to 21 knots) is described by Admiral Beaufort in his original definitions as that wind which causes smacks to shorten sail (Heaton 1951). The Barland's Farm boat would be neither as well found nor as seaworthy as any 19th-century fishing smack of a similar size. As for any undecked boat, a deep reefed sail and a good bailing technique would extend her chances of reaching a haven in worsening weather conditions.

In open water waves would develop over a metre and more in height in a steady wind of 20mph or 17 knots velocity. At certain states of the tide, say at headlands or especially when the wind and tide are in opposition – as could happen in the Severn Estuary twice a day – lower wind speeds will create closer-spaced, crested waves of a size out of all proportion to the apparent conditions. No matter how well ballasted, ultimately the safety of the Barland's Farm boat would depend on the experience and local knowledge of her crew.

8.6.7 Performance underway

The performance of the Barland's Farm boat has been considered by:

- calculating various coefficients and ratios that allow comparison with other vessels (Marchaj 1964);
- calculating the power required to move her, both under sail and by oars.

Table 8.5 Wind speed and sail area

displacement in tonnes	*sail area sq m*	*wind mph*	*safe heel*	*GZ m*	*max heel downflooding*
2.1	21	20	11°	0.3	
	21	29		0.55	24°
4.1	31	20	9°	0.23	
	31	27		0.39	18°
7.1	35	20	7°	0.15	
	35	28		0.29	15°
2.1	25	27		0.55	24°
4.1	25	30		0.39	18°
7.1	25	34		0.29	15°

Table 8.6 Coefficients and ratios compared

boat	*date*	*LWL*	*volume coeff*	*block coeff*	*prismatic coeff*	*L/Displ ratio*	*slenderness coeff*	*theoretical max speed*
Hjortspring	300 BC	14.7	0.83×10^{-3}	0.36	0.69	10.6	9.8	9.7
Barland @ 4t	AD 300	10.4	3.7×10^{-3}	0.56	0.75	6.5	4.4	7.8
Barland @ 7t		10.7	5.7×10^{-3}	0.56	0.74	5.6	4.1	7.9
Graveney	AD 900	10.1	10.7×10^{-3}	0.46	0.59	4.5	2.8	7.6
Skuldelev 3	AD 1000	11.7	4.77×10^{-3}	0.27	0.5	5.9	4.0	8.7

Notes:

1 Volume coefficient (displ/length^3): boats with values less than 2×10^{-3} are very easily driven and usually fast.

2 Block coefficient. (∇/ L× B× D where ∇ is the underwater volume): boats with values less than 0.85 may have a good speed potential.

3 Prismatic coefficient (∇/ L× mid-section area): boats with values less than 0.6 usually have fine form. Between 0.5 and 0.6 suits light-wind sailing if operating near the boat's limiting speed.

4 Length/displacement ratio ($L/^3\sqrt{\Delta}$): lower values imply full hull forms.

5 Slenderness coefficient (L/ Bwl): high values suggest good speed potential.

6 Maximum theoretical speed: an optimistic guide to true maximum speed if used without reference to the various coefficients. Found from the formula Velocity = $1.34\sqrt{\text{Lwl}}$.

From Table 8.6 the Barland's Farm boat would seem to need a steady breeze to move her, though a good average speed may be maintained if conditions are suitable. A displacement of about 7 tonnes makes her rather bulky underwater and reduces the advantage of the fineness of her lightly loaded shape to the detriment of the maximum speed that might be expected. When carrying less cargo the coefficients show her performance would have been comparable with the others in Table 8.6. Her block and prismatic coefficients are greater than the others listed because of the flat-bottomed chine form of her hull.

Another coefficient is available which is intended to indicate to an archaeologist the likely environment in which a flat-bottomed boat used to operate (Roberts 1983). It should be noted that the formula has no naval architectural significance. From limited remains, usually only the bottom and a little of one side as in the Barland's Farm boat, measurements are inserted into the formula. For the Barland's Farm boat the flat-bottomed boat index is 0.43 which, when compared with others in a table published with the formula, places her within a group of craft intended for estuarine and coastal work where conditions would require good stability and buoyancy even when loaded.

8.6.8 Speed and resistance

The range of speeds at which the Barland's Farm boat might have been sailed or moved under oars is restricted by the resistance of the water to the hull's movement. The speed depends on the power available from the wind or from the stamina and strength of the oarsmen. The resistance from the water is known as drag or resistance and is derived from two sources.

First the smoother the surface of a hull the less it drags at the water flowing over it. This source of resistance is important to sailing and oared boats that work at less than optimum speeds most of the time, since the skin or surface drag arising from the disturbance of the flow at the hull surface is the first to be established at the lower speeds. The rough and ready hull finish of working boats merely compounds the problem.

Secondly as speed begins to increase, the form or bulk of the hull passing quickly through the water aggressively alters the flow around it. The power being used produces the diverging waves seen as part of a boat's wake. At maximum speed these are reduced to two large waves, one at each end of the water-line separated by a deep trough, all travelling at the same speed. The power required to move a boat at any velocity is a measure of the drag working against her sailing performance. The graph (Fig 8.19) plotted for the Barland's Farm boat shows the rapid rise in drag as speed increases plotted against various displacements that also encourage drag by increasing the amount of hull that is immersed. As seen in Table 8.7 (showing power needed at various speeds and displacements) the power required to attain 6 knots when displacement is over 4 tonnes is unrealistically high given its source, unless driven before a gale. Above 8 tonnes displacement the bow wave might overcome her freeboard and cause her to sink, since there is no evidence for a watertight deck.

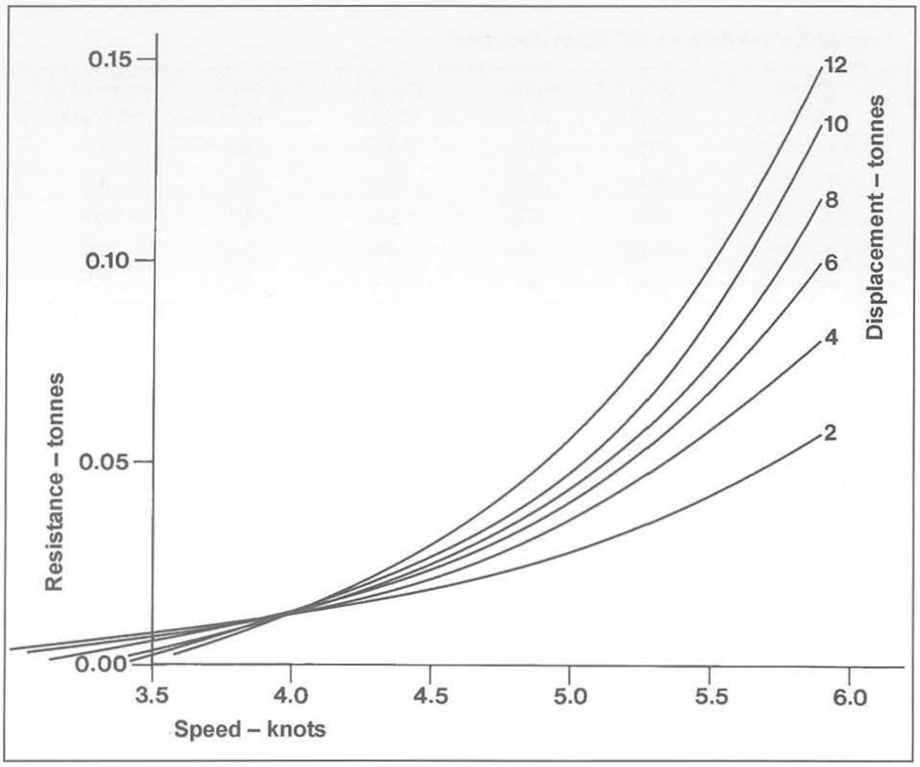


Figure 8.19
Graphs of speed against drag at six displacements. (Diagram by Owain Roberts)

Table 8.7 Driving force from two types of sail

	lug sail area 25m² wind speed			*Square sail area 25m² wind speed*		
angle of apparent course to wind	*10 knots 5.1m/sec*	*15 knots 7.7m/sec*	*20 knots 10.3m/s*	*10 knots 5.1m/sec*	*15 knots 7.7m/sec*	*20 knots 10.3m/s*
30°	9 kg	20 kg	30 kg	5 kg	11 kg	21 kg
45°	21 kg	47 kg	84 kg	13 kg	30 kg	53 kg
60°	34 kg	79 kg	140 kg	24 kg	54 kg	96 kg
90°	62 kg	141 kg	200 kg	49 kg	112 kg	200 kg
120°	77 kg	175 kg	314 kg	66 kg	150 kg	269 kg
135°	53 kg	121 kg	216 kg	69 kg	157 kg	281 kg
	driving force in kilograms			*driving force in kilograms*		

8.6.9 Performance under oars

Table 8.8 was developed from resistance values obtained from the lines of the Barland's Farm boat entered in the Hullform computer design programme. The sustainable output of an oarsman has been calculated to be 60 to 70 watts (Coates *et al* 1990). Two working hard could, therefore, move the boat in light displacement at 3.5 knots for a short time but at 3 knots without much effort for many hours, say over the duration of a favourable tide when the wind had failed. As displacement is increased so the workable speeds decrease if limited to manpower.

8.6.10 Performance under sail

Table 8.8 may also be used to assess likely speeds at various wind forces at the most efficient point of sailing, ie with the apparent wind on the beam and just abaft it. Using the formula for deriving driving force and the driving force coefficients for a gaff sail and a square sail (Marchaj 1964), Table 8.7, showing power available from the proposed sail, was produced at different wind strengths and at different course angles to the apparent wind. Because of the position of the mast step and the requirements of sail balance (see section 8.6.13), it was considered that the Barland's Farm boat probably had a single lug sail. Since a lug sail is a fore-and-aft setting sail similar to a gaff sail but with sheeting and tacking methods akin to a square sail, the table was calculated to give values for both kinds of sail.

The values for the lug sail may be slightly low for courses at 30° and 45° to the wind, since the gaff sail is not as efficient when close hauled due to the interference of the mast with the flow of the wind over the leading edge of the sail.

Table 8.8 Propulsive power for various speeds and loadings

knots	*m/sec*	*resistance kg*	*2 oarsmen watts*	*watts per oarsman*	*Barland's Farm boat*
3	1.56	6.3	96	48	'light' displacement
3.5	1.83	8.4	150	75*	2.08 tonnes
4	2.1	12.8	264	132	3 men aboard
4.5	2.34	19.5	448	224	
5	2.58	27.6	699	–	
5.5	2.79	39.4	1078	–	
6	3.1	59.6	1812	–	
3	1.56	9	138	68*	displacement 6.87 tonnes
3.5	1.83	12	215	107	@ 50% waterline
4	2.1	15.4	317	158	3 men aboard
4.5	2.34	27.8	638	–	
5	2.58	43.6	1104	–	
5.5	2.79	68	1861	–	
6	3.1	109	3315	–	
3	1.56	9.9	152	76*	displacement 8.87 tonnes
3.5	1.83	13	233	116	@ 60% waterline
4	2.1	16.8	346	–	3 men aboard
4.5	2.34	29.4	675	–	
5	2.58	48	1215	–	
5.5	2.79	76.5	2094	–	
6	3.1	125.6	3820	–	
3	1.56	11.6	177	88*	displacement 12.87 tonnes
3.5	1.83	15.4	276	138	@ 80% waterline
4	2.1	19.7	405	–	3 men aboard
4.5	2.34	32.7	751	–	
5	2.58	57	1442	–	
5.5	2.79	95	2600	–	
6	3.1	160	4865	–	

* 60 to 70 watts effective output is a comfortable rate for an oarsman.

Clearly the lug sail is more powerful and efficient than the square sail until the wind is blowing from abaft the beam. The unsupported luff and the resulting full shape of the square sail are only slightly responsive to trimming when sailing close to the wind, whereas the luff of the lug sail may be given great tension with a consequential increase in sailing efficiency when the wind is from ahead of the beam. The difference in values between the driving force from the lug and the square sail give further support to the interpretation of the evidence for the lug rig proposed for the Barland's Farm boat.

The power available from the lug sail at 45° (Table 8.7) may be compared with drag values in Table 8.8 so that the speeds at varying wind strengths and displacements may be interpolated. At 2.08 tonnes displacement the boat could exceed 6 knots in a 10mph wind on the beam. In a wind from ahead of the beam, 4 to 5 knots would be likely. Greater displacement at 8.8 tonnes would not necessarily permit 6 knots in a 20mph wind, since the excess drive force would make steering difficult. Reefing the sail would, therefore, be a prudent means of retaining control. When in use as a lighter displacing 13 tonnes, sailing would be foolhardy except in a very light, following wind on quiet water. These speed figures indicate that the flatter portions of the curves shown on the earlier graph of drag against speed (Fig 8.19) are the ones related to actual speed.

8.6.11 Cargo capability

The commercial usefulness of the Barland's Farm boat can only be measured by her cargo-carrying capability. Calculations for this were based on the figures for displaced volume and displacement tonnage derived from the set of lines produced using the Hullform design programme. When loaded to a draft of 0.45m or 50% of hull depth the displacement is 6.875 tonnes. A hull weight of 2.08 tonnes and three crew at 225kg limits the cargo weight to 4.57 tonnes. Since cargoes vary in their density, it is necessary to compare volumes of cargo to appreciate the problems of stowage that arise. Cargoes of high density take little space and are set low in the boat, contributing enormously to the stability that can never be too much in a small estuary coasting vessel like the Barland's Farm boat. Low-density cargoes tend to stack higher in the hull, even above the sheer, perhaps to the serious detriment of stability since the combined centres of gravity of hull and cargo may be significantly raised. As the distance GM (Fig 8.16) is made shorter, the ability to recover from heeling is also reduced.

Stowage factors for various cargoes were calculated. These are based on a notional shipping ton of 40 cubic feet or 1.133m^3. Its greater volume than the ton/tonne displacement of 35 cubic feet or 1m^3 makes allowances for voids and uneven cargo space within the hold area. Dividing the volume of a ton/tonne of cargo by that of the shipping ton/tonne produces its stowage factor.

A cargo which had a stowage factor of 1 would occupy 4.57m^3 ÷ 1.025 (sea water) = 4.5m^3. As an example 4.57 tonnes of iron ore would occupy 1.89m^3, that is 4.5 × 0.42 (SF) of available space, whereas 4.57 tonnes of bagged charcoal would need about 12m^3, that is 4.5 × 2.7 (SF). Since the total internal volume of the Barland's Farm boat is 15m^3 and some space would need to be left for managing her, such a cargo would rise above the sheer. With the cargo of iron the temptation would be to pile in some more since it would look insignificant as a quantity, especially if the loading were done while the boat was aground. With the bagged charcoal, less would be carried in order not to upset the stability beyond what the skipper considered acceptable.

Table 8.9 shows a list of possible cargoes with their stowage factors and the volume that 4.57 tonnes of each cargo would occupy when the Barland's Farm boat floated at a draft of 0.45m and a total displacement of 6.875 tonnes. Calculations are based on a list of materials and their weights published for shipmasters (Aubrey-Rees 1943).

Table 8.9 Stowage factors and cargo volumes

cargo (4.5 tonnes)	*stowage factor*	*cargo volume m^3*	*Effects on stowage*
sandstone	0.36	1.7	low/small – amidships
slates	0.39	1.8	ditto
copper ore	0.39	1.8	ditto
limestone	0.40	1.8	ditto
gravel	0.42	1.89	ditto
iron ore	0.42	1.89	ditto
sand	0.47	2.1	ditto
salt in bags	0.85	3.8	stacked one layer abaft mast
Welsh coal in bags	0.9	4.0	ditto
grain bagged, average	1.2	5.4	stacked up to sheer abaft mast
wattle in bales	1.2	5.4	ditto
firewood	1.4	6.3	loaded up to sheer abaft mast
oak bark bagged	1.43	6.4	stacked up to sheer abaft mast
sheep skins in bales	1.75	7.9	stacked above sheer abaft mast
wine in casks	1.78	8.0	stowed below sheer fore and aft
wool in bales	2.2	9.9	ditto
leather in bales	2.2	9.9	ditto
charcoal bagged	2.7	12.2	probably only part-load
hides dried in bulk	4.3	19.4	part load only
hay lightly baled	4.4	19.8	part load only – stacked above sheer
leather rolls	4.7	21.2	part load only

Table 8.10 Livestock as cargo

aft	*forward*	*cargo*	*displacement*
35 sheep @ 30kg	+ 15 @ 30kg	= 1500kg	3.6 tonnes
35 sheep @ 45kg	+ 15 @ 45kg	= 2025kg	4.2 tonnes
35 sheep @ 60kg	+ 15 @ 60kg	= 3600kg	5.8 tonnes
8 beasts @ 500kg		= 4000kg	6.5 tonnes
10 beasts @ 500kg		= 5000kg	7.5 tonnes

8.6.12 The carrying of livestock

Other studies may decide the economic relevance of moving livestock around the Severn Estuary by vessels such as the boat from Barland's Farm, but her suitability for this activity is certain.

The flat-floored area down her middle would enable cattle to stand comfortably while sheep could be confined conveniently by hurdles, some forward of the mast but with most in the space between the mast and the helmsman. Two aspects of the carrying of livestock need to be considered – the number that may be loaded with respect to the displacement and the effect of the common centre of gravity of the live cargo on the boat's stability.

8.6.12.1 Sheep as cargo

The 'plan' area of a sheep is about $1 \times 0.33\text{m} = 0.33\text{m}^2$. This allows three sheep per square metre. The area available forward of the mast is conservatively measured to be about 4m^2 and abaft the mast about 10m^2. A load might then be 42 sheep but could easily be 50 sheep if slightly tighter packed or given more freedom within the hull. Estimations based on three weights of sheep are given in Table 8.10.

The centre of gravity of all standing sheep would be about 0.5m above the hull bottom and would not adversely affect stability. Their movement about the cargo area would be restrained by being tightly herded. Smaller numbers would need restraining by tethering or being loaded with legs trussed, since a sudden surge of weight to one side would endanger the boat's stability. Penning-in might be a possibility if sheep were part of a mixed cargo.

8.6.12.2 Cattle as cargo

Cattle of this period are known to have been smaller than their modern descendants, weighing about 500kg and having a 'plan' area of about $1.75 \times 0.6\text{m}$. Because of their weight it would suffice to load them abaft the mast only. From the preceding figures and Table 8.10 a cargo would consist of no more than eight to ten beasts.

Tethering athwartships would be necessary to prevent changes in trim due to cargo movement. Perhaps having alternate beasts facing port and starboard would be the practice. The cargo's centre of gravity could be on a level with the sheer line and, due to movement of the boat, despite tethering, might vary away from a central position. For passage making no more than eight beasts would be carried but for moving part of a herd down stream or across a river to new pastures then a cargo of ten might be usual. The loading of beasts after trussing their legs and placing them on their sides would only be possible if a simple crane and slinging facilities were available.

8.6.13 A rig based on the evidence

A short length of timber securely bridging a floor and two half-frames and with a rectangular hole has been identified as the boat's mast step (Fig 6.21). The mortise would have accepted the squared heel of a mast. Though the mast could have been a short stump to take a tow rope, this seems unlikely in the estuarine environment in which the boat was found, since towing at that time was a feature of navigation found where rivers had continuous and accessible banks. A full-sized mast could still have a secondary use, however. If a voyage ended up a river a towrope might be bent onto the mast at a low point.

The sail area suitable for this boat has been calculated in Table 8.5 for various displacements. The form of the sail depends on the position of the mast step and the historical and archaeological evidence for sailing rigs.

It is significant that the mast is stepped 32% of the water-line length (LWL) from the stem at a draft of 50% of the hull depth with slight trim aft. Two forces contribute to the sailing ability of a boat (Fig 8.20). One is the sum of the drive obtained from the wind by the sail, which is assumed to be located at its geometric centre called the centre of effort (CE). The

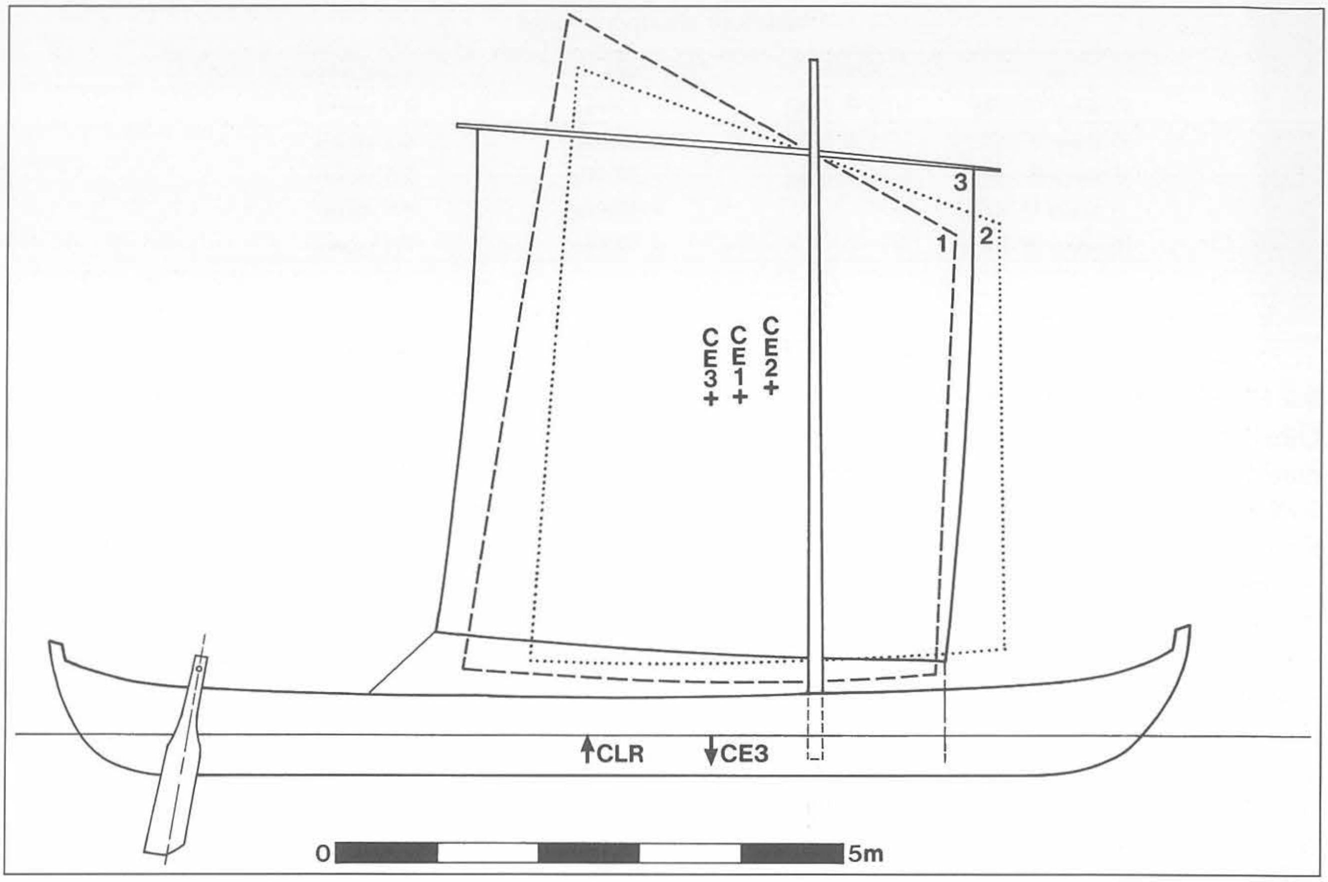


Figure 8.20 Diagram showing the boat with three forms of lug sail each 25m² in area.
CE = Centre of Effort of sail;
CLR = Centre of Lateral Resistance of the hull. (Diagram by Owain Roberts)

other is due to the oblique flow of the water past the hull both from the side and from ahead and related to its centre of lateral resistance (CLR). This is assumed to be at the geometric centre of the lateral area (including the rudder) below the water-line when viewed in profile. Both centres move depending on wind force, point of sailing, hull speed, and heel angle. Weather helm, ie when the boat is tending to turn towards the wind if not steered, suggests that CLR has moved ahead of CE and if by only a small amount it is a preferred situation.

A square sail set on the Barland's Farm mast would mean that any course across the wind could not be undertaken because of the leeward-turning effect of the CE, which it would be at or ahead of the mast. Nor could the CLR move far enough forward to prevent a lee helm (dangerous) condition. The boat could only turn away and sail before the wind. Except for sailing before the wind it would not be expected that a square sail would be the correct rig for the Barland's Farm boat. To sail across the wind on a reach she would need to set a sail having a CE further aft, for example, a lug sail. Since the CLR and CE move different amounts when sailing, their static spacing is based on what has worked in other boats. The lead, ie the amount the CE is ahead of CLR, varies from 1% to 15% of the water-line length in practice (Skene 1936; Barnaby 1954). The builder of the Barland's Farm boat would have based his positioning of the mast step by a similar rule of thumb, with the intention of setting a fore-and-aft sail having its CE aft of the mast but still with the estimated correct amount of lead over the CLR. A fore-and-aft sail may have all or most of its area abaft the mast. The first arrangement with all the sail abaft the mast would mean that the CE could be too close to the CLR in terms of lead or even have negative lead. Such a sail would be a gaff sail or a sprit sail that has one edge laced to the mast. The fore-and-aft sail that has only some of its area ahead of the mast would have its CE still abaft the mast but closer to it. A suitable lead would then be maintained over the CLR. Such a sail, known as a lug sail, has many variations of proportion around the world. Its better performance in a beam wind when compared with a square sail is exemplified by the values given in Table 8.7.

The single-square-sail rig appears to have predominated in Europe during the period in question, though a second mast in the form of an artemon protruding over the bows had been used in the Mediterranean for some centuries (Casson 1959) and was brought to northern Europe by the Romans (Ellmers 1994). Evidence for the development of a fore-and-aft rig also comes from the Mediterranean (Casson op cit) showing both the spritsail rig and the lateen rig. No evidence supports the use of those rigs in Britain at that time. In any case they would be difficult to balance in the Barland's Farm boat.

8.6.13.1 The lug-sail rig

Historically there is no support for the pre-medieval use of the lug-sail rig in Europe, but from the technical evidence obtained from the boat's remains it becomes the likely option. In Fig 8.20 three forms of lug are shown, all of the same area of $25m^2$. Their individual CEs are shown, as is their lead over the CLR. Forms 1 and 2 reflect a developed shape that appeared when the rig became common in Europe, say one thousand years and more later. Form 3 is a lug-sail arrangement which is produced by simply shifting the attachment point of the halyard along the yard of a square sail. As is usual with lug sails, putting a strong vertical tension on the tack sets up the sail and keeps the yard at or above the horizontal. The best place for the halyard would be found by experience. It could be shifted a little depending on the wind strength and returned to its central position for running before the wind. The construction of this shape of lug sail would be no different from that of a square sail. The transition from square to lug is effortless and flexible by this method and it is quite possible that this arrangement was used aboard the Barland's Farm boat.

One other method is shown in Fig 8.21 in which a broad square sail is used but is canted downwards for sailing with the wind from the side. Tilting the sail moves the CE aft by an effective amount and limits the lead over the CLR which would otherwise be too great on a reach. It is suspected that this second method may have less flexibility than Form 3 in Fig 8.21. The position of the Barland's Farm mast suggests that her builder had no intention of using a square sail alone as he had avoided stepping the mast nearer the centre of the water-line as would be usual with that rig. As noted earlier, the performance of such a rig, even tilted, would not match that of the lug sail on a reach.

8.6.14 Steering requirements

In conditions met at sea, a rudder is subjected to continuous, vicious, and prolonged jarring and twisting forces under sail that require it to be attached to the

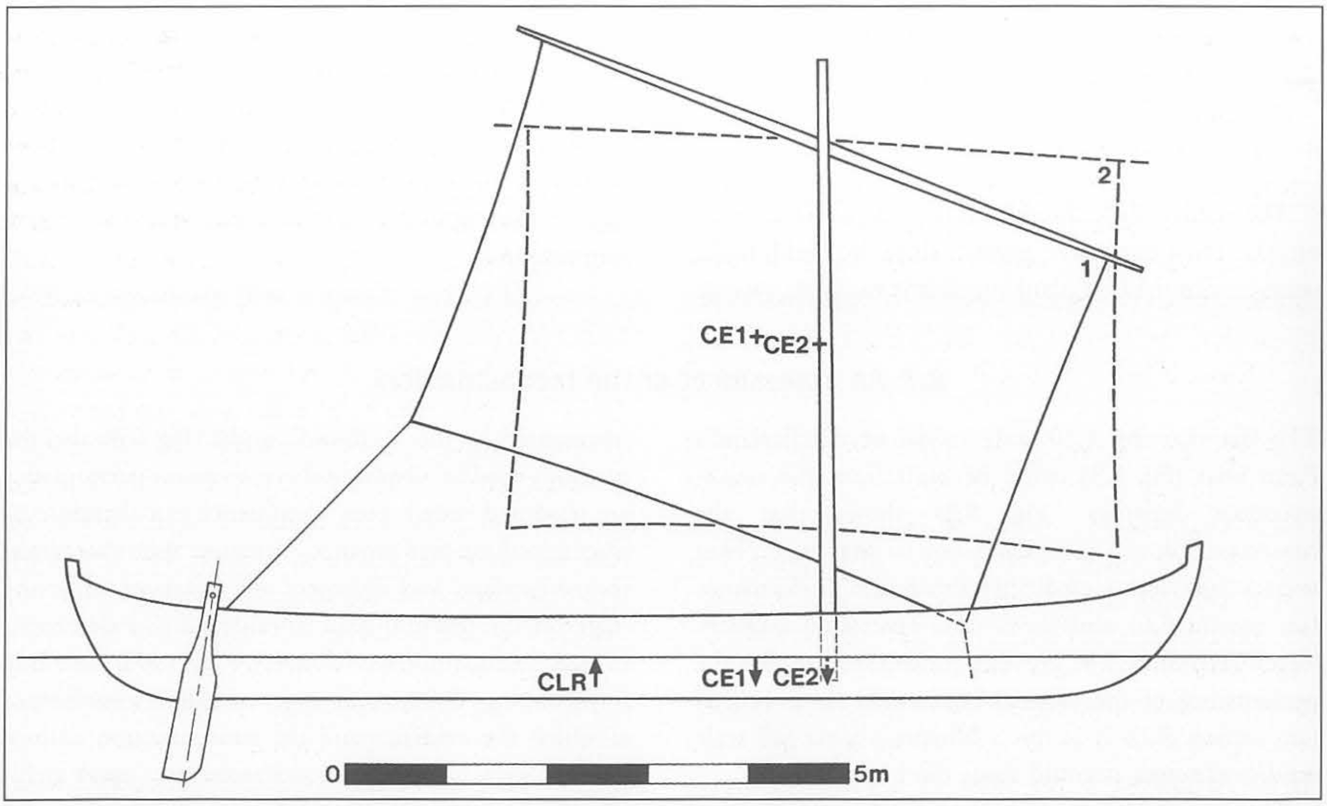


Figure 8.21 Diagram showing the boat with a broad square sail (2) which has been canted (1). (Diagram by Owain Roberts)

hull soundly and by more than a single pivoting device. No evidence has survived with the Barland's Farm boat of any rudder arrangement. If the evidence for the use of sail is accepted, an effective rudder must once have been part of the boat's equipment. Iconographical evidence, both contemporary and spanning a period from the earliest times to about the 13th century AD, shows the universal use of a rudder hung over one quarter of all seagoing ships and boats, while those from the Mediterranean carried a rudder on each quarter. It may fairly be assumed that the Barland's Farm boat hung a rudder from her starboard quarter of the type referred to as a side rudder (McGrail 1998). It would have been pivoted at two points, one at the sheer line and one near the waterline. For shallow water the upper pivot would be relaxed and the rudder stock allowed to angle forwards, thus reducing the depth of the blade below the hull.

In the design of sailing craft, a relationship is recognised between the area of the hull's submerged lateral plane and that of the immersed blade of the rudder (Barnaby 1954; Philips-Birt 1972). It is unlikely that early boat builders did not have a similar set of rules when matching a rudder to a hull. The rudder shown in Fig 8.21 has been drawn to meet that relationship after the following calculation:

$$\frac{\textit{area of lateral plane}}{\textit{area of rudder}} = \textit{rudder area ratio}$$

Since the area of lateral plane at 50% draft is 5m^2 and ratio for that area is 9.6 then

$$\frac{5m^2}{9.6} = 0.52m^2 \ \textit{area of rudder blade}$$

The rudder blade should not be wide where it turns on the boss (its lower pivot), since it could make contact with the hull planking. If it is made on average 0.4m wide, the length of blade below the boss would be 1.3m. This length takes it below the turbulence of the water flow around the hull.

On such a shallow hull the rudder contributes to resisting leeway besides keeping the boat on course (Roberts 1997). When held at an angle to leeward to resist the windward-turning tendency of the bows, some of the force acting on the rudder acts against the excessive leeway the boat would otherwise make.

8.6.15 Conclusions on handling characteristics

The remains of the Barland's Farm boat were of a vessel that would have been capable of accepting and delivering a wide range of cargoes while operating within the mixed demands made on the seaworthiness of a vessel working in an estuarine and coastal environment. There is little doubt about her ability as a sailing vessel, nor about her suitability for being rowed when conditions warrant. Such performance is essential in the presence of strong tides and generally westerly winds that are a feature of the Severn Estuary and the upper reaches of the Bristol Channel. Since the concept of an enclosing weather deck did not become a sure feature of European seagoing cargo carriers until the late Middle Ages (Roberts 1994), the Barland's Farm boat could have voyaged on occasions as far as the Irish Sea and beyond. Those values that define her performance would be common to other similar vessels built beyond the confines of the Bristol Channel. The owners may never have considered that her usefulness was limited to the Severn Estuary and sent her wherever freights were offered. Being an open boat, her safe conduct would be dependent ultimately on local knowledge, careful pilotage, and the skills inherent in good seamanship.

8.7 An assessment of the reconstruction

The fact that the 1:10 scale model of the Barland's Farm boat (Fig 8.3) could be built from the reconstruction drawings (Fig 8.2) shows that the reconstruction is a practicable one at that scale. That such a boat has a creditable theoretical performance (see section 8.6) underlines this. This is an archaeological reconstruction, however, undertaken so that the performance of the original boat could be estimated (see section 8.2). It is not a blueprint for a full-scale model, although it could form the basis for one.

The minimalist reconstruction published here (Figs 8.2 and 8.3) is derived from the excavated remains as represented by the 'as found' model (Fig 6.4) and the methods used by Owain Roberts to assess performance are tried and tested ones. Confidence can therefore be placed in these performance estimates. Such theoretical reconstructions and estimates are, however, only one stage on the research path towards a full-scale experimental reconstruction (Coates *et al* 1995; McGrail forthcoming). Subsequent stages would be: a conference at which the evidence and the reconstruction derived from it were criticised by archaeologists, naval architects, and others; investigation of the effects of varying heights of posts and of different sheerlines;

consideration of other propulsion outfits and steering arrangements; and the building of alternative reconstruction models. In this context it is relevant to note that Caesar (*De Bello Gallico* iii. 13) reported that the ships of the Veneti ships had 'exceptionally high bows and sterns'.

In the longer term, it might prove possible to design and build an experimental full-size reconstruction. Providing a rigorous attitude to experimental work is adopted, the design, building, and testing of such a replica of the Barland's Farm boat should demonstrate the practicability of her design and give a more reliable estimate of her performance. Such a vessel could also be used to compare lug sail with square sail, side rudder with steering oar, and sit/pull use of oars with stand/push.

9

BUILDING THE BOAT

9.1 Raw materials

9.1.1 Timber

Since all the surviving timbers were of oak, there is every reason to think that the original boat was built entirely of this timber species. In general terms two types of timber were required – long straight runs for the planking and crooks for the framing.

9.1.1.1 Planking

Given that two planks were probably sawn from each log (see sections 6.3.1 and 6.3.4.1), two oaks 8m or so in bole length were needed for the plank-keel and the outer bottom planks, one of *c* 1.55m girth (0.5m diameter) the other *c* 1.85 (0.6m diameter). Two similar oaks were needed for the longer planks in the side strakes. The remaining side planking and the four bow/stern bottom planks could probably be converted from eight other oaks each *c* 6m in length of bole. If four planks could be sawn from each log, however, as appears to have been done at least occasionally (section 7.7.5.1), these shorter lengths of planking could have been converted from the four 8m oaks needed for the plank-keel, outer bottom planks, and the long side planks and from three further oaks some 5 to 6m in length of bole.

The total length of planking required would be *c* 30m for the main bottom planking (plank-keel and outer bottom planks) and *c* 115m for the side planking and the bow/stern bottom planking. The oaks that would give such runs of relatively knot-free planking would be found in a forest.

9.1.1.2 Posts and framing

Oaks likely to grow the shapes and sizes of curved limbs and branches (crooks) needed for the boat's posts and framing are nowadays to be found mainly in open ground with isolated trees. Some of these crooks were bigger than the oaks needed for planking in girth/diameter. For example, the post needed a parent bole of 2.37/0.7m, floor F4 – 1.63/0.52m, half-frame F10Pt – 2.17/0.69m and even side timbers such as SF 8Pt –2.07/0.66m. Some of these probably had to come from curved boles rather than branches. At the other end of the scale, some of the side timbers were fashioned in the round from branches only 0.3 to 0.5m in girth (0.1 to 0.16m diameter).

Some of these crooks could have come from the crowns of the oaks chosen for planking; others would have been specially selected from trees that did not necessarily have to be felled. When searching for timber for full-size reconstructions of the 11th- to 12th-century Skuldelev ships, Crumlin-Pederson (1997, 180) found that large branches suitable for framing had to be cut down separately to avoid fractures in such branches when trees with their crown were felled. Crumlin-Pedersen considers that 'a considerable part of the time spent on building the ship [the original Hedeby 3 ship] will have been used in the forest, finding trees and branches of the right species and shape' for the framing. This may have been true in the medieval Baltic, but in the late Roman Severn Estuary region the frame-first builders of the Barland's Farm boat seem to have been more pragmatic than idealistic since the grain of the selected crook only partly matched the curve required in most of the surviving framing members and there is almost always short grain and indeed sapwood on these timbers. The Barland's Farm builders probably went into the forest with the size and shape of crook needed in mind (possibly carrying thin wooden moulds or templates of the curves required) and came back with crooks that matched the ideal by and large rather than precisely. In both the medieval Baltic and in Roman Wales it seems likely that 'foresters', if not the boatwrights themselves, knew where trees were to be found with a suitable range of crooks. Indeed if the boats being built were of a fairly standard shape, crooks with appropriate shapes could have been located and cut down well in advance of requirements and stored underwater until needed (McGrail 1998, 101).

It seems likely that the timber destined for the Barland's Farm boat was used soon after it was felled. Fresh green hardwoods such as oak are easier to work and bend more readily than when seasoned. The dangers associated with seasoning by air drying – shrinkage, distortion, checks, and splitting – are thus avoided. Furthermore in a well-ventilated open boat such as Barland's Farm the dangers of fungal rot are minimised (McGrail 1998, 27–8, 108, and 149–50).

The majority if not all the treenails inserted in fastening holes before planks were fastened to frames were of hazel (*Corylus avellana*) or willow (*Salix* sp; Table 3.6.5). Willow and hazel were also used in the caulking (Table 3.3.4).

9.2 Designing the boat

Unlike her contemporaries in the Mediterranean and Nordic/Scandinavian traditions, the Barland's Farm boat was not built plank-first, ie her shape was not determined by her planking. Nor was her hull shape partly determined by her bottom, as Arnold (1991) has suggested was the case with the truly flat-bottomed, post-less, and keel-less 'barges' of this Romano-Celtic tradition. Like the St Peter Port 1 and Blackfriars 1 ships, the Barland's Farm boat was not flat-bottomed – her plank-keel projects below the outer bottom planks (Fig 6.7) – and some framing elements must have been in place *before* these two planks were installed. The shape of these outer bottom planks (specifically the outer edges) was thus determined by the framing and not vice versa.

The Barland's Farm boat's planks were fastened to the framing and not to each other. Nor is there any sign of plugged holes in the structure that might suggest that planks had been temporarily fastened together before frames were positioned – as Arnold (1992) has suggested for the Lake Neuchâtel boats of this tradition and as Marsden (1994, 77, fig 26) has speculated for *some* of the bottom planking of the Blackfriars 1 ship. The Barland's Farm boat was built frame-first or more precisely she was built framing-first, ie elements of her framing defined and determined her hull shape (McGrail 1995, 141). This does not mean that a full framework or 'skeleton' was erected before any planking was installed (as known in 19th-century Europe and America – see Greenhill 1988); rather that, before planking was added to the structure, some framing was in position to receive it and to determine how it should be shaped. Indeed it was not possible to build a full framework before beginning to plank the Barland's Farm boat, since her side timbers were not fastened to her floor timbers. Precisely how much framing and which particular frames had to be erected before any planking began and the building sequence that followed are discussed below (section 9.3). Here how such a framework might have been designed and thus the desired hull shape obtained is considered.

Nowadays in Britain frame-first boats are built in a number of ways ranging from 'building mostly by eye' to 'total dependence on drawings' (McKee 1983, 118). In terms of design this means that, at one end of the spectrum, the builder himself has a form of boat in mind. He fashions and sets up keel, posts, and elements of the framing and he then fairs individual timbers, possibly with the aid of ribbands running along the positioned frames, until he recognises that the combined elements define an 'eye-sweet' shape, a shape that is as close to his ideal hull as he can make it. How close actuality is to ideal will be influenced to a degree by the timber available to him. Throughout this sequence, it is possible for this builder to impose his individuality on his boat, modify his 'design', and incorporate new ideas.

At the other end of the spectrum, the shape of the hull has been designed by a naval architect or similar person before building begins. This builder has little if any scope for innovation and has to ensure that he obtains the right timber to match the naval architect's design.

The Romano-Celtic way of building a boat is the earliest use of the framing-first technique as far as we know. It seems likely, therefore, that the design methods used were not over-complex and probably close to if not actually at the lower end of the technological spectrum described above (McGrail 2003). A relatively simple method is known to have been used in 14th-century Venice (and subsequently elsewhere in Mediterranean and Atlantic Europe) to design the framing of seagoing ships (Bellabarba 1993). This procedure was standardised so that once a particular hull shape had been proven at sea that hull form could be built again and again. To use this method (known to us as Mediterranean moulding) the essential requirements were:

- a basic linear module, usually the length (L);
- the maximum breadth and depth of hull in terms of ratios relative to L;
- the shape of the master-frame either in the

form of a wooden mould/template or as orthogonal coordinates;

- the inclination of the posts;
- the number of designed frames and/or their spacing;
- The total rising and narrowing of the designed hull relative to the master frame.

The Venetian master shipwright used a simple geometric construction involving an inscribed wooden tablet to derive the shape of all other designed frames from that of the master frame. In this way he designed the framing that defined the hull shape (McGrail, 2001b).

There is an even simpler though related design method is use today in Tamil Nadu, India (Blue *et al* 1998). Instead of the wooden tablet and the geometric construction, rules of thumb, including simple ratios, are used systematically to modify the shape of the master frame. This Tamil design system is otherwise very similar to that used in 14th-century Venice. If any of the methods of designing a framework that are known today had been used in earlier times, it might be thought that something similar to this Tamil Nadu method would have been used.

There are two distinct groups of timbers within the Barland's Farm boat's framework: the floor timbers with their associated side timbers; and the five pairs of half-frames. Each of these could, in theory, have been used independently to define the hull shape.

As the floors and side timbers are not fastened together, there seem to be no timber or timbers in the first group that could be thought of as a master-frame. Thus neither of the design methods described above is likely to have been used in this case. On the other hand two half-frames (say F10Pt and St) positioned side-by-side on the plank-keel although not fastened together define the hull shape at that particular station and, therefore, might have been used as a master frame. The other half-frames for which there is more than vestigial evidence (F5Pt, F7Pt, and F12Pt) have a general similarity to F10Pt, with a radius of bilge curvature of 0.85 to 0.90m (see section 6.3.3.5) and sides flaring 30° to 40° from the vertical. There are no half-frames at the midships station, however, and no simple relationship can be established between the individual shapes of the five pairs of Barland's Farm half-frames which might suggest that a formal design method had been used to design their shapes by systematic modification of the shape of a master-frame.

On present evidence, therefore, it seems likely that the Barland's Farm framework, or rather those elements of it that defined the hull shape, was designed 'by eye'. From experience, or possibly using measurements taken from another boat, the boatwright may first have fashioned plank-keel, posts, and some of the framing. He may then have set up these posts and framing on the plank-keel to give the approximate form of the hull. This shape may then have been refined by shaping and bevelling the outer faces of individual units of framing until a pair of temporary splines (ribbands) between the posts appeared to lie in a fair curve. If his eye also told him that the hull shape given by this framework was close to the shape he had in mind, he had finished the design of the lower hull, or even the entire hull, depending on which timbers had been included in the framework. Otherwise the framing was further fashioned until the required hull shape was obtained. Subsequently the shapes of the outer bottom planks and the side strakes may have been obtained by using further ribbands and marking plank breadths on the outer faces of certain framing timbers.

With this 'design' method, it seems unlikely that a subsequent boat could have been built which would have had precisely the same shape as the Barland's boat, but rules of thumb may have been developed so that the outcome was a very similar boat. Blackfriars 1 and St Peter Port ships were much bigger than the Barland's Farm boat, but there seems to be no intrinsic reason why the general idea behind this 'design' method could not have been used for them also (see section 9.4.3).

9.2.1 A unit of measurement?

Regularities in the spacing of the framing timbers indicate that a standard unit of measurement may have been used in the 'design' of this boat (see section 6.3.3.6.2). Such a unit would probably have been 'natural', eg related to some feature of the human body, rather than any documented legal unit (McGrail 1998, 105). Data in Tables 6.2 to 6.4 point towards the Barland's Farm unit being the equivalent of 275mm which is the approximate length of a human foot. Some support for this conjecture comes from two of the three measurable shoes found on the boat site – no.1 was 270mm in length and no. 2 265mm (Table 4.5.1). Furthermore Rule and Monaghan (1993, 29) have identified a unit of 282mm used in marking the frame positions on the centreline of the St Peter Port 1 ship.

It is possible that this 275mm 'foot' was also used when marking out the curvature of the Barland's Farm half-frames, the end of the main floor timbers, and the lower post. Half-frame curves had a radius ranging from 850 to 900mm, with a mean of 872mm ± 19mm (see section 6.3.3.5); the curved ends of the floor timber were in the range 780 to 880mm with a mean of 806mm ± 36mm (see section 6.3.3.3); and the post's radius of curvature was approximately 1150mm (section 6.3.2.1). If these radii were the equivalent of 3 'feet', 3 'feet', and 4 'feet' respectively, the units used would have been 290mm, 269mm, and 287mm. These units bracket the 275mm unit identified for the frame spacing, which suggests (no more than that) that a similar 'foot' may have been used to set out these curves.

Frame spacing can be more accurately measured in the Barland's Farm remains than can framing and post curve radii. The evidence for the use of the 275mm 'foot' unit in spacing the frames is more convincing than its use in defining curves. It might be thought that this 'foot' had also been used to measure the length of the plank-keel, since 7.18m is the equivalent of 26.1 'feet'. This is more likely, however, to have been determined by the length of the available timber.

9.2.2 The use of proportion

In the design of 16th-century frame-first ships of the Mediterranean and Atlantic, the principal dimensions of the hull were defined as proportions of a modular length such as that of the keel or the maximum beam. In Basque ships, for example, the ratio of maximum beam to keel length to overall length was 1:2:3 (Grenier *et al* 1994, 137–8). It is more logical to investigate whether a comparable rule was used by the builder of the Barland's Farm boat by reformulating the relationship in terms of the length of the plank-keel since this is known, whereas the overall dimensions are reconstructed and can only be approximate. With a plank-keel length of 7.18m and reconstructed dimensions of 11.40 × 3.16 × 0.90m (Table 8.1) the ratio of plank-keel to maximum beam to overall length becomes 1:0.44:1.59: in other words, Barland's Farm's maximum beam as reconstructed was about half the length of the plank-keel and the length overall was about one and a half times. Rearranged in terms of maximum beam, as in the Basque rule, this ratio becomes 1:2.27:3.61. The plank-keel was, therefore, approximately two and a quarter times the maximum beam and the overall length was approximately three and a half times. That these hull proportions are not unlike the 1:2:3 of the ideal Basque ships does not imply any direct connection between the design methods used. It seems more likely that, in both cases, experience had shown that hulls of approximately these proportions (and the implied general shape at bow and stern) were the best for seagoing, cargo-carrying vessel in north-west European waters.

9.3 The building sequence

9.3.1 Active and passive framing

As shown above the hull shape of the Barland's Farm boat was defined by the plank-keel, the posts, and some (possibly all) of the framing. Those framing elements that determine hull shape are known as 'active' framing timbers; any remaining framing timbers are 'passive', ie after the hull has been built, these timbers are shaped to fit it and then fastened at their station.

The spacing of active framing timbers must be such that the hull is well defined, with smoothly flowing lines. For example, towards the ends of a boat, where the cross-sectional shape of the hull can be changing rapidly, active frames may need to be closer together than they need be near amidships. If active frames are too widely spaced, irregularities of shape can creep in and the resulting un-fair lines may not only be difficult to plank but also adversely affect performance. For archaeologists trying to reconstruct former skills, the spacing of active frames must remain a matter of judgment, possibly enlightened by recent frame-first practices.

The theoretical possibilities of using one or other of the two distinct groups of framing timbers in the Barland's Farm boat to define her hull shape will first be considered.

9.3.1.1 The floor timbers and side timbers

These consist of the main floors (F4, F6, F8, F9, F11, F13, F14, F16, and F17) and the bow and stern floors (F1, F2, F3, and F18) each with their associated side timbers. If these timbers were to be used by themselves to give the shape of the hull, the half-frames would become passive frames, their individual shapes determined by the planking after (some of) it had been fastened to the defining (ie active) framing timbers.

The distances centre to centre between the main floor timbers are given in Table 6.3. This shows that they are reasonably well, though not regularly, spaced along the hull, the intervals ranging from 0.52 to 1.14m, with a mean of 0.897 ± 0.27m (n=8). There is a greater space at the bow, where the distance between F4 and the stem post averages *c* 2m and at the stern where F17 to the stern post averages *c* 1.3m. It is conceivable that floors F1, F2, F3, and F18 could have been used to reduce these spacings.

These floors generally speaking only define the hull up to the second side strake (P/S4). If the side timbers which all overlap their associated floor could be fastened to the lower strakes of planking at this stage, however, the entire hull would be defined. In essence, this is the building sequence that has been suggested for Blackfriars 1 (Marsden 1994) and for St Peter Port 1 (Rule and Monaghan 1993): floor timbers are fastened to the lower planking, and project above it; the upper hull is then planked. This has been called the sequential, intermediate, or alternating form of frame-first or skeleton building (McGrail 1997a).

9.3.1.2 The pairs of half-frames

These consist of the port and starboard elements of F5, 7, 10, 12, and 15. Blackfriars 1 and St Peter Port 1 do not appear to have had such timbers. Generally speaking these half-frames define the Barland's Farm hull up to the top strake (P/S7). If this group was used by itself to define the hull, the floors and side timbers would be passive, ie they would be fitted after (most of) the planking and their shape would be determined by that planking.

The distances between the pairs of half-frames are given in Table 6.4. The spacing ranges from 1.11 to 1.65m with a mean of 1.20 ± 0.37m (n=4). This spacing is some 33.3% greater than with the floor timbers and side timbers. The spacings at the ends are also greater – *c* 2.75m between F5 and the stem post and *c* 2.35m between F15 and the stern post. The wider spacings mean that a hull planked up to the half-frames alone would not be as fair or as tight as one planked to floors and side timbers.

When turning from theory to practice, there is evidence in the surviving remains that the Barland's Farm boat was not built solely by either method – on the contrary, frames from both groups were used to build the defining framework. The spatial relationships between planks, frames, and fastenings (the internal stratigraphy of this boat, as it were) and certain boatbuilders marks (see section 7.1.3) demonstrate that neither of the two types of frame could be used by itself. Furthermore these relationships and marks suggest at least part of the building sequence. Practical methods used today to ensure that a vessel with fair lines and tight butts and seams is built in, for example, Greece (Daminiades 1991) and in Tamil Nadu, India (Blue *et al* 1998) may also help to elucidate the building sequence of the Barland's Farm boat.

9.3.2 Twentieth-century frame-first methods

In plank-first boatbuilding the strakes are fastened together in a regular sequence, almost invariably from the keel (or bottom planking) upwards, but occasionally from the top strake to the keel when small boats are built upside down. It might be thought that in framing-first building, on the other hand, there need not be such regularity, that planks could be added to the framing almost in a random pattern, that planking could start on any strake for which framing had been positioned, and that one strake need not be finished before another (not necessarily contiguous) one was begun.

In 20th-century thinking, however, there are procedures that must be followed if a fair, watertight hull is to be built. One such concerns the order of planking within strakes – planks next to the posts should be fitted and fastened first. In this way the end planks can be made to fit accurately within the post rabbets so that the fastenings there will not be over-stressed. The remaining planks in that strake are then fitted. During this operation it is necessary to ensure that no plank end is left 'flapping' but is fastened to an appropriate frame in a tight and smoothly flowing butt joint with the next plank. The final plank in a strake may be fitted slightly oversize (a 'shutter') so that all butts are further tightened.

Another widely used procedure concerns the sequence of the strakes. One particular upper strake that runs parallel to the intended sheer line is chosen as the stabilising or 'clamp' strake. In Tamil Nadu this is the highest but one on a flat-bottomed boat with six side strakes (Blue *et al* 1998). In Greece it is the fourth strake from the top in a twenty-strake small ship (Daminiades 1991, fig 3). This strake is the first to be fitted and fastened, thereby stabilising the framework. It may also be used as a ribband from which the shapes of passive frames can be determined. The remainder of the hull is then planked working down from the 'clamp' strake and simultaneously up from the garboard or first side strake. The last strake to be fitted in this sequence is about halfway between the garboard and the 'clamp' strake. This is known as the 'key' or 'shutter' strake and is fashioned to fill the gap with great precision to give an interference fit. In this way the whole planking is given a coherent strength (Daminiades 1991, 99–100, table 1). A different procedure with a similar effect has been described by Eric McKee (1983, 123). Alternate strakes are fastened to the framework leaving a strake-wide gap between each one: these gaps are then filled by other strakes.

The question that must be asked is whether these procedures, the origin of which is unknown, can be applied to early finds of framing-first boats. If they can, the resultant constraints may assist in determining the building sequence.

9.3.3 Frame-spacing data

Marten de Weerd (1988, 1990, and 1994) has attempted to show that analysis of the frame spacing in Romano-Celtic boats can reveal the order in which frames were erected. His demonstration is, however, based on two assumptions: that the ancient boatwright measured distances between frames accurately using some historically documented unit of linear measure (in this case, the Roman *pes monetalis*); and that the modern investigator of incomplete, fragmented, and distorted remains can readily identify which measurements should be taken and can measure them with equal accuracy. Neither of these assumptions is valid. If there are detectable regularities, frame-spacing data may be used (see section 9.2.1) to suggest the *approximate* size of measuring unit that might have been used, but such measurements are too imprecise to identify some particular legal measure (McGrail 1998, xxvi). Moreover the unquantifiable errors at all stages of this process (from ancient builder to modern reconstructor) mean that reliance cannot be placed on present-day measurements of frame intervals to deduce the order in which frames were placed in position.

9.3.4 Framing to define the lower hull

There are distinctive features in the boat's structure that can throw some light on the building sequence. As with all excavated structures there are problems of distortion and of incomplete data – the latter is especially the case on the starboard side of the boat and aft of floor F13. There is also the problem of recognising which if any elements are secondary – repairs, reinforcements, or replacements. Unrecognised secondary material may make a simple sequence of building appear to be complex. Nevertheless a rigorous evaluation of the evidence as it now appears should throw some light on the building sequence.

The plank-keel had first to be placed in position since, at some stage in the sequence, the half-frames and floors from F4 to F17 were all fastened to it. This plank-keel consists of two units (P1 and S1) that have to be brought together in a tight seam, but without any fastenings between them. As there is no sign of temporary fastenings, some frames (say two dividing the plank-keel into roughly three equal lengths) must first have been fashioned and fastened to the plank-keel to ensure a tight seam between P1 and S1.

The posts cannot have been the first timbers to have been fastened to the plank-keel, since the fastenings between posts and plank-keel also pass through floors F4 and F17. The posts are, however, needed fairly early in the sequence as they are essential to the visualisation of hull shape. Floors F4 and F17 form double-notch joints with the posts and thereby reinforce the plank-keel/posts scarves. These floors must, therefore, have been among the first timbers to have been fastened in position. At this stage it is clear that the boat's active framing timbers – those that defined hull shape – could not be half-frames alone.

A temporary centreline was probably drawn (in charcoal or chalk?) when the two units of the plank-keel were first brought together. After the backbone of the plank-keel and posts had been stabilised by the addition of several framing timbers (which must have included F4 and F17), a permanent centreline would have been needed. Blind holes were bored along this line, but this must have been after floors F4, F6, F13, and F17 had been fastened in position, since there are no such holes underneath them (see section 7.1.3) nor probably under F8. Floors F6 and F13 (and probably F8) may thus have been the framing timbers which first held the two elements of the plank-keel together, while F4 and F17 would have been positioned next to fasten the posts to the plank-keel.

With these four floors in position the framing pattern would be A in Fig 9.1.

It might be just possible to visualise from this set-up the general shape of the lower hull up to the second side strakes (P/S4). This shape would, however, be more readily appreciated if temporary splines were to be run as ribbands at strake P/S4 level from post to post. The hull shape changes relatively rapidly forward of F4 and aft of F17 and it may, therefore, have been necessary to insert floors F2 and F18 before the ribbands were positioned. Although hull shape changes only slowly between F6 and F13, there is a gap here of nearly 4m. It would probably be necessary to insert a frame approximately midway between them to ensure that the ribbands ran fair and true. There is no frame at the mid-point of the plank-keel or at the mid-point

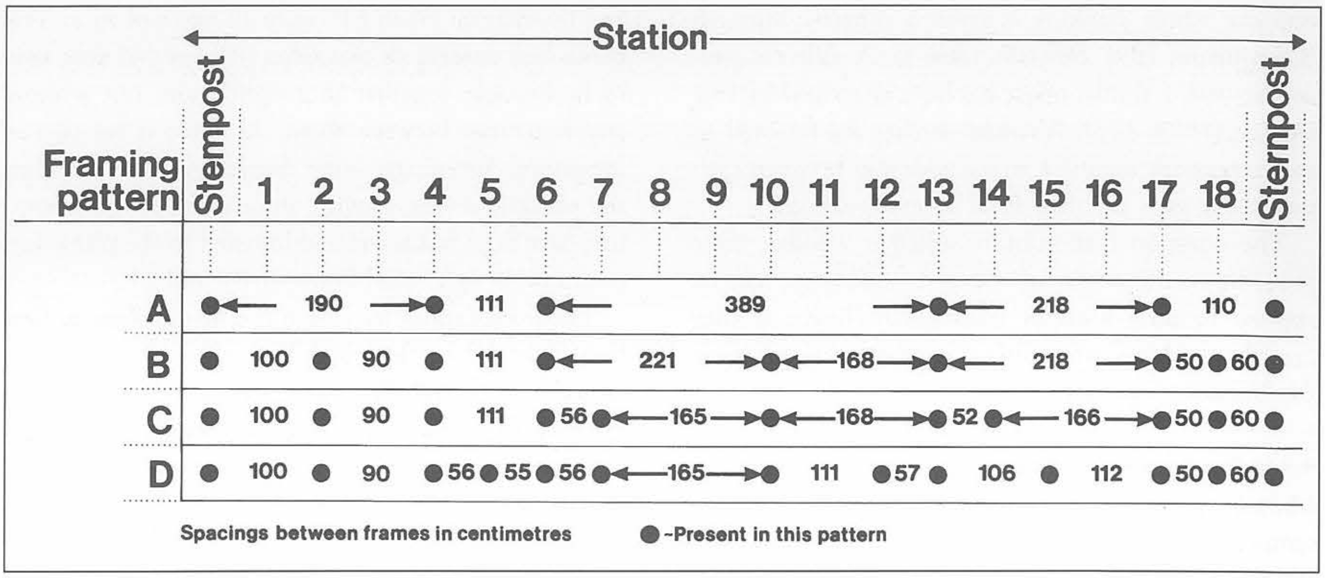


Figure 9.1 Diagram showing four potential patterns (A, B, C, and D) which might be used when building the active framework for the Barland's Farm boat. The stations are at the main frames. Distances between frames are in mm.

of the reconstructed boat. Half-frames F10Pt and St, lying between these two mid-points, are the nearest to a central frame that this boat has. If the two bow/stern floors and this pair of half-frames were to be added to the framework, the framing pattern would be B in Figure 9.1.

This pattern gives a reasonable spacing that should ensure a fair run for ribbands and enable the lower part of the hull to be defined. Other arrangements are possible, but pattern B is the one with the minimum number of framing timbers. Since this arrangement includes a pair of half-frames, it seems that the active framing of the boat cannot be solely floors.

Two other features of the Barland's Farm boat place constraints on the order of planking and upon which frames must be in position before certain planks can be added to the active framework. These are the position of the known plank butts and a series of boatbuilders' marks on the frames.

9.3.4.1 Plank butts

There are no butts in the outer, bow, or stern bottom planks. The known butts in the side planking are shown diagrammatically in Fig 6.19. It is clear from this figure that much information is missing and that if the position of all butts were known there would be more constraints on the framing pattern. The minimum framing requirements before the known planks in each surviving strake can be fastened in position is given in Table 9.1.

To ensure symmetry, it is likely that this boat would have had equivalent strakes port and starboard fastened at the same time. It is also assumed here that half-frames would always have been added in pairs and that side timbers would be added only after their associated floor had been fastened in position. The framing requirements due to plank butts then becomes as in Table 9.2.

The following framing timbers would, therefore, have to be added to pattern B in Figure 9.1 before the *lower* hull (up to strake P/S4) could be planked: F7 Pt and St; SF13 Pt and St; F14. This leads on to pattern C in Figure 9.1. This pattern raises three problems:

1 This active framework now consists of 5 out of the 9 main floors and 2 out of the 5 pairs of half-frames. Furthermore the 2 added frames (F7 Pt and St and F14) are positioned where the hull shape is not changing rapidly and adjacent to timbers already in the framework.

2 The use of side timbers for plank butts complicates the framing/planking sequence: since they are not fastened to their associated floor, other strakes to which they can be fastened have first to be in position. For example, SF13Pt was not fastened to strake 3. It, therefore, could only be in position to receive a butt joint in strake P4 if strakes P5, 6, or 7 were already fastened. Similar constraints apply to SF8Pt that supports

Table 9.1 Minimum framing requirements for plank butts

port strakes	*framing*	*starboard strakes*	*framing*
P3	F14	S3	F13
P4	F7, SF13Pt	S4	F10
P5	F5, F11, F16	S5	IK
P6	SF8Pt	S6	IK
P7	IK		

Table 9.2 Realistic framing requirements for plank butts

strakes	*framing needed*
3Pt and St	F13, F14
4	F7Pt and St, F10Pt and St, SF13 Pt and St
5	F5Pt and St, F11, F16
6	F8, SF8Pt and St

butt joints in strake P6. If there was no convenient framing timber already in place, it may be argued that the boatbuilder would not have shortened his plank so that it ended on a frame already installed, but left the fastening of the butt ends until later. In recent times boatbuilders in such circumstances have been known to use a temporary butt strap to hold in position the butted ends of two adjacent planks (O Roberts pers comm). Such possibilities are considered further below (section 9.3.6).

3 In pattern C the *upper* part of the hull is defined only by the two posts and the two pairs of half-frames at stations 7 and 10, with spacings of 3.67m, 1.65m, and 5.11m; these were probably too sparse. Since a higher strake has to be fitted before strake 4 (see above), that strake cannot be a stabilising strake or ribband. Moreover, strake 4 is too low to act as a stabiliser or a ribband for the upper hull.

All three points raise the possibility that the Barland's Farm active framework may not have consisted of the minimum number of frames: rather more than fewer. Furthermore with pattern C the upper hull remains inadequately defined.

9.3.4.2 Boatbuilders' marks

Before investigating these matters further it is necessary to take account of another set of constraints imposed on the planking and framing sequence. It has been shown above (section 7.1.2) that marks on the outer faces of many of the frames were probably cut by the builder during the planking-up phase of building. These defined a fair curve delineating the edges of succeeding strakes, rather than being over-deeply cut tool marks that were a guide to the shape to which individual framing timbers had to be fashioned. To establish the position of these marks after the 'designed' framework had been faired, a spline, scarfed or otherwise jointed to form a ribband, was probably run from post to post at the approximate position of the upper (if planking upwards) or the lower (if planking downwards) edge of the next strake to be fashioned. After framing timbers had been faired to the ribband, marks were cut on the timbers where the ribband crossed them. The outline shapes of planks thus defined would be marked on boards and the planks fashioned to shape. This should ensure that plank runs would be fair and the seams tight.

In theory all such marks on the framing timber could have been cut before any planks were fashioned, but this is most unlikely as it would be tantamount to designing all the plank shapes at once. It is much more likely that a series of marks were made along a ribband set in relation to a strake already fastened and that this process was repeated for each succeeding strake. Thus a framing timber with such a mark had to be in position before that strake was shaped and fastened. These marks are tabulated in Table 7.1.

As with the constraints imposed by butt joints, the constraints imposed on the sequence by the marks on the timbers surviving are fewer than if the whole framework had survived in a pristine condition.

9.3.5 Framing to define the whole hull

It is now time to investigate framing patterns that could define the whole hull from the start, since there are difficulties in identifying a framing pattern that would allow the active framing to be built sequentially, ie first the lower hull, then the upper. Framing pattern C is, therefore, left aside to return to pattern B in Figure 9.1 which takes account of the requirement to bind the two elements of the plank-keel together and the requirement to 'lock' the posts to the plank-keel.

There are two ways in which Pattern B could be modified to define the upper hull more closely: add side timbers – but these could only be added if the strakes to which they were to be fastened and the floors with which each side frame was associated, were already in place; add the remaining half-frames – this is more promising since the only extra requirement is that a stabilising strake should be added to the framework before other planking began.

With the other four half-frames added, the framing pattern is now D in Fig 9.1. The upper hull is now defined by the two posts and the five half-frames, although F12Pt and St do not reach the top strake. The longest gap is only 1.65m between F7 and F10 or 1.68m between F10 and F13 where F12 does not extend beyond strake 5. If the bow and stern floor timbers F1, F2, F3, and F18 were to be omitted, there would be gaps of *c* 1.9m in the bow and *c* 1.1m in the stern. This pattern adequately defines the whole hull. All the half-frames and four of the nine main floors are, however, included in this pattern and most of the missing ones (F8, F9, F11, F14, and F16) lie where the hull form changes relatively slowly. Again there is a suggestion that most if not all main frames may have been installed in the set-up at an early stage.

9.3.6 Planking problems

It is now necessary to investigate pattern D in the light of: the requirement for a stabilising strake; the pattern of plank butts; and the pattern of boatbuilders' marks.

From a structural point of view the best stabilising strakes would be P/S6 and failing that, P/S7 or 5.

9.3.6.1 Strake P7 (S7 did not survive)

There would have been butts in this strake (and in S7), but the constraints they would impose cannot be known. The only constraint imposed by the boatbuilders' marks is that F5Pt would have to be there – as it is. Since the minimal remains of P/S7 impose no known constraints and since the starboard frames did not survive to this height, it would be unwise to postulate P/S7 as the stabilising strake unless all other strakes had been positively ruled out.

9.3.6.2 Strake P6 (S6 has not survived)

A butt means that SF8Pt must first be in place. Marks mean that F5Pt and St and F7Pt and St must also be in place – as they are. The butt constraint means not only that floor F8 and associated side timbers would have to be added to pattern D, but also that at least one other strake would have to be in position so that SF8Pt could be fastened to it – this could be P7, P5, P4, or possibly P3. P6 thus could not be the first strake, but might act as a stabilising strake if a lower strake had first been fastened.

9.3.6.3 Strakes P5 and S5

The remains of S5 impose no constraints since there are no surviving butts and there are no surviving builders' mark at seams S5/6 and S4/5.

Butts in P5 mean that F5Pt and St, F11, and F16 must be in framing pattern D. Marks at seams P5/6 and P4/5 mean that the following frames would have to be in position: F2, F3, F4, F6, F7, F9, F10, F11?, and F12.

Thus F3, F9, and F11 would have to be added to pattern D. Floors F9, 11, and 16 can readily be added to the pattern. By then only two of the main floors would not be active framing. The addition of bow floor F3 at this stage is also no problem. Thus P5 and S5 can be stabilising strakes.

9.3.6.4 Strakes P/S4 and P/S3

The first and second side strakes (P/S4 and P/S3) are too low in the hull to be framework stabilisers or ribbands. It is of some interest, however, to see whether they could be the first strakes to be fastened to the framework given in pattern D.

Butts in strakes P/S4 mean that F7, F10, and SF13Pt have to be positioned. Marks require F2–4, F6, F7, F8–10, F12, and possibly SF8Pt(?). Floors F3, F8, and F9 can readily be added to pattern D. The side timber SF13 presents the usual problem; for this reason P/S4 cannot be the first strake.

Butts in strakes P/S3 mean that F13 and 14 are needed. Marks require F2–4, F6, F8–10, F12 and F13, and SF8Pt(?). F8, F9, and F13 can readily be added to pattern D. If the possible mark on SF8Pt were to be confirmed, strakes P/S3 could not be the first strakes.

9.3.6.5 The outer, bow and, stern bottom planks

These can be shaped and fastened to the framework at any time. Side timbers cannot be fastened to these planks.

9.3.7 Possible solutions to the planking problem

It would be possible to work out a planking sequence using pattern D framing, with P/S7 as the first strakes fitted. This is a least desirable solution because it is based on absence of evidence. A planking sequence can also be devised, however, that would satisfy all known constraints by using P5 and S5 as stabilising strakes and as the first side strakes to be added to pattern D framing:

1 mark seam 2/3 on framing;
2 fashion and fit outer, bow, and stern bottom planks;
3 mark seams 4/5 and 5/6;
4 fit strakes P/S5 – act as framework stabilisers;
5 mark seam 6/7;
6 fit strakes P/S7;
7 fasten SF8 to P/S 7 and P/S5;
8 fit strake P/S6 as a shutter;
9 mark seam 3/4;
10 fit strakes P/S3;
11 fasten SF13 to P/S 7, 6 and 5;
12 fit strakes P/S 4 as a shutter.

9.3.8 A building sequence (Fig 9.2)

Since framing pattern D (used in the example above) includes almost all the floors and half-frames, it seems reasonable to suggest that originally all of them were fitted to the framework as soon as they could be accepted. There would have been few if any problems in doing this *providing that each framing timber could be fashioned to its near-final shape before installation* – see section 9.2 on design. With this hypothesis in mind, a sequence of building the Barland's Farm boat may be outlined based on the planking sequence given in section 9.3.7. This sequence does not include details of the following operations:

- the preparation of the building stocks;
- spacing out individual frames, using the human foot as a unit;
- the use of shores and plank-bending devices;
- shaping the individual planks and framing timbers;
- details of caulking and fastenings;
- formation of rabbets, scarves, notches, and bevels (on frames as well as planks);
- installation of propulsion and steering equipment, except the mast-step timber.

It is assumed in the sequence below that, within strakes, end planks are fashioned, fitted, and fastened first and that pairs of strakes, port and starboard, are completely planked before another pair is begun:

A P1 and S1 bound together as a plank-keel; temporary centreline and approximate frame stations measured using human feet and marked using chalk or charcoal (Fig 9.2.1);

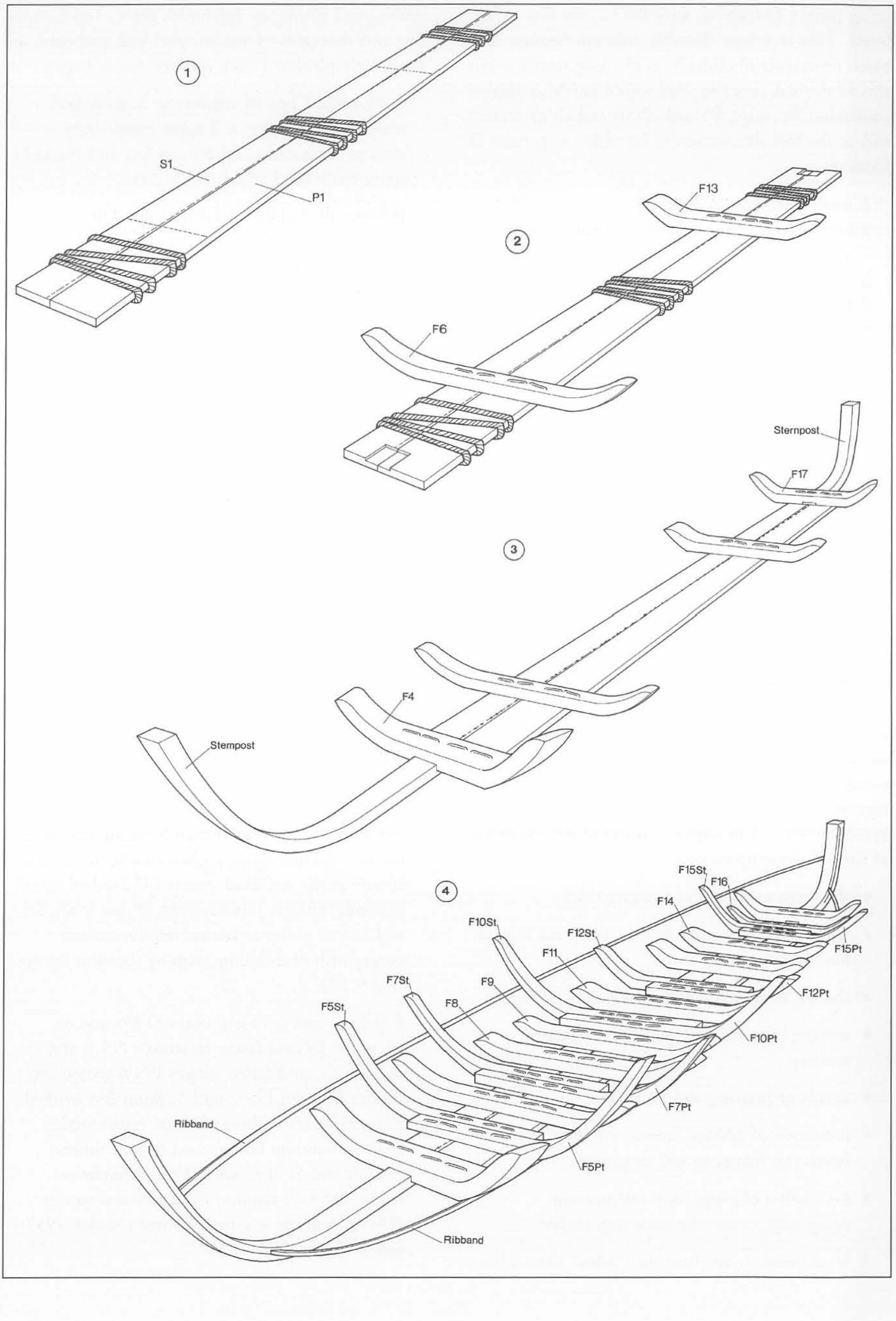
B floors F6 and F13 (and probably F8) fashioned to approximate shape and fastened to the plank-keel forcing P1 and S1 together; housing for posts cut (Fig 9.2.2);

C posts and floors F4 and F17 fashioned; posts stepped on plank-keel; floors F4 and F17 positioned; floor and posts fastened to plank-keel. Initial fairing and bevelling of outer faces of frames; permanent marking of centreline with blind holes; lashings removed (Fig 9.2.3); line rigged between tops of posts (not shown);

D all half-frames fashioned, added to set-up, and faired; remaining floors fashioned (possibly except those at bow and stern) and added; refined fairing and bevelling of half-frames and floors using ribbands; seam 2/3 marked on framing (Fig 9.2.4). At this stage the hull would have been visibly defined by the plank-keel below and posts at the ends, with floors and half-frames along the length giving the cross-sectional shape; there was no planking;

E outer, bow, and stern bottom planks fashioned, fitted, and fastened to framing, Seams 4/5 and 5/6 marked on framing using ribbands; fashion, fit, and fasten strakes P/S 5: framework is now partly stabilised; seams 6/7 marked using ribbands; fashion (overbreadth) strakes P/S7, fit, and fasten: set-up is further stabilised; final fairing of hull including shaping sheerline by eye (Fig 9.2.5);

F fashion and fit side timbers SF8Pt and St alongside F8 and fasten to strakes P/S 5 and 7; fashion, fit, and fasten strakes P/S 6 to framing – shutter between P/S 7 and 5. Seam 3/4 marked using ribbands; fashion, fit, and fasten strakes P/S3 to framing; fashion and fit side timbers SF13Pt and St alongside F13 and fasten to strakes P/S5–7; fashion, fit, and fasten strakes P/S4 to framing – shutter between strakes P/S3 and 5 (Fig 9.2.6);


1
S1
P1
2
F13
F6
3
Sternpost
F17
F4
Stempost
4
F15St
F16
F14
F10St
F12St
F15Pt
F11
F12Pt
F7St
F9
F5St
F8
F10Pt
F7Pt
Ribband
F5Pt
Ribband

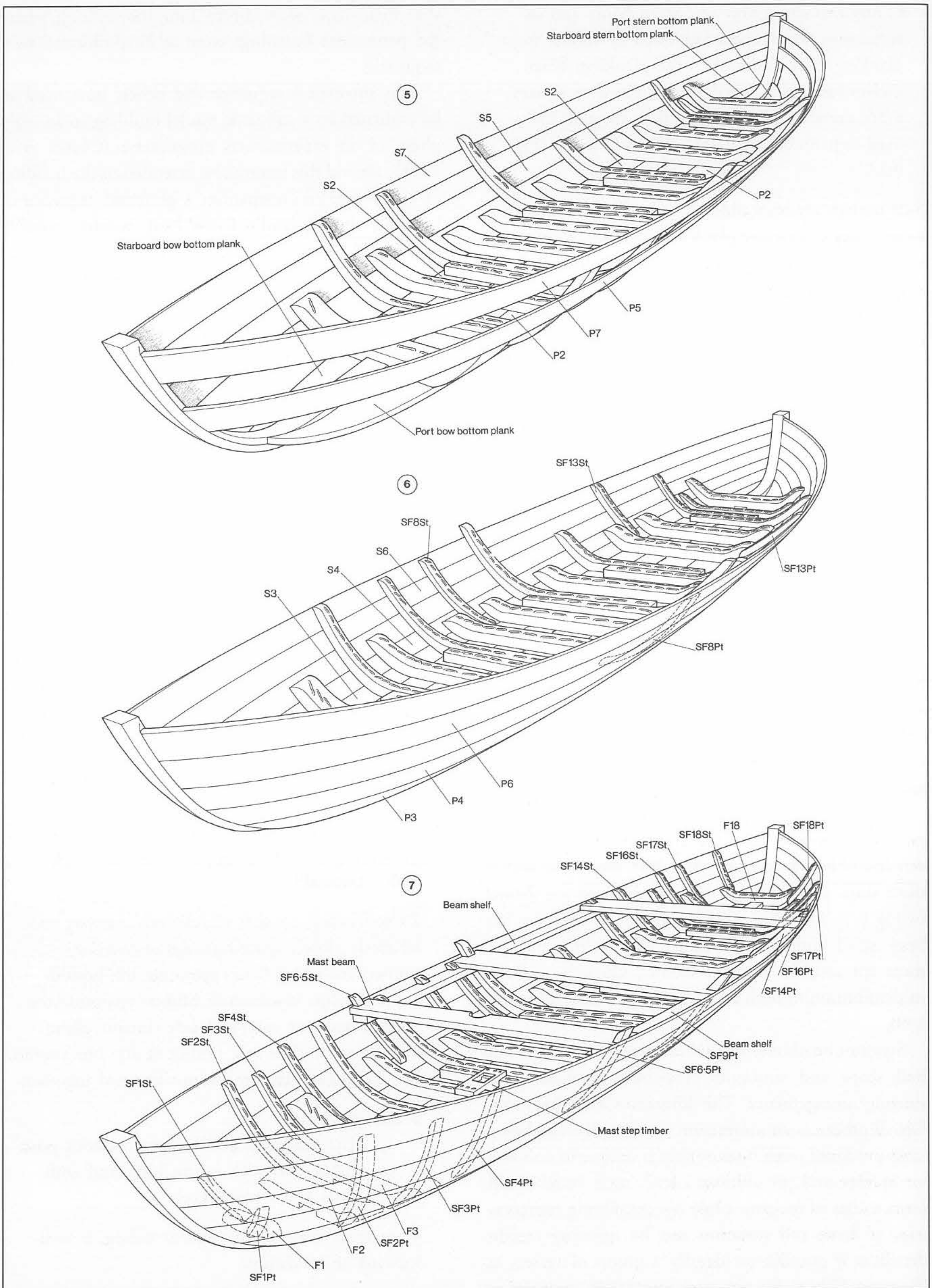


Figure 9.2 (*opposite and above*) Diagrams showing seven stages in the conjectural building sequence of the Barland's Farm boat.

G any remaining bow and stern floors and all remaining side timbers fashioned by spiling from planking, then fastened to the planking; beam shelves fashioned, fitted, and fastened to strakes P/S6; crossbeams at stations 6.5, 10, and 13; mast-step timber between stations 6 and 7 (Fig 9.2.7).

Side timbers are only added in stage F of this sequence so that they can receive plank butts. If this requirement were to be dropped and plank ends temporarily butt-strapped, a shorter sequence could be evolved.

No fastening holes have been found in the framing other than those used to fasten planking permanently to framing. The small nails/light tacks that were probably used to fasten ribbands temporarily to the framing could have left an imperceptible mark or it may be that these tacks were driven into the framing where the permanent fastenings were to be positioned subsequently.

This theoretical sequence and others now need to be evaluated by small-scale model building in an early phase of an experimental programme (Coates *et al* 1995). Should this research be extended to the building of a full-scale reconstruction, a preferred sequence of building the Barland's Farm boat would probably emerge. Although theoretical assessments have an important part to play in the evaluation of this boat, it is only by experimental work, such as small-scale and full-scale model building, that many of the interacting factors and constraints involved can be fully taken into account (section 8.7).

9.4 The Barland's Farm boat in the Romano-Celtic boatbuilding tradition

9.4.1 The Roman-Celtic tradition

A boatbuilding tradition is an archaeological/historical construct, a conceptual tool (comparable with, for example, Dressel 1 in amphora studies) that can be used to increase understanding of the past. Such a tradition may be defined as 'the perceived style of boatbuilding generally used in a certain region during a given time range' (McGrail 1995, 139 and 1997b, 205). It is inevitable that the definition of particular traditions should be changed as more vessels are excavated and more research undertaken.

The time range of the Romano-Celtic finds so far recognised extends from the 2nd (possibly 1st) to the 4th (possibly 5th) century AD. The sites from which these ships and boats have been excavated are shown in Fig 8.5. This ship- and boatbuilding tradition has been called both 'Gallo-Roman' and 'Celtic', but the more apt term is 'Romano-Celtic', since this reflects its distribution in both time and space (McGrail 1995, 139).

Styles of boatbuilding are best described in terms of hull shape and structure, propulsion methods, and steering arrangements. The Romano-Celtic tradition, like all others, is an abstraction from reality: not being mass produced, each boat or ship is unique in one way or another and, in ultimate detail, each vessel could form a class of its own. Only by simplifying complexities of form and structure and by ignoring certain details is it possible to identify a group of vessels as 'Romano-Celtic'. By not requiring 100% conformity of features, such polythetic groups (Doran and Hodson 1975, 160) reflect an understanding of the real world (McGrail 1995, 140).

Several of the early finds thought to be of this tradition were only sketchily published, while some of the later ones have not yet been published in detail. With these cautionary words in mind, it may be said that boats and ships of the Romano-Celtic tradition as it appears to us today generally have the following characteristics:

1 built framing-first, with non edge-fastened, flush-laid planking that is fastened to the framework by relatively large iron nails clenched by turning the emerging point back through 180° ('hooked');

2 the framing consists of relatively massive and relatively closely spaced groups of framing timbers including floors spanning the bottom and the bilge, asymmetric timbers spanning the bottom and one side, and side timbers; there may be more than one timber at any one station, but individual timbers are not fastened together;

3 hulls are either:
   flat-bottomed, keel-less and without post;
or full-bodied with a firm bilge and with posts and a plank-keel;

4 the mast step, towing and/or sailing, is well forward of amidships.

As a group these characteristics distinguish the Romano-Celtic style of boat- and shipbuilding from those of contemporary traditions in northern Europe (Scandinavian/Nordic) and in southern Europe (classical Mediterranean). Some of these features seem to be foreshadowed in Julius Caesar's 1st-century BC description of the ships of the Veneti, a Celtic seafaring people of north-west France (*De Bello Gallico* iii. 13; Strabo, *Geographia* iv.195). These boats of the Veneti were solidly built and had bottoms that were flatter than those of the Roman ships, enabling the Celts to sail closer inshore and to take the ground readily in tidal waters. Their frames were one foot (0.3m) thick and the planking was fastened to them by iron nails one inch (25mm) in diameter. This description raises the possibility that the vessels of the Veneti were forerunners of the Romano-Celtic ships and boats known from excavation.

Romano-Celtic vessels are from two different environments, inland waters and estuaries and channel.

9.4.1.1 Group A – inland waters

These boats used the the rivers, canals, and lakes of the greater Rhine region. Examples are the boats from Bevaix, Zwammerdam, and Pommeroeul (McGrail 1981, 23). These were flat-bottomed 'barges', keel-less and without posts (ie type 1 hulls). They were propelled by paddle, pole, oar, or were towed; some may also have been sailed in a fair wind. The Mainz boats (Hockman 1982, 1993, and 1997) are also from the Rhine, but uniquely have hulls comparable with those of type 2 – this may be due to their military rather than cargo-carrying primary function (McGrail 2001a).

9.4.1.2 Group B – estuaries and channel

The two vessels in this sub-group are the mid-2nd-century Blackfriars 1 from the River Thames at London (Marsden 1994) and the late 3rd-century St Peter Port 1 from the principal harbour of Guernsey (Rule and Monaghan 1993). These seagoing ships had plank-keels and posts; they had a full-bodied transverse section with a firm bilge (ie they had type 2 hulls) and they were propelled by a sailing rig which probably allowed them to be sailed by and large (McGrail 1995, 143). A late 2nd-century boat excavated from new Guy's House, London, in 1958 by Peter Marsden (1994, 97–104) may also be a member of this sub-group. From the features then recorded it is clear that she has some structural similarities with Blackfriars 1, but was more the size of the Barland's Farm boat.

9.4.2 The Barland's Farm boat

The Barland's Farm boat is clearly a member of the Romano-Celtic tradition as defined above: her date is within the defined time range; she was excavated from the site of a former river which in the early centuries AD flowed south into the Severn Estuary; and the details of her structure, her shape, and the position of her mast step are all 'Romano-Celtic'.

That she was found in former tidal waters (see section 3.7) and has posts and a plank-keel identify her with the seagoing/estuary vessels of Group B. Her transverse section is similar to those of Blackfriars 1 and St Peter Port 1 (though somewhat flatter in the floors) and significantly different from the box-like sections of the group A 'barges' (Fig 8.4). Barland's Farm, measuring *c* 11.4 × 3.16 × 0.9m, is of boat size, whereas Blackfriars 1 (*c* 18.5 × 6.12 × 2.86+m) and St Peter Port (*c* 25 × 6 × 3+m) may be described as 'ships'. From the hull shape and structural viewpoint, however, all three are very similar, having been designed as sailing cargo vessels able to cope with estuary conditions and also to undertake coastal and overseas voyages with some regularity in the case of the two ships.

Within a range of generally similar features, each Romano-Celtic vessel has her own distinctive features. There are three such features of the Barland's Farm boat that are worthy of comment.

9.4.2.1 The framing

The two types of framing timbers in the Barland's Farm boat, paired half-frames and floors with side timbers, are each found in other Romano-Celtic vessels, but no other vessel known at present has both types. The ships, St Peter Port 1 (Rule and Monaghan 1993, figs 5, 6, and 7) and Blackfriars 1 (Marsden 1994, figs 23 and 70), have floors generally alternating with side timbers, but no half-frames, while several of the 'barges' have paired half-frames but no floors – see, for example, Woerden, Kapel Avezaath, Zwammerdam 4, Druten, Bevaix, and Yverdon 1 and 2 (Arnold 1992, 100).

9.4.2.2 The mast step

Another distinctive Barland's Farm feature is her mast step in a simple mast-step timber that is aligned in the fore-and-aft direction and fastened to frames F6 and F7Pt and St (Fig 6.21). Several Romano-Celtic vessels have their mast step in a floor timber (for example, St Peter Port 1, Blackfriars 1, Bruges, Bevaix, and Zwammerdam 4). Three others had (or may have had) mast steps in a fore-and-aft timber. In Zwammerdam 2 and 6 these timbers are of great length and are probably best described as keelsons. One of the two small mast steps excavated with Yverdon 2 was found in a fore-and-aft alignment but its original position is unclear (Arnold 1992, 39). At present it seems that the Barland's Farm mast-step arrangement is unique within the Romano-Celtic tradition.

9.4.2.3 The joint between the plank-keel and posts

The method of fastening the posts to the plank-keel in the Barland's Farm boat is different from the methods used in the two other group B vessels. In the St Peter Port ship the stern post was evidently merely butted against the after end of the central plank in the three-unit plank-keel. A stout floor timber (T51) was positioned on top of the plank-keel and notched to fit over the forward end of the stern post, but not over the plank-keel. Floor T51 was fastened to the post by five nails, to the central unit of the plank-keel by three nails, and to each of the outer units of the plank-keel by two. The heads of the nails to the post were countersunk into the outer face of the planking and their points were (unusually in this ship) hooked into pre-cut grooves in the inner face of T51. This floor was further constrained from movement by being sandwiched between floors T50 and T52 (Rule and Monaghan 1993, figs 5, 6, 7, 20, and 41).

The lower end of the stem post of Blackfriars 1 appears to have fitted into a recess in the inner face of the two-unit plank-keel at its forward end. This is comparable with the arrangement in the Barland's Farm boat. Unlike Barland's Farm, however, Blackfriars 1 did not have a corresponding recess in the outer face of the post, nor were the Blackfriars plank-keel and post fastened together. Thus the Blackfriars' 'joint' cannot be described as a 'half-lap scarf', the term applied to the Barland's Farm joint. Floor 3 in the Blackfriars ship was positioned on top of this junction of post and plank-keel (but not notched to fit over the post) and fastened by four or five nails to the post (Marsden 1994, 54, figs 30 and 70).

All three types of post/plank-keel joints were reinforced by a specially chosen floor timber that helped to keep the 'backbone' timbers together. The Barland's Farm interlocking joint was clearly the most complex and structurally the soundest. The Blackfriars arrangement had the basis of an interlocked joint, with its post set into a plank-keel recess rather than merely butted as was the corresponding St Peter Port joint. There appear, however, to have been no fastenings between the Blackfriars associated floor timber (F3) and the plank-keel (Marsden 1994, 54, figs 30 and 70), whereas there were such fastenings in the St Peter Port arrangement.

Since Blackfriars 1 was built 100 years or so before St Peter Port 1, the evident technological efficiency of the three plank-keel/post joints cannot be interpreted as a simple progression over time. Nevertheless it does seem that in this key joint, upon which the whole structure depended, the builders of the AD 300 Barland's Farm boat had developed a stronger arrangement than in the Blackfriars ship of *c* AD 150 and the St Peter Port ship of *c* AD 280.

9.4.3 'Design' methods and sequence of building in the Romano-Celtic tradition

The methods of 'design' and the sequence of building deduced for the Barland's Farm boat could generally have been used by the builders of the other vessels in group B of the Romano-Celtic tradition, Blackfriars 1 and St Peter Port. There is one major difference, however, due to the difference in size between the boat and the two ships. Whereas certain elements of the boat's framework (the five pairs of half-frames) define (in conjunction with the plank-keel and the posts) the hull shape from plank-keel to sheerline, there are no corresponding framing elements in the ships. Thus the shape of the upper hull of Blackfriars 1 and St Peter Port had to come from side timbers that extended upwards from the fourth strakes (P/S5) possibly as far as the sheer. The sequence of building these ships was, therefore, framing-first and not frame-first: first, plank-keel, posts, and floor timbers; then, lower hull planked; next, side framing followed by upper hull planked. The boat was also built framing-first, but because some of her half-frames extend near to the sheerline, she has some resemblance to 17th-century European frame-first ships (Reith 1996): at one stage (phase 4 in Fig 9.2) the hull shape of the Barland's Farm hull was visibly outlined by posts and plank-keel, floor timbers, and half-frames before any planking or side timbers had been added. Many if not all side timbers in Blackfriars 1 and St Peter Port were active, defining hull shape, whereas Barland's Farm side timbers were generally passive.

For a number of reasons, it is more difficult to compare the method of 'design' and the sequence of building of the Barland's Farm boat with those of the Rhine boats in group A of the Romano-Celtic tradition. There is evidently more variability in these boats and they are not all recorded and published to a uniformly high standard. Some of the Zwammerdam planking is fastened together and not just to the framing; the Mainz boats, unlike all others in group A, have posts, a plank-keel, and full rather than box-like sections.

Furthermore there is no consensus about the building sequence. Some appear to have been built framing-first, but Arnold (1999) has argued for a plank-first approach in the 'design' of the Neuchâtel boats, while Hockman (1982 and 1997) has suggested that the Mainz boats were built 'mould-first' which appears to be a variant of the frame-first approach. It may be that this group of boats is not sufficiently homogeneous, and other groupings should be considered (McGrail 2001a, chapter 5 and 2001c). More research clearly needs to be undertaken before the relationship of group A boats to the seagoing vessels of group B can be clarified. This could well lead to the redefinition of the Romano-Celtic tradition.

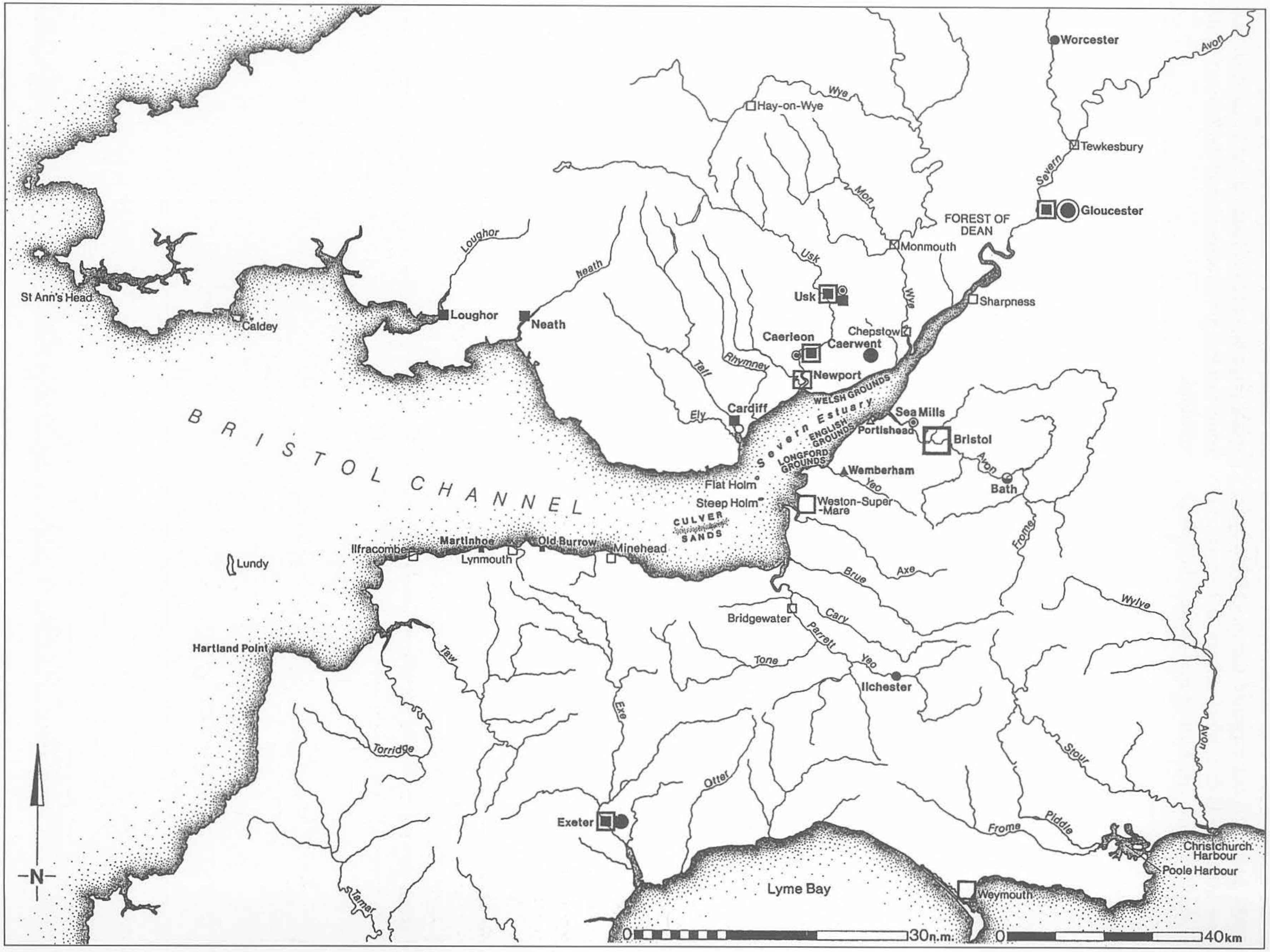


Figure 10.1a Map of the Bristol Channel and Severn Estuary region showing places mentioned in the text.

10

SEAFARING

10.1 The maritime environment (Fig 10.1)

Today the Severn is tidal to Gloucester and beyond. It has strong tidal streams especially at springs, with a large tidal range that is over 14m at springs and 6m at neaps at Kingroad off Portishead – the second or third greatest range in the world. Since the predominant wind is from the westerly sector, wind can frequently be in opposition to ebb tides, causing variable and difficult sailing conditions even in summer, as can also occur around headlands.

To the west of Weston-super-Mare and Cardiff, in the vicinity of two conspicuous mid-channel islands, Steep Holm and Flat Holm (collectively known as 'the Holms'), the Severn widens to become the Bristol Channel in geographical terms. Nineteenth-century mariners, however, and probably those of earlier times, tended to consider that channel changed to estuary around the mouth of the River Avon where Kingroad was the first real haven for inbound, up-channel vessels (Hobbs 1859; Bedford 1872).

Above the two Holms there are reefs and unstable shoals. Furthermore the rapid narrowing of the waterway and the shelving of the seabed in this region increase wind and tidal effects, and wave action is often greater than expected. Like the few rivers without weirs or other constraints that still have an unrestricted flow into the Bristol Channel, the River Severn above Sharpness has a tidal bore or *hygre* some metres high which advances up the river with the first of the flood tide and is most noticeable at springs.

10.1.1 The Bristol Channel and the Severn Estuary in earlier times

From the mariner's viewpoint, the earliest surviving account of the Bristol Channel is contained in late 15th-century sailing directions for the circumnavigation of England (Gairdner 1889). There are four aspects of the maritime environment mentioned there which are also discussed by the 19th-century hydrographer Hobbs (1859) and the naval officer Bedford (1872):

1 the entrance to the Bristol Channel is marked by the islands of Lundy (*Londay* in the 15th century) to the south and Caldey (*Calday*) to the North; in Hobbs and Bedford these are Hartland Point and St Anne's Head;

2 the Holms (*Holmys*) are invaluable landmarks in mid-channel, guiding the mariner away from coastal hazards;

3 Kingroad (*Kyngrode*), an anchorage

Key to symbols :-

Civilian
- ◉ Coloniae
- ◉ Major settlement
- ○ Minor settlement
- ● Tribal city
- ● Town
- ⊖ Spa
- ▲ Villa
- △ Other buildings

Military
- ▣ Fortress
- ■ Fort
- ■ Fortlet

Later/Modern □□□

Key to symbols used on Fig 10.1a (*opposite*).

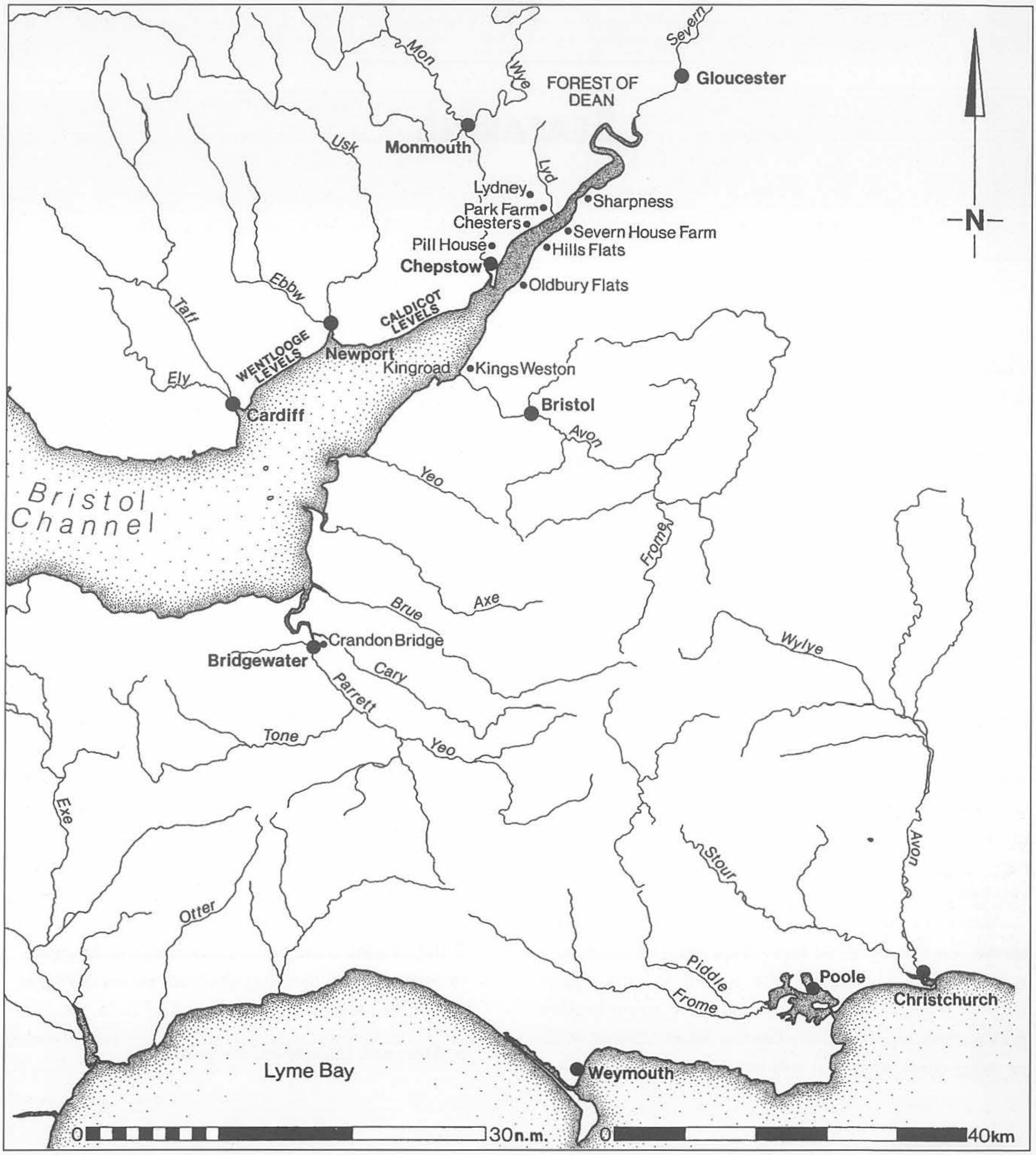


Figure 10.1b Map of the Severn Estuary region and the rivers of Wessex. Based on Ordnance Survey 1:50,000 maps 171, 172, 183, 193, and 194 and on the 1994 Map of Roman Britain. Crown Copyright.

east-north-east of Portishead Point (*Portis hede*), is the first natural haven within the Bristol Channel for an inbound vessel;

4 Specific hazards to avoid include:

the ironbound coast (*Iron groundis*); this refers to the rugged coast between Ilfracombe and Minehead where the rocks rise perpendicularly from the sea and there are no safe anchorages;

Culver Sand (*Columsonde*) and Longford Grounds (*Longbors*/*Langborde*); Culver Sand, on to which vessels can be set by both ebb and flood tides, lies near mid-channel off the mouth of the River Parrett; closer inshore, on a lee shore in Bridgwater Bay (*Briggewatir*) and northwards, lies a long and broad stretch of coastal shoals, flats, and sands at the northern end of which lie Longford Grounds. Shoal and hazardous waters to the north of Longford are called 'of England' and 'of Wales' (*Banco de Gualses*) in a late 16th-century Spanish pilot's account of the English coastline (Loomie 1963, 293); these English and Welsh Grounds, on either side of the main channel, are dangerous since the tides set furiously over them.

10.1.2 The Bristol Channel and Severn Estuary at the time of the Barland's Farm boat

Comparison of the 15th-century sailing directions (Gairdner 1889) with those of the mid-19th-century (Hobbs 1859; Bedford 1872) suggests that, over the intervening 400 years, the general oceanographic and geomorphological framework did not change. Until more environmental data is available, as a working hypothesis it, therefore, seems not unreasonable to assume that (slightly lower sea levels apart) the Bristol Channel and Severn Estuary had much the same *general* characteristics in the 4th century AD (McGrail 1998, 258–9). On the other hand there evidently have been great changes in *detail*, even over a short time span. For example, Hobbs (1859, 99) points out that between 1831 and 1859 'great and extraordinary changes' took place in the position of several shoals in both English and Welsh Grounds. Such changes must have occurred many times between the 4th century, when the Barland's Farm boat was in use, and the 19th century, when we have reasonably comprehensive descriptions of the conditions a Bristol Channel seafarer could expect to encounter. It is the detailed description and the precise position of such hazards, seamarks, and landmarks that are of immediate concern to the mariner. It is clear, therefore, that detailed local knowledge has always been needed by Bristol Channel/Severn Estuary seafarers. It always was a region noted for the 'rapidity of tides and variability of sands' (Bedford 1872, 141). Bedford's opinion (1872, 132) that no 'stranger would voluntarily run up [from seaward] as far as the Holms ... without a pilot' conveys some idea of the hazards to be faced and of the skills needed to cope with them.

10.1.2.1 Environmental evidence

Environmental evidence (section 3.7) shows that the Barland's Farm boat was deposited in a tidal reach of a river (possibly one of several channels) that flowed southwards through salt-marsh into the Severn Estuary.

During Roman times mean sea level in this region was generally some 1.5–3m lower then than today (Heyworth and Kidson 1982, fig 2; Allen and Fulford 1987, 280–3). Thus river gradients would have been somewhat steeper, resulting in less silting of river mouths than there has been in recent centuries. Roman sea level, however, was still well within today's tidal range (the vertical distance between high water mark and low water mark) that can be over 13m at nearby Newport and is seldom less than 5.5m. In general terms, therefore, the coastline in AD 300 would have appeared much as it was in the early-20th century, before recent industrial-scale developments. Furthermore the Roman tidal regime in the Severn region (tidal cycle and tidal streams) was probably not unlike that of today, but tidal flows were probably greater, especially on the ebb. Other palaeoenvironmental research has shown that generally speaking the weather at that time, including the predominant wind, was also much the same as it is today (McGrail 1998, 258–60).

For the 3rd- to 4th-century estuary and channel seafarer, conditions would, therefore, have been no better than today and possibly worse, if only because there were no man-made harbours on the coast. Well before those times, all the habitable islands in the dangerous waters of the British and Irish archipelago had been colonised. Moreover from Caesar's description (*De Bello Gallico* iii. 13; Strabo, *Geographia* iv. 195) of the boathandling abilities of the Veneti in the difficult waters off the Brittany coast, it is clear that Celtic seafarers were very competent seamen. There is no reason to doubt that their contemporaries in the Bristol Channel/Severn Estuary were equally capable.

10.2 The boat's general character and capabilities

As reconstructed (Figs 8.2 and 8.3) the boat is clearly suited in shape and in structure to use in the Bristol Channel, in the Severn Estuary, and in the tidal reaches of the many rivers that feed the Severn. Roberts' analysis (section 8.6) allows him to suggest that she could even have crossed St George's Channel to Ireland in the right weather. The boat's shape is a reasonable compromise between the competing requirements of cargo capacity, stability and resistance to leeway when under sail, stability when beached, achievable speeds, and sea kindliness. For example, her plank-keel, like those of the ships from St Peter Port and Blackfriars 1, projects below the bottom planking sufficiently to generate some anti-leeway lift when sailing close-hauled, yet not so proud that she cannot take the ground – a frequent occurrence in such waters – and remain more or less upright on the foreshore.

Owain Roberts' analysis of her lines has shown that she had a form that could be easily driven under sail or be propelled in the right conditions by a pair of oars. He has also shown that she was suitable not only for passages along and across the Bristol Channel, but also in the marshy margins of the estuary and on the tidal-drying rivers on both coasts, since she could carry useful loads in relatively shallow water. In sum the Barland's Farm boat was designed for this estuary and channel environment and was a good all-rounder, not just a boat with a specialist performance in one aspect of seafaring.

10.2.1 The crew

Although in fair conditions this boat could probably be sailed by two men, in the estuary and channel, whatever the weather, she may well have had had a crew of three to ensure a speedy reaction to rapidly changing conditions. Furthermore two oarsmen and a helmsman would probably have been needed when it proved necessary to row the boat, for example, when trying to reach a landing place in fickle winds or catch a tide, or make a headland in difficult conditions. During much of the time on passage, at least one man would have been bailing out. He would have been stationed forward of the mast or forward of the helmsman, ie forward or aft of the cargo, but probably the latter. A bailer aft would have been close to the helmsman, but need not have been in his way, since bailing would have been done from the lower side of the boat and the steering from the higher side.

10.3 Performance

10.3.1 Under sail

It is not possible to be certain that the Barland's Farm boat had a lug rather than a square sail. Robert's analysis shows, however, that for sail balance and for windward performance, a fore-and-aft sail such as a lug is the better rig (Tables 8.7 and 8.8). Her best displacement for passages under sail is when loaded to drafts between a little less than 40% to a little more than 50%, ie when loaded with *c* 2 to 5 tonnes of cargo (sections 8.6.11–12, Tables 8.9 and 8.10). Within this range of drafts she could be sailed in the estuary in winds up to force 4 (a moderate breeze of *c* 15 knots, with wave heights of 1 to 2m). If encountered, she could have coped with Force 5 winds (a fresh breeze of *c* 20 knots, with wave heights up to 4m). In these conditions her windward limits would be reached when the wind was a little forward of the beam.

At drafts deeper than *c* 60% (0.54m), her freeboard of less than 0.36m could have proved insufficient except in light breezes, while at 80% draft (with only 0.18m freeboard) she would have been limited to river use in fair winds.

At sea, in favourable conditions under sail, she could have made 4–5 knots at her optimum displacement of 4–7 tonnes (equivalent to a cargo of 2–5 tonnes).

10.3.2 Under oars

Two men, each manning an oar at 40% draft could propel this boat at a steady 3 knots in light winds. When laden, speed would have been in the range 1.5 to 2 knots.

10.3.3 Carriage of cargo and livestock

Based on Roberts' analysis (see section 8.6), Table 10.1 lists the cargo tonnage that could be carried by this boat when loaded to selected drafts. Drafts equivalent to roles 2, 3, and 4 are all in the range for best performance under sail. How cargo is stowed depends upon its cargo density (McGrail 1989). Table 10.2 lists the stowage parameters for a range of cargo of different stowage factor when the boat is loaded to a draft of 0.45m (role 3). Plant macrofossils identified in samples taken from limber holes in the Barland's Farm boat's framing (Table 3.3.3) may have come from straw used as dunnage to protect boat and cargo from each other or may have been fodder or bedding for animals (see also section 3.7).

From Tables 10.1 and 10.2 it can be seen that with a crew of three and in an optimal condition for a passage under sail, the Barland's Farm boat could have carried: 15 medium-sized barrels of wine; or *c* 90 sacks of grain; or 4.5 tonnes of salt or coal in sacks; or 4.5 tonnes of iron, slate, or stone laid on dunnage in the bottom of the boat. At deeper drafts down to *c* 0.54m (role 4), yet still in the optimum conditions for sail, she could have carried correspondingly more. These are all goods that were traded within the Severn Estuary region during the late Roman period (Chapter 5; Allen and Fulford 1987). There is also much evidence for trade in pottery (see section 4.2; Chapter 5; *ibid*; Allen and Rippon 1997) within the Severn Estuary and its tributary rivers during the late Roman period. Although pottery containers filled with other goods can themselves make up a boatload, a full load of empty pottery cannot be carried on a seagoing voyage – its stowage factor is too low, causing stability problems unless compensating ballast is carried (McGrail 1989). Pottery and similar goods are best thought of as 'space fillers'. A respectable quantity of pottery (suitably packaged) could have been added to all the loads listed in Tables 10.1 and 10.2 without appreciably affecting the draft or adversely affecting stability.

Table 10.3, also based on Roberts' calculations, shows that useful numbers of livestock could be carried at drafts within the optimum range for sailing. The flat bottom of the Barland's Farm boat means that animals can be expected to stand, probably on dunnage spread on the (conjectural) bottom boards.

At 50% draft (4.57 tonnes cargo) under sail, up to 50 sheep could be carried in the estuary temporarily penned by hurdles or with their legs trussed. At 60% draft (role 4 –6.57 tonnes), eight cattle could be transported on short passages. Theoretically it would be possible to load ten beasts, resulting in a draft of 65% to 70%, but such a load would only be safe on a river because of freeboard and stability considerations.

Table 10.1 Cargo capacity at selected drafts

role	*T (m)*	*F (m)*	*%*	*displacement*	*load*
1	0.19	0.72	21	2.30	–
2	0.36	0.54	40	4.87	2.57
3	0.45	0.45	50	6.87	4.57
4	0.54	0.36	60	8.87	6.57
5	0.72	0.18	80	12.87	10.57

Notes:

1 T = draft; F= freeboard; % = draft/height of sides. Height of sides = T + F = 0.9m.

2 Role 1 = empty boat and 3 crew.

Table 10.2 Selected loads in role 3 (50 % draft)

in role 3 the boat can carry 4.57 tonnes of cargo.	
3A	iron, slate or stone in bulk stored amidships well below the sheer strake
3B	salt or coal in sacks in one layer abaft the mast
3C	grain in sacks – 90 or so sacks abaft the mast reaching to the sheer strake
3D	wine in barrels – *c* 15 barrels, some before, most abaft the mast up to the sheer strake

Notes:

1 3C – using sacks each holding 0.05 tonnes which can be carried by one man.

2 3D – using barrels *c* 1m in height and with a mean diameter of *c* 0.6m; such barrels, when full, weigh *c* 0.3 tonnes; they can be rolled in transit, and loaded and discharged by ramp or parbuckle.

Table 10.3 Carriage of livestock

role 3E	50 sheep herded tight, mostly abaft the mast
role 4A	8 cattle standing athwartships abaft the mast, possibly head to tail alternately

Notes:

1 In role 3E 4.57 tonnes can be carried.

2 In role 4A 6.57 tonnes can be carried.

10.4 Voyages in the Bristol Channel and the Severn Estuary

10.4.1 Waterborne trade routes

Evidence from three sources may be used to investigate which routes may have been used in the Bristol Channel and Severn Estuary by the Barland's Farm boat: the distribution of Roman sites close to (former) river courses; the distribution of iron mined in the Forest of Dean; and the distribution of pottery from known kilns.

10.4.1.1 Roman sites (Fig 10.1)

Among known sites that could have been supplied by boat are: the military sites of the legionary fortresses at Gloucester and Caerleon and forts at Cardiff, Neath, and Loughor; the fortlets at Martinhoe and Old Burrow on the ironbound Somerset coast could probably have been supplied from the sea in fair weather; the villas at King's Weston on the River Avon, Wemberham on the Congressbury Yeo, and Chesters and Park Farm on the western shores of the River Severn, north of the Wye mouth; settlements at Caerwent (via Sudbrook/Portskewett), Usk, Worcester, Sea Mills, Bath, and possibly Ilchester.

10.4.1.2 The distribution of iron

In a discussion of the Severn Estuary region in the Roman period, Allen and Fulford (1987, 281–4, fig 20) drew attention to the widespread distribution of Forest of Dean iron ore and blooms and possibly also finished iron objects. The sites at which such finds have been made (Fig. 10.1) include: Rumney Great Wharf on the Wentlooge Levels on the north side of the Estuary, west of the River Usk; Lee Pill, Horse Pill, and Pill House, all on tidal creeks of the Severn north of the River Wye confluence; Severn House Farm, Hill Flats, and Oldbury Flats close to the southern shore of the Severn below Sharpness; and Worcester on the upper Severn. In the 19th and early 20th century coal, iron, timber, and bark from the Forest of Dean were loaded on board sailing trows in Lydney Harbour, a canalisation of the River Lyd (Bedford 1872, 140; Eglinton 1982). During the Roman period there would probably have been a tidal landing place on the River Lyd somewhere between the iron ore mine at Lydney Park and the confluence of the Lyd with the Severn.

10.4.1.3 The distribution of pottery

Dorset Black-Burnished Ware 1 from a Roman period kiln near Poole Harbour has been excavated from many sites in the Bristol Channel/Severn Estuary region. These include: Gloucester; Caerleon, on the Usk above Newport; Rumney Great Wharf on the Wentlooge Levels; Magor Pill on the Caldicot Levels, east of Newport; Severn House Farm, Hills Flats, and Oldbury Flats; Sea Mills, on the northern side of the River Avon; Bath, also on the River Avon; Ilchester on a River Yeo which flows into the River Parrett; and at Crandon Bridge on the River Parrett, north-east of Bridgwater (Allen and Fulford 1987, fig 20; Allen and Rippon 1997, 359; see also section 4.2).

Allen and Rippon (1997, 362) have concluded that this pottery was distributed around the Severn and its tributeries by boat after it had been brought overland from Poole by road to the southern shores of the Severn Estuary. Distribution by boat as a part load is very feasible, but road haulage is not the only way that pottery (and other goods) could have been brought from south Dorset to north Somerset, thereby avoiding the long and arduous passage by sea around Land's End. As Sherratt (1996) has emphasised when discussing an earlier period, short portages connect the headwaters of rivers flowing into the harbours at Poole (Frome) and Christchurch (Avon and Stour) with those of rivers flowing into the Severn Estuary or Bristol Channel (Avon, Brue, and Parrett). If such river/portage/river routes were practicable they would generally have been preferred to carriage solely by pack animals or men and it is likely that they would be used in both directions. Just how far up these rivers boats could have gone in the Roman period – and thus the length of portages (here of goods not boats, unless of hide) – would depend on river speed, breadth, and depth, but such refined environmental data are not yet available.

10.4.2 The Barland's Farm boat's sphere of action

It is likely that estuary boats such as that from Barland's Farm would have been used on the tidal stretches of those rivers and smaller craft (logboats? hide boats?) on the upper reaches. There should be signs of such transit points near the former head of tide (if such sites could be identified and excavated). Away from Roman towns and military bases, landing places, both coastal and on rivers, would have been informal ones with few if any built structures. Such boat places were used in the Severn Estuary/Bristol Channel into this century (Eglinton 1982). These Roman-period landing places would have been approached on a flood tide and the boats either anchored in the shallows or beached as convenient. Goods would have been discharged by hand into smaller boats or into animal-drawn vehicles, or carried ashore by wading. In the early years of the 20th century, in the Bristol Channel/Severn Estuary region, vessels able to carry 60 to 80 tons of cargo frequently used such procedures on beach berths (Eglinton 1982, 71–2; McGrail 1993, 206–7).

Some idea of the extent of tidal rivers in former times, before the widespread building of weirs and locks and the canalisation of rivers, may be obtained from Bedford's (1872, 136–41) observations in the mid-19th century. In his day tides in the Severn reached Tewkesbury, but in earlier times before weirs were built, they had occasionally reached Worcester. On the River Usk they reached Newbridge (as they do today). On the Wye they reached well above Chepstow almost to Monmouth and boats could be taken as far as Hay. With lower sea levels at the time of the Barland's Farm boat, the head of tide may have been downstream of its position in the 19th century.

The Barland's Farm boat would have been able to undertake voyages in the tidal sections of the River Severn and in all its tributary rivers within the sector from the Taff and Ely in the north-west around clockwise to the Parrett in the south-west. Being of relatively light draft – only 0.54m when carrying 6.57 tonnes of cargo – it is likely that she would have been taken above the head of tide on certain rivers. In winds up to force 4, passages across and along the Severn Estuary and out into the Bristol Channel as far as Cardiff and Bridgwater would have been within her capabilities. Thus most of the Roman sites listed above and the sites where Poole pottery and Forest of Dean iron have been excavated would have been accessible to her. The only exceptions would probably have been that the Roman forts and fortlets at Neath, Loughor, Martinhoe, and Old Burrow could only be visited in settled weather in light but reliable winds. As Owain Roberts has suggested (8.6.15), in such conditions voyages to Ireland may also have been contemplated.

Voyages would have been under sail and courses steered so that the wind was from the sector aft, from beam to beam. In foul winds the boat would be anchored to await a wind shift. Timings would be such that the tidal streams were used to advantage. During foul streams (especially in light winds) the boat could be anchored for the six or so hours needed for the tide to turn. Oars would be used on occasions (possibly in conjunction with sail) to manoeuvre within rivers or to gain some advantage in fickle or foul winds, light airs, and other difficult conditions.

10.4.3 Estuary work in the Barland's Farm boat

Sailing directions from the 15th to 19th century (see section 10.1.1) emphasised that the four basic requirements for a successful voyage in the Bristol Channel/Severn Estuary were a knowledge of tidal streams, an awareness of sands and grounds, the use of the sounding lead, and a good lookout. Familiarity with sands included knowing the swashways; these relatively deep-water channels through sands, as over the Welsh Grounds to the south-east of Newport (Hobbs 1859, 107), are often only usable by vessels of light draft. Timing in relation to tidal flows was all-important: the 15th-century sailing directions advise 'if you have a quarter tide [*c* one and a half hours of the flood] at the Flatholm [island] you may go east-north-east or east by south and go over Langborde [Longford Grounds] . . . for you shall have 3 fathoms on the sound or more . . .' (Gairdner 1889, 18). If a vessel left Flatholm earlier than this recommended time she would probably arrive at Longford Grounds when the water was too shallow to cross them.

Edmund Eglinton, who worked sailing trows and ketches in this region during the early years of this century, published two accounts (1982 and 1990) of the navigation and ship-handling methods then in use. Most probably similar techniques to these had been used in this region for 2000 years and more. Some examples are: navigating by 'log, line, and lookout' (essentially pilotage methods supplemented by a form of dead reckoning when necessary); the use of natural leading marks and transits to keep in the deep-water channel; anchoring off the mouth of a river during an ebb tide; 'dredging' stern-first when using the flow or ebb to enter or leave a tidal river in foul winds (that is to use an anchor as a 'drogue' along the sea bed in order to have steerage way); avoiding taking the ground on a beach that might become a lee shore; and sending away an anchor to warp the vessel clear of the surf before sails were set. The master of the Barland's Farm boat would have been familiar with many of these techniques.

In his descriptions of numerous voyages under sail in this region, Eglinton (1982) gives some idea of the time, from slipping to final berthing, that such passages could take in the days when all depended on wind and tide, as in the Roman period:

- a passage from Lydney in the Forest of Dean to a tidal landing place in the River Axe, south of Weston-super-Mare, took *c* 30 hours, including 'dredging' up the Axe sternfirst; since the *direct* distance is *c* 32 nautical miles, the average speed overall was *c* 1 knot;

- a passage from the mouth of the River Yeo, north of Weston-super-Mare, to Kingroad, off the mouth of the Bristol Avon, was done within one tide, ie in *c* 6 hours or less; this is 10 nautical miles direct, giving an average overall speed of 1.75 or even 2 knots;
- a passage from Newport to Lynmouth including 'dredging' down the Usk and anchoring in Cardiff Roads and off Lynmouth during foul tides took *c* 24 hours; the cargo could not be discharged for another 12 hours because of darkness; a distance of *c* 32 nautical miles, giving an overall average speed of *c* 1.3 knots (or *c* 1 knot);
- A passage from the River Yeo to Newport took 10 hours; the return passage with coal took 24 hours because of foul winds and tides; the direct distance is *c* 12 nautical miles, giving an average overall speed out of *c* 1.25 knots, with a return speed of *c* 0.5 knots.

Similar passage times (lengthy to a 20th-century landsman) would have been familiar to the crew of the Barland's Farm boat 1600 years earlier.

11

INTERPRETATION AND LOCAL CONTEXT

In this chapter an attempt is made to draw together the various strands of evidence generated by the excavations and subsequent analysis. This commences with interpretation of the structures found occupying palaeochannels and their relationship with the boat find. The character of the contemporary landscape is then considered with particular reference to hydrology, drainage, and agricultural exploitation.

11.1 Structural interpretation

11.1.1 Area 50

Interpretation of the structure encountered in Area 50 is not facilitated by the damage caused by the geotechnical pit that had been excavated through it. Rubble appeared to have been concentrated on the western, eroding side of a meander bend of a small palaeochannel with sediment accreting on the opposite bank. The disposition of the timber piles showed no clear pattern, as might be expected if they had carried a timber superstructure associated with a bridge, and no well-defined abutment was encountered. Alternative interpretations, eg as a fish weir, are no more convincing, however. In the light of discoveries in Area 54, an interpretation as a river crossing of some form is favoured.

11.1.2 Area 54 (the boat site)

With the exception of the boat itself, the main structural features identified during the excavations in Area 54 were a rough stone abutment, regularly positioned timber piles, and recurrent depositions of rubble and assorted waste in the bed of the palaeochannel complex. It did not prove possible to investigate the south-western edge of the contemporary palaeochannel for logistical reasons. Hence the presence or otherwise of an abutment on the opposing bank of the channel was not determined. Even had it been feasible to extend the excavations, the post-medieval reen that cut through the south-west corner of the excavation area may well have removed any evidence. A further limiting factor in the site's interpretation is the restricted data available on the chronology of the piles, commonly encountered with driven timbers. Although tree-ring dates indicating possible felling dates exist for a number of the piles, the relationships between the piles and spreads of stone were not fully explored during the excavations.

The remains could represent a number of site types associated with river fronts and crossings, not all of which are necessarily mutually exclusive. At its simplest perhaps, the features could have formed a consolidated river bed providing a causeway or ford across the watercourse. Given the tidal nature of the channel indicated by palaeoenvironmental studies (see section 11.3.1), such a crossing might have been usable (near) dry-shod during low-water periods of the tidal cycle. The repeated recovery of shoes might be taken as evidence for the passage of people on foot, although the poor condition of some could point to intentional discard rather than accidental loss. The construction of a near-vertical revetment of stone on the eastern bank of the watercourse, stratigraphically one of the earliest features on the site, would appear counterproductive if the intention was to provide easy access for walkers and livestock into and across the channel. The regular configuration of the piles is also at odds with interpretation as a causeway. At least one of the spreads of stone recorded in the bed of the channel (2382) extended over 1.5m to the south-east of the most southerly line of piles. This material could not only have consolidated the bed in the vicinity of the piles, but also acted as a hard for a variety of traffic including boats.

The regular placement of the piles suggest they carried some form of superstructure, possibly cross-beams, which in turn could have carried longitudinal planking providing a surface for a bridge or jetty.

Parallels for Roman bridges on a similar scale to the structures encountered at Barland's Farm are necessarily rare. In Dymond's review of British sites (1961), substantial bridges with stone piers tend to dominate, while smaller structures were usually identified through the presence of abutments alone due to limited excavation. O'Connor (1993) in a more recent study of bridges throughout the Roman Empire suggests that timber bridges were probably more numerous than those constructed purely of stone, but are less evident in the archaeological record due to decay. The former presence of timber bridges has often been inferred from the presence of a clear barrier (such as a gorge) interrupting the line of a clearly defined road. Even when excavation occurs in circumstances where timber might be expected to survive, such as the site of a bridge in the Fens at Nordelph near Denver (Kenny 1933), where gravel abutments were present but no timbers were identified, evidence may be limited by riverine erosion prior to the accretion of silts within the associated watercourse.

Although only one side of a structure comprising a timber abutment with rubble infill and piles running out into the contemporary channel were excavated at Aldwincle, Northamptonshire (Jackson and Ambrose 1976), its interpretation as a bridge seems secure, given the continuation of the associated road to the south-east on the opposite side of the former watercourse. A distance of 24.4m was estimated for the span of this bridge. A limited number of the uprights was excavated suggesting the presence of rows of piles at right-angles to the line of the road, the first row located some 3.65m from a timber abutment 5.49m wide. This latter measurement is comparable with that of the stone abutment encountered in Area 54 of the Barland's Farm excavations that measured 5.2m. The presence of three phases of agger in the road at Aldwincle and partial collapse of some of the piling and superstructure were interpreted as evidence for multiple phases of construction of the bridge, but secure association of particular piles with individual phases was not possible. Within the collapsed material were a number of jointed timbers interpreted as horizontal elements of the superstructure and displaced piles with tenons cut into their tops to take these timbers. The absence of evidence for joints lower down these piles, such as angled lap joints to take diagonal braces, suggests that the piles in the Barland's Farm structure with their truncated tops could also have been tenoned at their tops and carried a superstructure without the need for bracing.

Excavations mainly of clusters of Roman kilns carried out between 1957 and 1961 at Rossington in Humberside also revealed the tops of piles within a former course of the River Torne (Head *et al* 1997, 278). The piles appeared to be arranged in groups of four or five, 1.6m apart. Seven groups of piles were counted in two rows approximately 2.5m apart. In a recent condition assessment of this structure (van de Noort 1997, 444–7), planks found in the bed of the former watercourse could have been part of the superstructure.

Hence the stone and timber structure in Area 54 exhibits a number of features encountered in excavations of smaller Roman timber bridges including a well-defined abutment and groups of piles at regular spacings. With the exception of pile 5131 (see Fig 2.6), the piles are located in groups of two or more, usually three. This clustering of piles also occurs at both Rossington and Aldwincle, where it has been interpreted as evidence for repair. No direct evidence for any superstructure was found at Barland's Farm, as the tops of the piles were not preserved and diagnostic displaced jointed timbers were not encountered. Truncation of the site by a later drainage ditch and limited access on an active construction site precluded excavation of potential evidence for an opposing abutment. Interpretation as a jetty rather than a bridge cannot, therefore, be excluded.

This interpretation is unlikely, however, since such structures are built only when large vessels of considerable draft have to be berthed. Such vessels would never have entered this small tributary. In such a watercourse boats the size and shape of the Barland's Farm boat would have been berthed alongside the river bank at around the time of half-tide so that they would take the ground at low water (see sections 8.5 and 10.4.3).

A further feature encountered in association with the stone and timber structure in Area 54 was at least three deposits of stone, usually found within a matrix of organic silty clays containing artefacts and animal bone. The earliest of these was a strew of sandstone conglomerate rubble (2373/2391) discovered on the bottom of the channel into which the piles had been driven. Its extent is unclear as it was only uncovered in a small trench alongside the base of the abutment (Fig 2.6). This is tentatively interpreted as an intentional deposition designed to consolidate the river bed around the piles. A second, more extensive layer of stone (2371/2382) occupied the bed of the channel associated with the boat. This appeared to have been laid around the piles of the bridge, petering out towards the stone revetment interpreted as an abutment in the east and running west in line with the westernmost pile encountered (Fig 2.6, 5131). It did not seem to continue far to the north (ie upstream) of the bridge, but was excavated to the south where it appeared to dip slightly where overlain by the boat. Its full extent to the south was not determined with certainty, although the paucity of stone uncovered during lifting of the boat timbers suggests it petered out rapidly. A single stone slab was found directly under the bottom of the boat at station 10/11 which could have been an outlier of this deposit. Its distribution suggests it was laid to consolidate the river bed around the piles, perhaps associated with repairs to the bridge. This included possible insertion of new piles but it also provided a hard bed downstream, possibly to facilitate the mooring of boats.

The latest deposit of stone (2370/2378) ran parallel to the face of the abutment, with its southern extent partially overlying the boat. Interpretation of this unit is problematic. It could be seen as partial collapse of the stone abutment indicating abandonment and decay of the bridge, although a higher concentration of stone immediately adjacent to the abutment might have been expected. The quantity of cultural material (especially animal bone) in surrounding sediments perhaps points to continued activity at the site although, given the plastic nature of channel bed sedimentation, it could be argued that the stone had sunk into these sediments rather than the sediments had accreted around the stone. The possibility that the stone is the last attempt to maintain this river crossing cannot, however, be excluded.

Dating evidence from the pottery and coins indicates activity up to the early 4th century, although the duration of the site is open to debate (see section 4.2). Tree-ring dates of AD 279, AD 282, and AD 283 from the bark edge of piles in Area 54 provide a probable start date for activity on this site. The date of abandonment is less clearly defined, occurring no later than the mid-4th century, but possibly as early as the end of the 3rd century with the unstratified find of a *follis* of Diocletian (AD 296–7).

11.2 Boat location – spatial and temporal

The location of the boat in relation to the contemporary watercourse and the bridge structure needs consideration both in terms of spatial and chronological relationships. Its deposition clearly postdates primary construction of the bridge, deposition of stone around the piles, and subsequent dumping of a further layer of stone interpreted as ongoing maintenance of this structure.

The aftmost surviving elements of the boat rested on this later dump of material. Displaced fragments of boat timbers were recovered from the matrix of organic silty clays found around this stone including two fragments interpreted as side timbers (5037=SFX2 and 5098=SFX1). The northern end of the boat was in turn overlain by a further deposit of stone which appeared to be concentrated along the face of the abutment but which extended south as far as station F12 in the boat. Given uncertainty about the function of this last deposit of stone, at least two reasons for the boat's location need consideration. If this stone is seen as collapse of the adjacent abutment, the boat could simply have been abandoned with the demise of this site and the economic activities that it implies. Subsequent deposits that seal the boat are characterised by low concentrations of artefacts and low organic content pointing to natural accretion of sediment within the watercourse.

Alternatively if the stone is interpreted as a last attempt to maintain the river crossing, the boat could have been placed deliberately, secured by the removal of parts of the stern and dumping of stone into this dismantled area. The robust nature of the joint that would have existed between the plank-keel, the stern post, and floor timber F17 suggests that the removal of the stern post and other timbers was intentional. The location of the partially surviving stern, immediately to the east of pile 5039 (see Fig 2.6) and close to the southernmost line of piles, suggests that the boat had been partially dismantled prior to being placed in this position. Projecting the centreline of the boat from the aft end of the bottom planks to intersect this line of piles gives a distance of approximately 1.2m. This is shorter than the length of the stern indicated by hypothetical reconstruction of the hull (approximately 1.7m).

Determining why the boat would have been so placed requires consideration of its spatial relationship with both the watercourse and bridge structure. The identification of palaeochannel fills to the east of the boat's surviving port-side edge, eg in the section cut to recover palaeoenvironmental samples (Fig 3.1.3), suggests that the contemporary watercourse ran from north-north-west to south-south-east. Hence the vessel was not aligned along the eastern edge of the channel, as might be expected if the boat had intentionally been placed to reduce erosion of the bankside. Rather the boat probably projected out into the middle of the channel. Intentional deposition could imply a secondary use of the vessel as a method of access to the centre of the channel where other vessels could lie afloat in deeper water. The deposit of stone that encroached onto the incomplete, northern (aft) end would have prevented the hulk from shifting with the incoming tidal stream. The distinct list of the vessel to port when discovered may not have been so pronounced during such a period of reuse, while loose bottom boards (section 6.3.3.5) would have made it easier to walk the length of the boat.

The evidence for the boat's function (if any) following its deposition is equivocal and no single interpetation of its presence can be definitive. Cross-matching between the boat timbers and some of the piles (section 3.6) could be taken to indicate that the vessel was local and, prior to its deposition, had used the site at Barland's Farm to load and unload goods, possibly including pottery. This deposition could be seen as abandonment of the vessel and the associated bridge consistent with evidence from elsewhere on the Levels for widespread abandonment in the early 4th century, possibly in response to relative sea-level rise. Alternatively, given the evidence for deliberate dismantling of the stern, the vessel could have been intentionally placed to provide a landing stage giving access to deeper water in mid-stream. This second hypothesis is preferred.

11.3 Contemporary topography, landscape, and vegetation

As seen in Chapter 5, the nature of the Gwent Levels during the Roman period has been the subject of considerable debate. For decades prior to the 1980s direct archaeological evidence was limited to sporadic observations in the intertidal zone and only occasional stray finds from within the Levels. The subject was dominated by discussion of the meaning of the Goldcliff stone and the relationship of this landscape to military infrastructure and the civilian settlement at Caerwent. Subsequent excavations in response to development on the Levels and more considered examination of intertidally exposed sites have rejuvenated debate and provided evidence for drainage and field systems, occupation, and settlement sites. The boat find and adjacent structures at Barland's Farm focus attention on the nature of the contemporary landscape, especially with reference to waterways which allowed the vessel ingress into the inner edge of the Caldicot Levels and the implications of such a system of drainage on our understanding of Roman 'reclamation'.

11.3.1 The contemporary coastline and hydrology

The position and nature of the coastline during the Roman period on the Gwent Levels continues to be a subject for research. The near-continuous presence of intertidally exposed, late prehistoric peat shelves along the present coast emphatically demonstrates retreat of this coastline during subsequent, historic periods. This should be seen against a background of apparently progressive relative sea-level rise in the region since the end of the last Ice Age. These peat formations, therefore, represent periods of temporary abatement of sea-level rise leading to the creation of a variety of environments encouraging peat growth such as fen, fen carr, and raised bogs. In contrast the deposits of alluvium that dominate the upper Holocene sequences characteristic on the Levels indicate periods of coastal retreat and sea-level rise. Unlike prehistoric peat horizons with associated evidence for occupation, contemporary Roman ground surfaces are less clearly defined, although the presence of gleyed horizons and shallow dark bands within the alluvial sequence have been seen as evidence for stabilisation of land surfaces.

Post-Roman coastal retreat is indicated: by the presence in the intertidal zone of unstratified Roman cultural material in mobile sediments such as sands and gravels on the foreshore (Boon 1967; 1975) suggesting erosion of coastal sites; well-defined, silted palaeochannel complexes which are seen to cut through both prehistoric peat horizons and estuarine alluvium and to contain stratified Roman material; and relict drainage systems pointing to erosion and abandonment of improved agricultural land.

On the Wentlooge Level at Rumney Great Wharf, all these features are present: concentrations of transposed Roman pottery, coal, slag, and iron ore on the foreshore; silted ditches exposed in the eroding mud cliff and on the foreshore – some of which have been shown to contain unabraded Roman cultural debris; and a substantial silted palaeochannel from which stratified Roman pottery has been collected. While the date of some of the ditches examined at Rumney and their correlation with existing drainage patterns on the landward side of the present sea wall are open to debate (see Chapter 5), there can be no doubt that Roman agricultural exploitation of coastal lands now lost to the sea occurred here. Further to the east, near Peterstone Pill and Great Wharf, further linear ditches have been identified on the foreshore and assigned a Roman date (Neumann 2000).

On the Caldicot Level significant quantities of unstratified Roman pottery from the intertidal zone at Uskmouth (Barnett 1961; Jarvis and Webster 1991) and Magor Pill (Allen and Rippon 1995; Allen 1999) point to coastal erosion of occupation sites. The relative paucity of intertidal Roman material at Goldcliff (Bell 2000, 9), in spite of the proximity of Roman drainage and occupation on the fringes of Goldcliff 'island', highlight the possibility of the existence of numerous similar sites just landward of the present coastline which are not indicated by high concentrations of intertidal material. Hence small foreshore assemblages may also be seen as indicators of coastal erosion of the Roman landscape, if not settlement sites.

Looked at as a whole, this intertidal material suggests that the Roman coastline was generally situated seaward of its present position. The extent of coastal retreat is less clear as erosion has obliterated most *in situ* evidence through the removal of Roman alluvium down to the upper peat shelves of the late prehistoric on the inner foreshore. Further out into the channel of the present Severn, erosion has been more severe and has removed these middle Wentlooge peats and exposed Neolithic and Mesolithic alluvium and even bedrock and periglacial head deposits. Only Roman features cutting down below the contemporary land surface, such as ditches and silted palaeochannels, survive on the foreshore, albeit in a very much truncated state. Indeed the ditches observed at Rumney Great Wharf and Peterstone can only be traced as far as the seaward surviving edge of the peat shelf, up to approximately 150m seaward of the present salt-marsh edge.

Some of the large palaeochannel complexes exposed on the foreshore of the Caldicot Level may have been active watercourses during the Roman period. Allen (2000a) in a recent assessment of palaeochannel systems associated with later prehistoric peat horizons (middle Wentlooge Formation) dates inception of his 'Cycle III' system to approximately 1000 BC while recognising the continued presence of Iron Age and Roman channel complexes. Where the edges of such channels can be defined on the foreshore, this implies the former existence there of dry ground, salt-marsh or at least high mudflats when water flows were active. Stratified black-burnished ware has recently been recovered from a palaeochannel at Redwick (Allen and Bell 2000) which runs out obliquely from the present shore (defined by a high sea wall) for approximately 500m before being lost below mobile sands. The width of this feature at around 100m exceeds that of the active watercourse at any one time, but indicates that this is a low-order channel into which numerous smaller channels drained the coastal wetland of the Levels. A large assemblage of transposed Roman pottery collected at Magor Pill and smaller quantities of stratified pottery recovered from an extensive palaeochannel exposed on the foreshore led Allen (2000b) to argue for the presence of an informal landing place here. Mapping of this channel complex, which can be traced for up to 800m from the present shore, and particle size analysis of the palaeochannel fills suggest that the location of the Roman coastline was approximately 800m seaward of its present position (Allen and Rippon 1997).

Much remains to be resolved concerning the Roman coastline of the Caldicot Level, but it seems reasonable to suggest that there has been coastal retreat of the order of kilometres in places. The presence of cultural debris stratified within palaeochannel fills at Redwick and Magor Pill demonstrates that the Roman Levels were drained by a number of tidally influenced channel systems which would have been fed in part by freshwater run-off from the hills forming the hinterland of the wetland but also by precipitation draining from the Levels proper. The number and location of such Roman channel networks remain unclear but could be comparable with Allen's speculative reconstruction for late prehistoric 'Cycle III' palaeochannels (Allen 2000, fig 17). Further large palaeochannels detected on the foreshore awaiting more detailed examination may also have been active during the Roman period, including Elver Pill some 2.5km west of the Redwick channel and the former outfall of the Troggy/Nedern at Sudbrook (Godbold and Turner 1993). These watercourses could have provided access via boat into the Levels, with the flood tide providing propulsion up the channel systems and the ebb tide providing similar assistance on the downstream voyage. The palaeochannels encountered at Barland's Farm located near the inner, landward edge of the coastal wetland represent the upper branches of a tidal network of channels in part fed by freshwater run-off from the Poolhead Valley. Either of the foreshore palaeochannel exposures at Elver Pill and Redwick could represent the lower reaches of this drainage system.

Palaeoenvironmental indicators are broadly in agreement in characterising the channels at Barland's Farm as being under tidal influence with salt-marsh habitats in the immediate vicinity, although a degree of freshwater input is also implied. The predominance of brackish flora and fauna show that tidal waters reached into the heart of the Level up a tidal creek system for more than 3km from the contemporary coast. This in turn must have bordered an estuarine environment. If similar conditions prevailed with respect to the other channels seen cutting through late prehistoric horizons on the present foreshore, it is difficult to envisage any large-scale scheme of Roman flood defence encompassing the whole of the Caldicot Level such as that argued by Allen and Fulford (1986). Rather any flood banks are more likely to have protected limited areas in a landscape that was dissected by branching networks of tidally influenced channels.

The suggested drainage pattern on the Caldicot Level in the Roman period may in part help interpretation of the two structures found within the palaeochannels at Barland's Farm. These may be seen as river crossings over tidally influenced tributaries of a watercourse located to the west that carried the fresh water running into the Level from the Poolhead Valley and ran southwards to meet the coast at Elver Pill or Redwick. Such crossings could indicate the line of a roadway running from permanently dry land in the north-east towards the west-south-west which could have terminated at the posited channel to the west or crossed it providing access to the heart of the Level. Why such a roadway might have been built requires discussion of the evidence for exploitation of the Caldicot Level at this time.

11.4 An agricultural landscape?

Characterisation of the contemporary landscape and vegetation through palaeoenvironmental studies was a key objective of this project to provide a context for the boat find and also to determine the nature of agricultural land-use.

Recent excavations in the north-eastern area of the Europark development (Greenmoor Arch) have revealed the presence of Iron Age peats postdating the Bronze Age horizons encountered in deep excavations at Barland's Farm (Walker *et al* 1998; Locock 2000b). Associated with these later peats were three sub-rectangular buildings reminiscent of those found in the intertidal zone at Goldcliff. Detailed analysis of this site awaits completion, but observation of cattle footprints suggest that exploitation of salt-marsh for seasonal grazing, as posited for Goldcliff, may have been the dominant subsistence activity here in the middle to late Iron Age. These buildings were sealed under alluvium that must have accumulated sufficiently quickly to ensure the survival of wooden uprights, perhaps pointing to a marine transgression in the late Iron Age. The extent to which such a transgression disrupted exploitation of the Caldicot Level by native populations is as yet unclear. Such communities may have continued to occupy salt-marsh margins up to and beyond the time of Roman military incursions into south-east Wales. Evidence of Roman occupation of the Levels in the 1st and 2nd centuries must be sought beyond Barland's Farm.

Pottery recovered in 1973 during construction of the Nash Waste Water Treatment Works on the western edge of the Caldicot Level was dated to the 1st to 3rd centuries (Webster 1992). Recent excavations have provided a context for this material with 1st- to 3rd-century material found within ditches and cut features interpreted as drainage of open land subject to tidal influence (Meddens and Beasley 2001). No flood banks were noted, while successive patterns of artificial drainage appear to have been dug to improve the quality of grazing on grassland habitats. The area was subject to at least intermittent flooding indicated by brackish flora and fauna in the primary silts of many of the ditches. Contemporary vegetation appears to be dominated by grasses and salt-marsh species, with limited indication of woodland in the region. Integration of the evidence points to modification of natural grassland for grazing of livestock (predominantly cattle) rather than wholesale transformation of the landscape through construction of extensive flood defences.

A similar landscape and agricultural system could have prevailed at Barland's Farm where environmental indicators also suggest grassland and salt-marsh were the dominant habitats and cattle and horse dominate the bone assemblage. Indications of arable production are stronger here than at Nash, but could reflect farming practices beyond the wetland fringe.

Given the growing evidence for agricultural exploitation and landscape modification (through limited drainage) of the Caldicot Level in Roman times, the suggested presence of a roadway running to the west of the Barland's Farm site could imply land-based communication between agricultural settlements on the Level. Such roads, where they met or crossed larger, tidally influenced streams draining the wetland, as at Barland's Farm, would also have allowed the export of agricultural produce and import of goods by boat.

12

WIDER PERSPECTIVES

12.1 The boat in Roman Wales

A notable feature of this boat find is its location on the northern shore of the Severn Estuary. This extends the known distribution of Romano-Celtic boats and ships well to the west of those already known (Fig 8.5). This is not to say that this boat was from a region beyond direct Roman influence. On the contrary, as with many of the finds of this tradition, the boat comes from a region which had been subject to centuries of Romanisation. Pre-Flavian military activities are reflected in the establishment of the legionary fortress at Usk, an auxiliary fort at Monmouth on the Wye, and probable military bases at Caerleon and near Chepstow some two and a half centuries prior to the boat's construction. The growth of the *civitas* at Caerwent (*Venta Silurum*), perhaps originating as a ribbon development on the main Caerleon-Gloucester road in the early 2nd century, can be seen from a number of perspectives. It implies the acceptance (or imposition) of Roman forms of administration, but is also an indicator of the relative strength or, as Arnold and Davies (2000) terms it, the 'precocity' of the native *Silures*. The prefix *venta* (market) stresses the trading functions of the settlement located on the eastern border of the *territorium* of Legio II Augusta, on the main coastal road with spur roads leading to possible informal landing places at Magor Pill and Sudbrook. The construction of large houses at Caerwent in the 3rd and 4th centuries, some interpreted as 'urban farms' (Arnold and Davies 2000, 53), highlights the agricultural source of at least part of the town's wealth. The nature of contemporary landholdings on the Caldicot Level remains unclear, but ownership of estates on the Level by inhabitants of Caerwent would be in keeping with the increase in the number of such building complexes at the time of the boat's construction. Hence culturally the boat should be seen within the context of a vibrant fusion of Roman and native influences.

With her ability not only to sail the estuary as far west as Cardiff to the north and Bridgwater to the south and also to use the tidal reaches of the many rivers flowing into the estuary, the Barland's Farm boat and other similar vessels would have been of great importance to the economic and social life of the Severn region. Being of slight draft –only 0.54m when carrying 6.57 tonnes of cargo – she could at times have been taken above the head of tide on certain rivers (section 10.4). This ability to venture well inland would have been invaluable in those parts of this region where trade and travel by overland routes was difficult. Such a boat could have embarked a variety of domestic animals and a wide range of traded goods. Tables 10.2 and 10.3 show only a few possibilities: within safe limits of freeboard and stability, the skipper of this boat would probably have agreed to carry almost anything that was offered.

12.2 The boat in the Romano-Celtic tradition

The Barland's Farm boat is a member of the Romano-Celtic tradition as at present defined (section 9.4). Within that tradition she is one of a group of sea-going/estuary vessels that consists of the two ships, Blackfriars 1 and St Peter Port 1, and possibly the boat from New Guy's House. This is clear not only from her deduced seafaring abilities (Chapter 8 and 10), but also because she has posts, a plank-keel, and a part-rounded hull, characteristics that the inland boats of this tradition generally do not have (cf the Mainz boats, sections 9.4.1–9.4.3).

The felling date range of AD 283–326 for the oaks from which the Barland's Farm boat was built means that she would probably have been in use for some decades around AD 300 until, say AD 325–330 when her stern was dismantled and she was left lying adjacent to a bridge, possibly acting as some form of partly floating landing stage. Some time after this the whole site including the boat appears to have fallen into disuse.

Milne (1996) has argued that the ships and boats of this Romano-Celtic tradition were built as transports for the *classis Britannica* or for individual legions from the mid-3rd century onwards. He further suggests that they did not constitute a 'new Romano-Celtic style: they were simply craft built to Roman specifications under Roman supervision but with whatever materials and labour were drafted in' (Milne 1996, 237). It may well be that some of these vessels (both the Blackfriars group – including the Barland's Farm boat – and the Zwammerdam/Neuchâtel group) were used for military purposes, but the the Blackfriars vessels (certainly) and those in the other group (probably) were not Mediterranean in style nor in the majority of the techniques used to build them.

Like other vessels of this tradition both seagoing and inland, the Barland's Farm boat was built within a technological context which was essentially Celtic but with some fusion of Roman and native techniques (see sections 5.5.3.2.2, 9.4, and 12.1). The use of sawn timbers is an obvious Roman trait but it may well be the only significant characteristic that is not Celtic, although a number of mortise-and-tenon joints were used to fasten parts of the side planking together in some of the Zwammerdam barges. There is also scope for debate about the use of hooked nails (section 7.4). Hooked bronze nails were used in the eastern Mediterranean to fasten framing to planking from *c* 400 BC (Kahanov 1999). Arnold (1999, 42, fig 7) has noted, however, that turned and hooked iron nails were used in the 2nd-century BC *murus gallicus* and before 500 BC in Halstatt cart wheels. Technological transfer could have taken place along the Rhône–Seine route or the Po–Rhine route that connected the North Sea and the Mediterranean. Whether such transfer took place and if so in which direction is unclear. The differences between the Mediterranean and the Romano-Celtic Blackfriars style of building are great, especially the fundamental difference in concept: the Roman builder thought of (or visualised) the shape of his ship in terms of the *planking*; the Celt in terms of the *framing*. The Roman vessel was built by fashioning, fitting, and fastening the planking together to achieve the desired shape before framing was inserted. The Celtic ship was built by first fashioning frames to give the required shape of hull; the planking was then fastened to that framework. Furthermore there are no parallels in contemporary or earlier vessels of Mediterranean tradition for the hull shape, the plank-keel, the framing pattern, or the joinery and other boatbuilding techniques of these Romano-Celtic vessels. All these features appear to be characteristic of Celtic technology during the early centuries AD if not earlier (section 9.4).

The late date of discovery (1993) and other factors have facilitated the detailed documentation of the Barland's Farm boat. A strong case can now be argued that an international team should rerecord some of the earlier finds of Romano-Celtic vessels – in so far as that is now possible – so that a comprehensive account of all vessels thought to be of this tradition may be compiled (McGrail 2001a and forthcoming).

12.2.1 The origins of the Romano-Celtic tradition and its aftermath

Of the several distinctive characteristics of the Romano-Celtic tradition, building framing-first fashion was the most innovative. This feature clearly distinguishes Romano-Celtic seagoing craft from contemporary plank-built vessels in both northern and southern Europe. It is also strikingly different from the techniques used in prehistoric logboats and sewn-plank boats that are the only wooden boats as yet known to have preceded Romano-Celtic vessels in north-west Europe.

The origins of this framing-first approach to the design and building of seagoing craft are obscure, but they may lie within north-west Europe. Well before the 1st century BC, when Julius Caesar (*De Bello Gallico* iii.13) described the seagoing vessels of the Celtic Veneti of Brittany, perhaps as early as the 2nd millennium BC, framing-first techniques were used to build seagoing hide boats, skin upon frame (McGrail 1990, 36–9). It is not difficult to visualise the transfer of technology from hide boat to plank boat, but further research, preferably excavation-based, is needed to investigate this conjecture.

After the 4th century AD, evidence for the Romano-Celtic style of building does not appear in the archaeological record of north-west Europe. It remains to be seen whether the framing-first technique lived on there through the migration period when there were significant changes in the dominant culture and technology. It may be that the late 6th- to early 7th-century coastal and river boat Port Berteau 2 is evidence for such survival. The flush-laid planking of this boat, excavated from the River Charente on the west coast of France, was not fastened together, but was fastened by treenails to the frames (Rieth 2000; Rieth *et al* 2001). Unlike the seagoing Romano-Celtic vessels, Port

Berteau 2 had composite frames with futtocks fastened to floor timbers (Rieth 2001, fig 112). She may, therefore, have been built to a degree at least frame-first (*sensu stricto*) rather than in Romano-Celtic framing-first fashion.

Several 7th-century wrecks from the central and eastern Mediterranean appear to have been built by frame-first methods, at least in part (McGrail 1997a). If they exist, the relationships between the Romano-Celtic tradition, Port Berteau 2, and the wrecks St. Gervais 2, Tantura 1, and Yassi Ada 1, clearly need further detailed research.

12.3 The Roman Severn Levels

The site at Barland's Farm adds to the evidence for the way in which the low-lying coastal plains fringing the Severn Estuary were exploited in the Roman period. This can be seen in terms of differing levels of alteration of the natural landscape that vary from exploitation of existing habitats, through modification by limited artificial drainage, to wholesale transformation by construction of extensive flood defences (cf Rippon 1996a, 1998b, and 2000).

It has been suggested by Rippon (1998b) that the central Somerset Levels south of the former river Siger were not reclaimed in the Roman period but exploited for natural resources including the production of salt. This was possibly to meet military demand in south Wales using supply routes indicated by the distribution of Dorset black-burnished wares. In contrast the north Somerset Levels appear to have been actively reclaimed in the mid-3rd century. Excavations at Banwell, Puxton, and Kenn recovered evidence for purely freshwater environments in the ditches of field systems, arable production, and hay meadows (Rippon 2000). Rippon suggests that such conditions would have necessitated either continuous flood defences along the north Somerset coast, with sluice gates to allow discharge of freshwater rivers, or embankment of these rivers and more limited floodbanks at the coast.

This contrast between different areas of the Somerset Levels may be repeated on the Gwent Levels, although the evidence is more limited and less compelling. Indications of freshwater conditions and arable production from excavation of the well at Rumney Great Wharf have been taken as proof of large-scale reclamation of the Wentlooge Level but further data will be required if debate on the status of this area is to move forward. The excavations at Nash point to modification of natural grassland through improvement of the natural drainage on the Caldicot Level. That this drainage pattern included a number of high-order, navigable watercourses that provided access by boat deep into the Level is clearly demonstrated at Barland's Farm.

12.4 Future research

The conserved boat timbers, along with the associated archive, are to be kept in Newport Museum and eventually displayed in a gallery yet to be built. Before that takes place a few very fragmented timbers which were lifted within fibreglass casts should be fully recorded.

Half-frame F10Pt also has to be remeasured since there are grounds for thinking that its constituent parts may not have been fitted tightly together when first recorded (see 8.1.1 and Appendix 2). Consideration should also be given to further dendrochronological work aimed at investigating whether pairs of timbers (such as P1 and S1 and P2 and S2) were from the same parent logs (see sections 6.3.1 and 6.3.4.1). Further tests should be made on caulking samples to determine whether resins or tars were incorporated (see section 7.4.3).

During the reassembly of the timbers for display, several matters that have not been fully resolved in this report should be further investigated by an archaeologist with a detailed knowledge of the boat as follows:

- the original positions of the two side timbers (SFX1 and SFX2) found within the wood and stone structure and other unplaced fragments (see section 6.3.3.4.4);
- the anomalies in plank thickness recorded at butts within strakes P3, P4, and P5 (see sections 6.3.4.4.1–2 and 6.3.4.5.2);
- the precise relationship between strake fragments P3A, P3A*, and P3B (see section 6.3.4.4.1);
- the alignment of the hole in side timber SF6.5PT with the groove in strake P7 (see section 8.3.1.3);
- the relationship between strake edges and boat

builders' marks on the outer faces of certain framing timbers (see section 7.1.2 and Table 7.1).

During this reassembly process further light may be shed on the sequence of building this boat (see section 9.3.8). After reassembly the lines should be taken off the boat and compared with those taken off the model (Fig 8.11). After allowing for shrinkage, any discrepancies other than minor ones should be investigated. It may also prove possible to reassess the unit of measurement (see section 9.2.1) and determine whether a rule of thumb was used to 'design' the individual shapes of the floors and half-frames (see section 9.2).

Finally serious consideration should be given to the reexcavation of the New Guy's House boat which was exposed by Peter Marsden near London Bridge in 1958 (Marsden 1994, 97–104. This was one of the first Romano-Celtic vessels encountered by archaeologists. Circumstances prevented it being fully excavated and the site was back-filled. Subsequently the site was scheduled as a 'protected monument'. The remains are well above the water-table (Marsden 1994, 97) and the boat must be deteriorating. Knowledge acquired in the past 40 years about the Romano-Celtic tradition should assist in the interpretation of this boat. Conversely and perhaps of more importance, features of the New Guy's House boat could give us a better understanding of the tradition.

12.4.1 A full-scale reconstruction?

A final phase of this long-term project could be the building and testing of a full-scale reconstruction (Coates *et al* 1995; see sections 8.2, 8.7, and 9.3.8). As a prelude to this, the 'as found' drawing (Fig 8.1) and the hypothetical reconstruction presented here (Figs 8.2 and 8.3) should be reappraised in the light of additional information then available, not least as a result of the reassembly of the timbers. A revised reconstruction of the shape and structure of the original boat – in the form of scale plans and a model (or models if there are alternative reconstructions) – could then be prepared for criticism at an international seminar. If justified (Coates *et al* 1995, 297–8), the building of a full-scale reconstruction may next be contemplated. If such a 'replica' project were to be undertaken in an academically rigorous manner, valuable information about the way the original boat was designed and built and about her seagoing performance should result. In this way the data presented in Chapter 7 would be supplemented and the deductions made and hypotheses advanced in Chapters 8, 9, and 10 would be confirmed, complemented, or refuted.

APPENDIX 1
GLOSSARY

active frame: any frame that, with others, defines the hull shape. See also 'passive frame'.

'as found' said of a scale drawing or model which depicts the boat as excavated, but with displaced members reinstated, fragmented members made whole, distorted and compressed parts restored to their original shape, and the hull rotated to the presumed attitude when afloat; Crumlin-Pedersen and Olsen (1997; 2002) use the term 'torso' with a similar meaning.

bevel: a surface which has been angled to make a fit with another.

beam shelf: a longitudinal member fastened inside the planking or framing to support the ends of crossbeams.

beating: to sail close-hauled on the wind.

bilge: region between the sides and the bottom of a boat.

blind fastening: see 'spike'.

bole: main stem or trunk of a tree.

bottom boards: lengths of planking (sometimes fastened together) laid in the bottom of a boat (often on top of floor timbers).

bowse: to haul down on a rope.

butt: 1 the lower end of a tree;
2 a joint in which two members meet edge to edge or, in the case of planks within strakes, end to end.

caulking: material laid between two structural members to make the junction watertight.

chine: the region where the bottom of a boat meets the sides.

chine breadth: breadth of a boat's bottom derived from measurement of frames (specific to the Barland's Farm boat).

cleat: a projecting wooden fitting to which a rope can be made fast.

clench: to deform or turn the tip of a fastening so that it will not draw out.

clew: the lower after corner of a fore-and-aft sail.

close-hauled: to trim sails so that a vessel can sail as close to the wind as practicable.

crook: a curved limb of a tree which has grown into a shape useful for boatbuilding.

crossbeam: a structural member extending across the boat.

displacement: the weight of water displaced by a floating hull; this equals the weight of the hull.

dolly: a metal billet held against the head of a boat nail while it is being clenched.

double-ended: a boat which is (nearly) symmetrical about the midship transverse plane.

downflooding: when water floods the interior of a hull due to an excessive heel or to waves or heavy spray.

draft/draught: vertical distance between the waterline and the lowest point of the hull (see also 'moulded draft').

faying surface: Adjacent surfaces on timbers which are closely fitted together

flare: the transverse section of a boat increases in breadth towards the sheer.

floor timber/ floor: a framing timber: a transverse structural member, often a crook, extending from turn of bilge to turn of bilge next to the planking.

flush-laid: planking in which adjoining strakes are butted edge to edge and do not overlap.

fore-and-aft sail: a sail which, in normal use, is set near the fore-and-aft line of the boat (see also 'square sai'l).

frame: a transverse structural member next to the planking made up of more than one timber.

frame-first/ skeleton-built: a form of boatbuilding in which the framework of keel, posts, and frames is set up and fastened before the planking is fashioned.

framing: those members which form the boat's framework.

framing-first: A form of boatbuilding in which keel, posts, and elements of the framing are set up and fastened before planking is fashioned; more framing and more planking may follow.

freeboard: height of sides above the waterline; usually measured amidships.

grommet: strands of rope laid up in the form of a ring.

half-frame: a framing timber; an L-shaped transverse structural member, often a crook, extending from (near) one sheer to the lowest strake in the opposite side; may be in handed pairs or set alternately, port and starboard.

halyard: line to hoist and lower yard and sail.

hard: a foreshore the surface of which has been consolidated by wooden hurdles, gravel, or stones to facilitate boat operations.

heel: 1 the lower end of a mast;
2 to incline over temporarily to port or starboard.

interference fit: said of a treenail in a hole when the wood fibres interlock.

joggle: to cut a notch in a structural member so that it will fit close against another.

keel: the main longitudinal strength member; usually joined to stems/posts forward and aft (see also 'plank-keel').

kevel head: upper end of a framing timber which protrudes above the sheer, and to which ropes may be made fast.

knee: a crook used as a bracket between two structural members set at about right-angles to each other.

limber holes: holes cut in structural members that cross the bottom of a boat to allow free passage of bilge water to a position where it may be bailed out.

list: an inclination to one side; a permanent heel.

leeway: displacement downwind (ie to leeward) of course steered.

mast step: fitting used to locate the heel of a mast.

moulded: the dimension of a post, keel, frame, or other framing member measured at right-angles to the run of the hull planking (see also 'sided').

moulded draft: the vertical distance from the upper face of the keel to the waterline.

neutral axis: a longitudinal boundary within a structure (such as a boat) under stress, on one side of which the structure is in tension and on the other in compression.

passive frame: any frame which is shaped to match the curvature of the hull planking at its particular station (see also 'active frame').

pay: to cover seams or a boat's bottom with tar or other waterproofing substances.

pith: the middle core of a bole.

plank: a component of a strake that is not all in one piece.

plank-first/ shell-built: a form of boatbuilding in which the planking is (partly) erected and fastened before the frames are inserted (see also 'frame-first').

plank-keel: a keel with the ratio of its moulded to its sided dimension less than 0.71 (McGrail 1998, 112–13).

rabbet: a groove or channel worked in a structural member to accept another without a lip being formed.

reaching: to sail with the wind approximately at right-angles to the boat's fore-and-aft line.

ribbands: long flexible strips of wood running from stem to stern used during frame-first building to hold the framing timbers in position until replaced by planking; they also enable the builder to visualise hull shape and to fair the framing.

rocker: fore-and-aft curvature of the bottom of a boat.

roundwood: said of a timber that includes the pith of its parent limb.

running: to sail with the wind from the sector astern.

scarf: a tapered or wedge-shaped joint between two timbers of similar section at the join.

seam: junction of two structural members required to be watertight.

set-up/stocks: temporary wooden supports on which boats are usually built.

sheer/sheerline: longitudinal curve of the upper edge of the hull.

sheet: line used to trim the foot of a sail.

shore: stout timber used to support a vessel during building or after she has taken the ground (beached).

short grain: formed when the axis of a worked timber is not parallel to the grain (the run of the main fibres).

shroud: rope leading from the masthead to the sides of the boat to support the mast athwartships.

side timber: a framing timber that lies next to the planking between the bilge and the top strake.

sided: the dimension of a post, keel, frame, or other framing timber measured parallel to the run of the hull planking (see also 'moulded').

spile: to transfer a curved line from a boat being built onto a board and thus mark out the edge(s) of a plank or frame.

spline: a long flexible strip of wood for setting out curves (see also 'ribband').

spike/blind nail: a fastening which does not penetrate right through the structural members being joined.

square sail: a sail that in normal use is set at near right-angles ('square') to the fore-and-aft line of the boat; usually rectangular in shape.

'standardised and pooled': a statistical technique used to merge data from several sources.

stations: regularly spaced reference positions along the length of a boat; in the Barland's Farm boat they coincide with the position of the main framing timbers.

stay: rope leading forward or aft from the masthead to support the mast.

strake: a single plank or combination of planks that stretches from one end of the boat to the other.

tack: 1 to alter course through the wind at intervals, so that the wind is alternately on the port or starboard bow;
2 lower forward corner of a fore-and-aft sail.

take against: when one timber is contiguous with another, but not fastened or joined to it.

thole: wooden pin projecting upwards at sheer level to provide a pivot for an oar.

timber: used generally to refer to any piece of wood used in boatbuilding; in the plural sometimes used as a synonym for framing.

treenail: wooden peg or through fastening used to join two members; or as a basis for a nailed fastening as in the Romano-Celtic tradition.

tree rays: layers of parenchyma cells in horizontal strands running out from the pith towards the sapwood.

tree rings: the sequence of complete sheaths of new wood laid down all over a tree between bark and old wood during each growing season.

yard: A spar suspended upon a mast and from which a sail is set

Other terms

m × s: the product of the moulded and the sided dimensions of a structural member; used as a measure of massiveness.

m/s: the ratio of the moulded to the sided dimensions of a structural member; used as a measure of cross-sectional shape.

60% waterline: that waterline where the draft = 60% height of sides amidships; it is used as a standard when comparing the load-carrying abilities of reconstructed cargo vessels.

Appendix 2
Catalogue of timbers

The timbers in this catalogue are arranged in five groups: 'backbone'; framing; bottom planking; side planking; and fitting. This is more or less in the deduced order of building the original boat. The conventions used in the drawings are given in Fig A2.0 on the following pages. The plan numbers in the text refer to their sequence in the Glamorgan-Gwent Archaeological Trust archives. The original measured drawings were compiled by Richard Brunning.

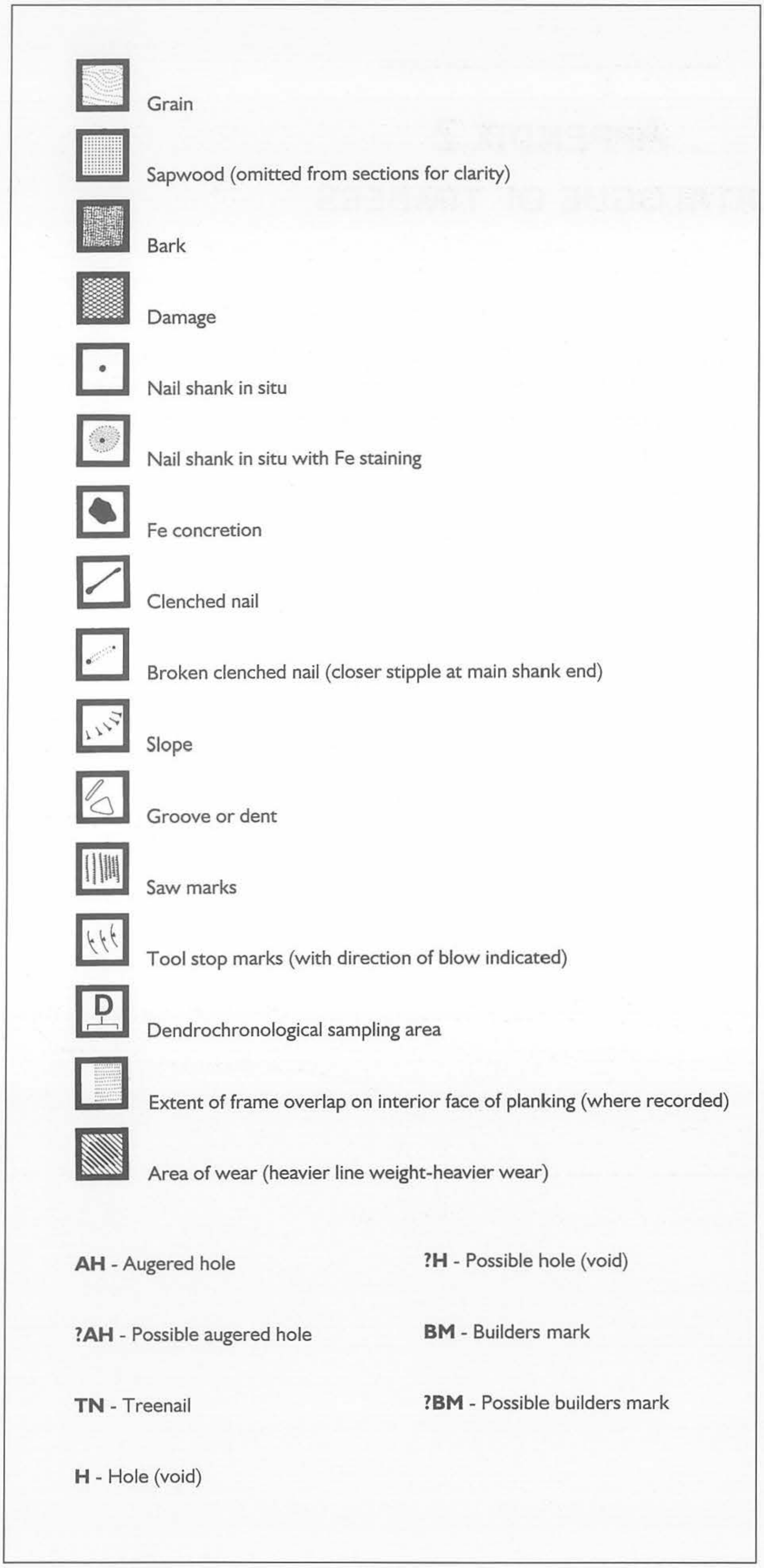


Figure A2.0.0
Key to conventions used throughout the catalogue of timbers in Appendix 2.

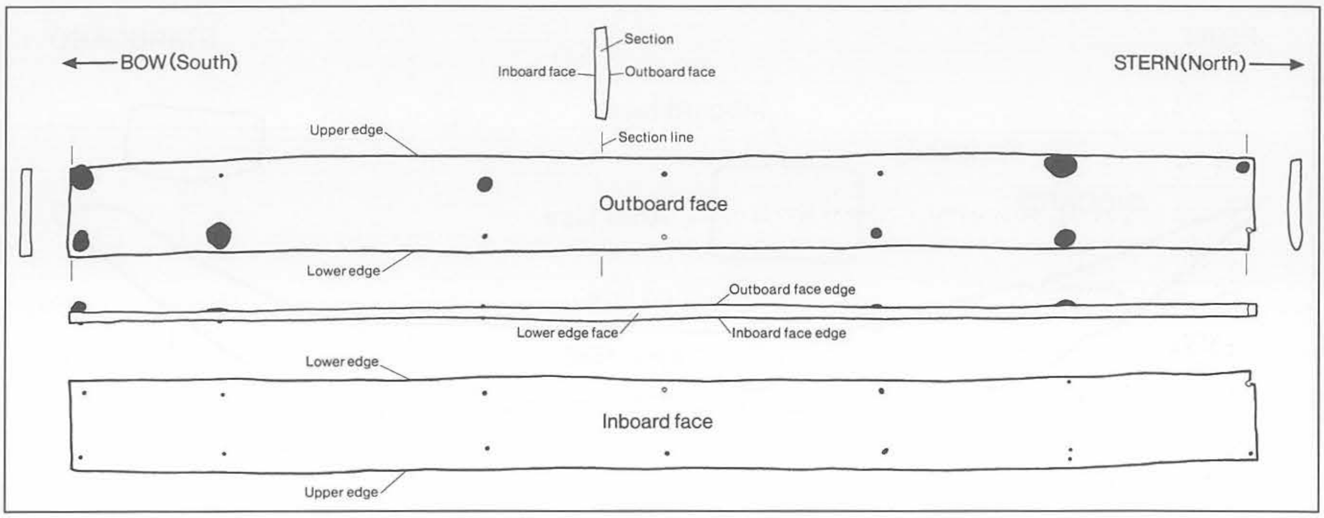


Figure A2.0.1 Orientation key: port planking.

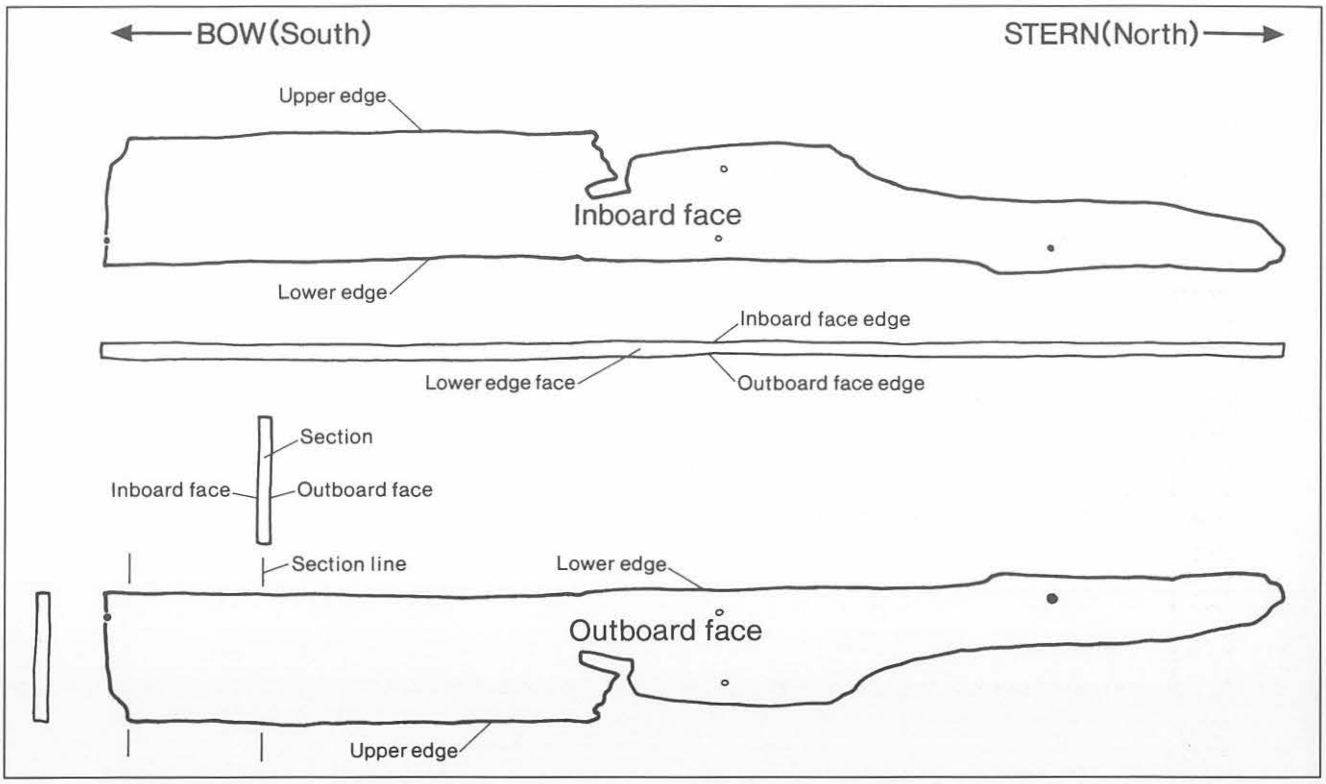


Figure A2.0.2 Orientation key: starboard planking.

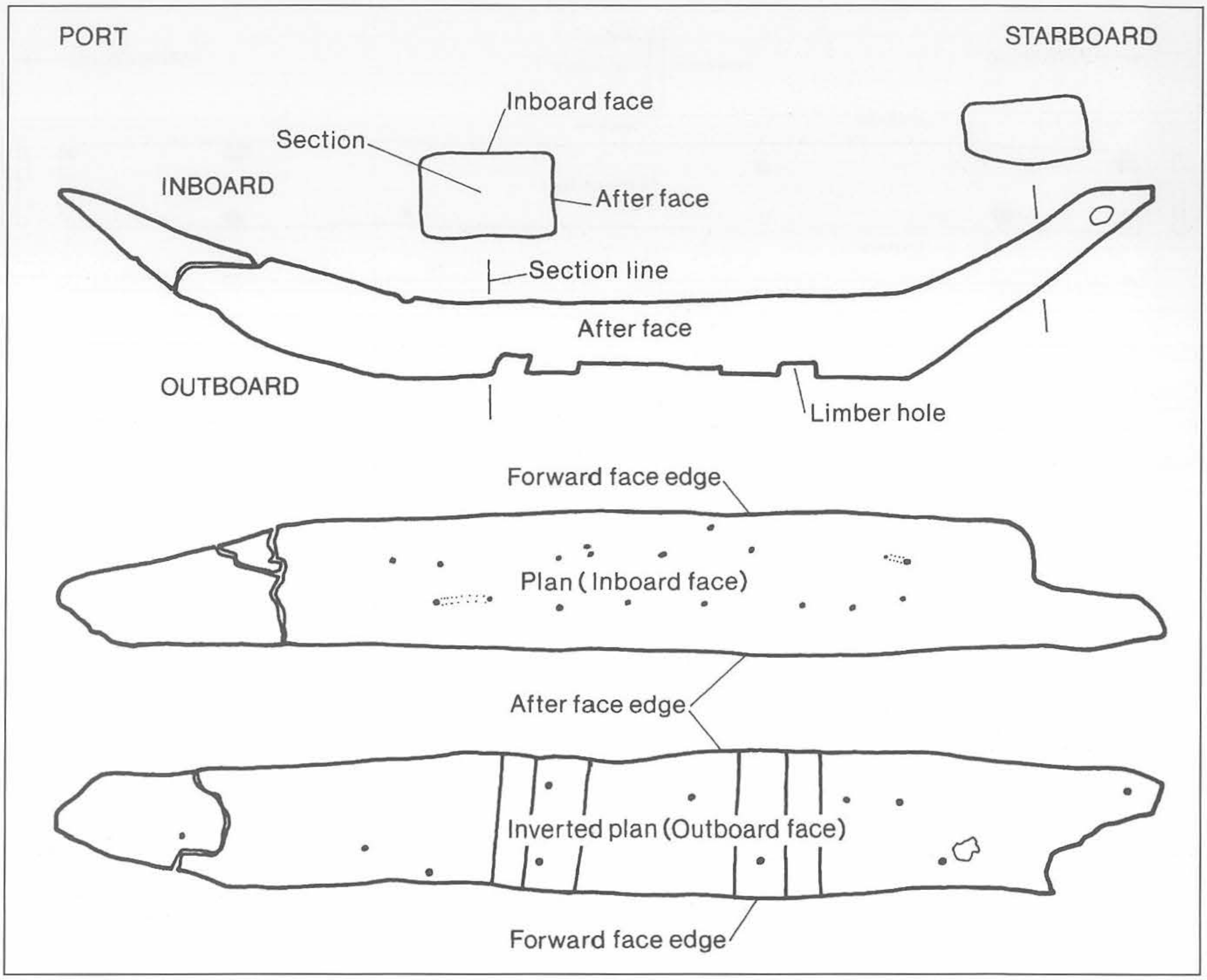


Figure A2.0.3 Orientation key: main floors.

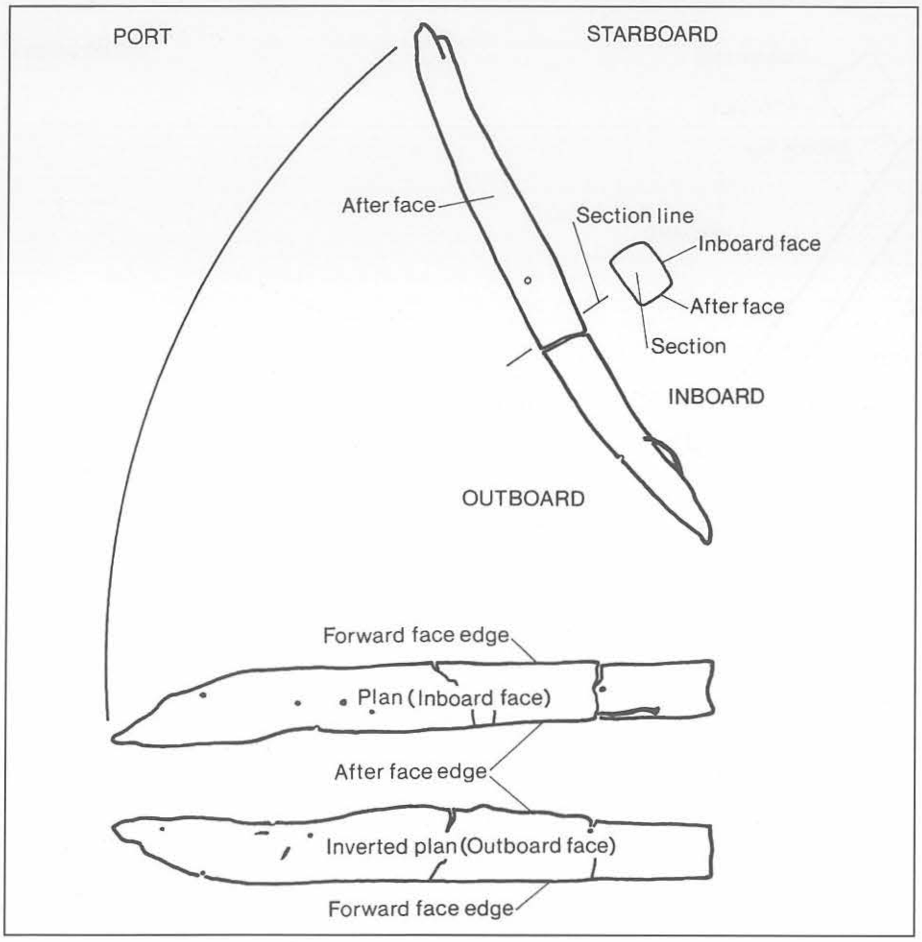


Figure A2.0.4
Orientation key: port side frames.

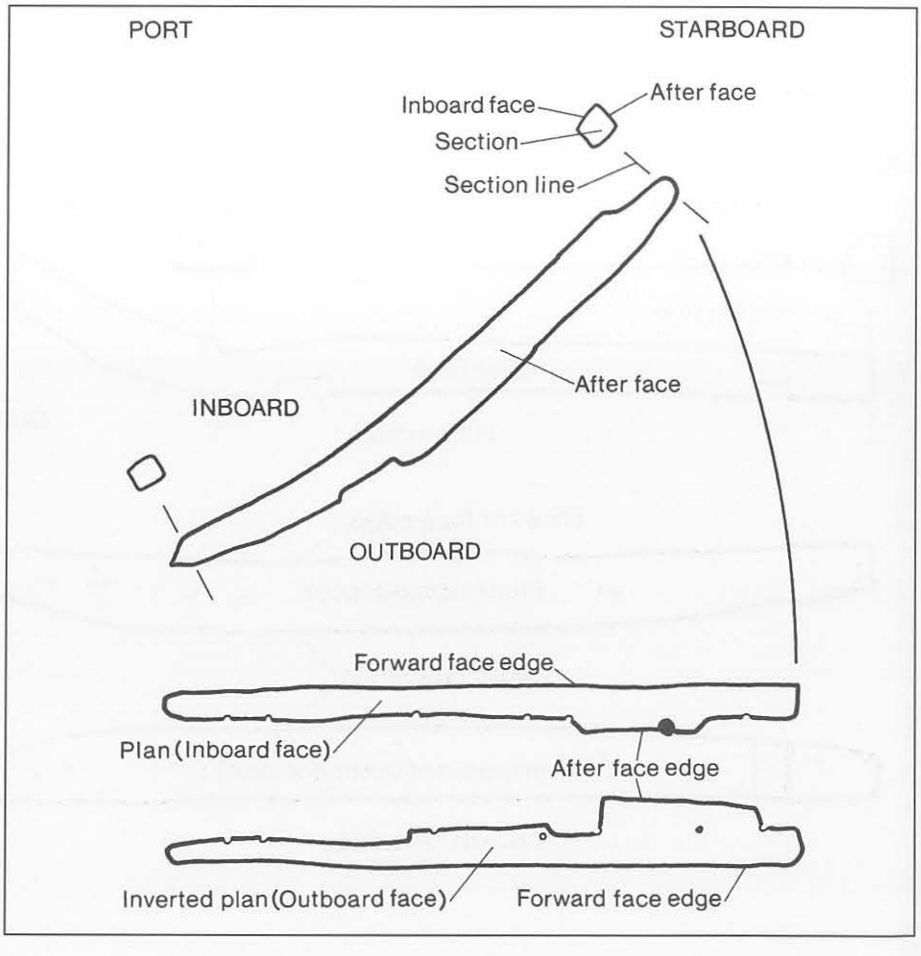


Figure A2.0.5
Orientation key: starboard side frames.

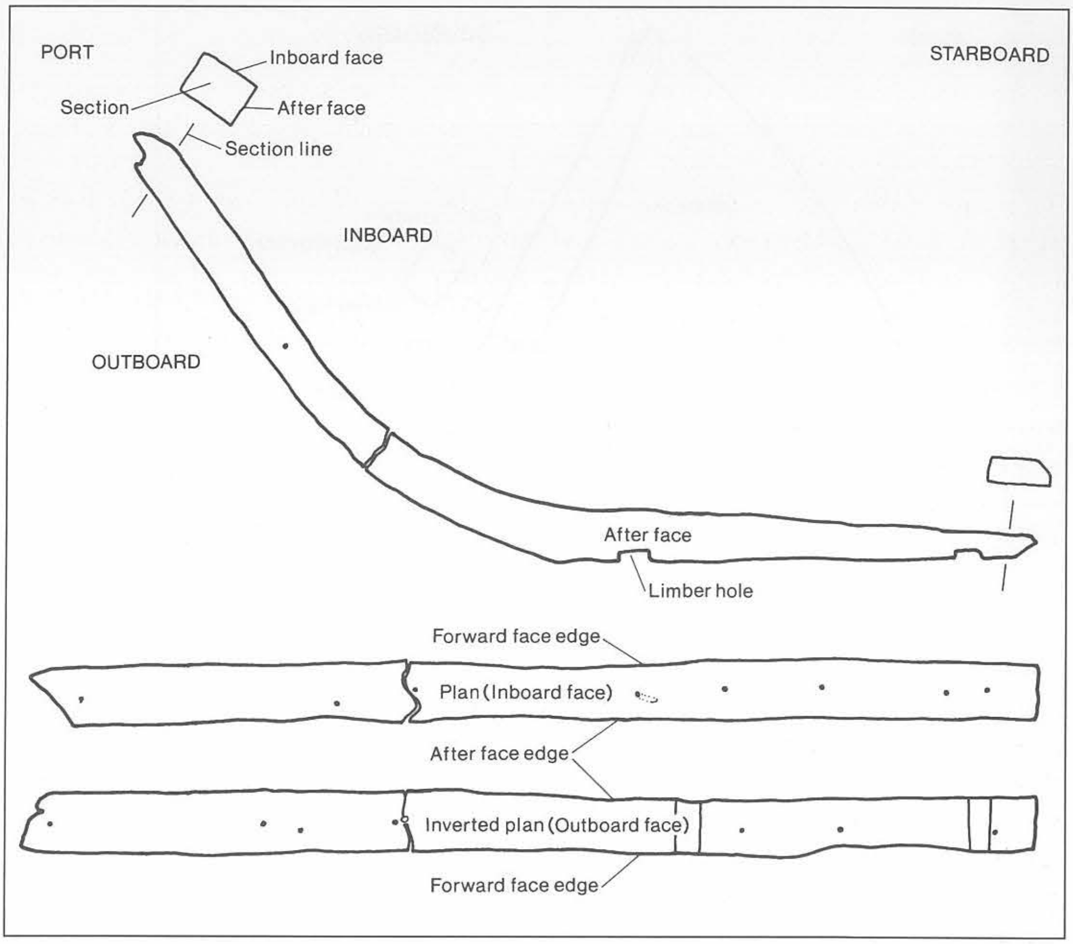


Figure A2.0.6 Orientation key: port half frames.

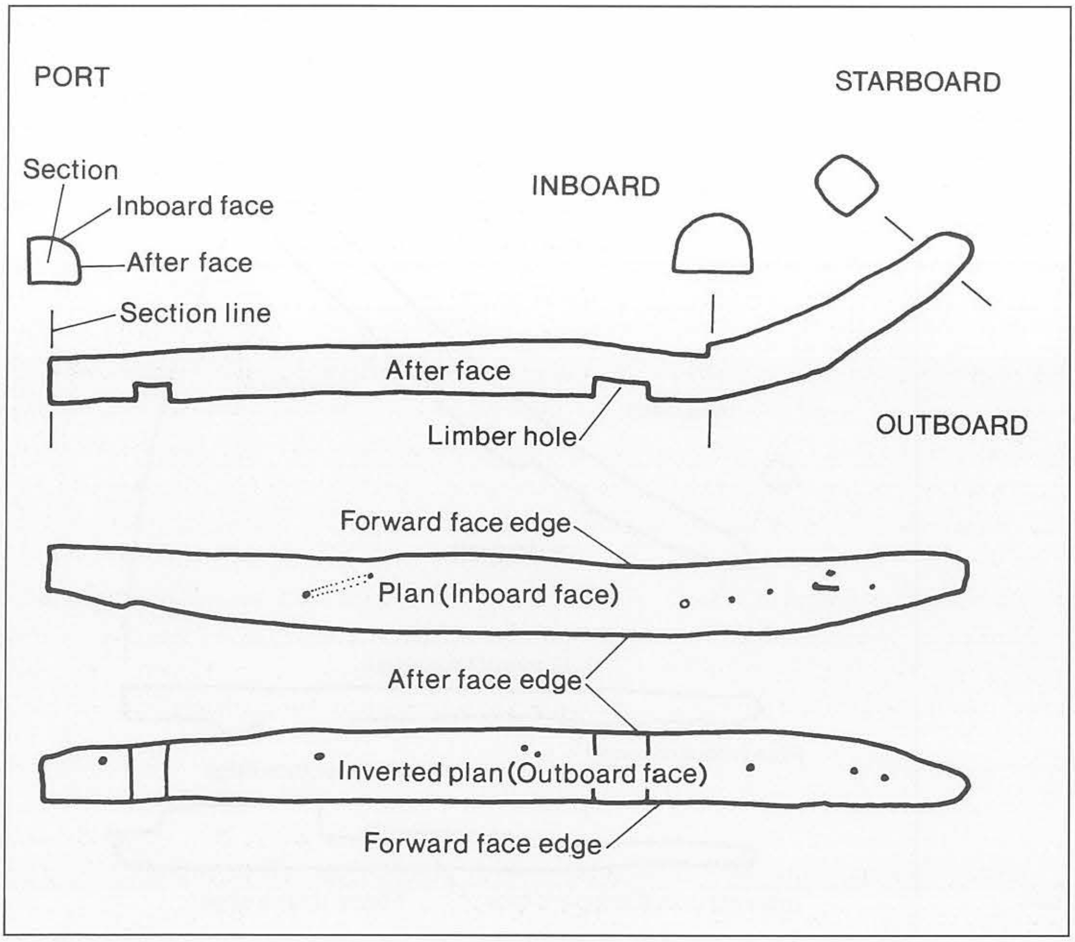


Figure A2.0.7 Orientation key: starboard half frames.

The 'backbone'

Plank-keel (PI and S1)

P1 (5112) – Fig A2.1

This port element of the plank-keel was lifted and drawn in three sections (plans 88, 89, and 90). The plank is in good condition, the inner face underneath the framing being particularly well preserved. As these areas are at a higher level than the frameless parts of the plank and in a contrasting colour, they show precisely where each frame was in contact with it. This plank extends most of the length of the bottom, from the half-lap scarf with the stem post under floor timber F4 to a similar joint at the stern under F17. It partly butts with the port bow bottom plank (PB) and with the (now missing) port quarter bottom plank.

Conversion

This plank was fashioned tangentially close to the pith from a straight-grained oak of medium growth rate (3mm per year). In the lower parts of this bole there were a few small branches; further up, branches increased in size and number, with two large branches at the top. This bole was more than 7m tall, had a maximum girth of c 1.38m (diameter 0.44m), and would have weighed *c* 726kg. In wood science terms, this parent log is similar to S1; these two planks may have been converted from halves of the same oak.

Much of the bole had been sawn away during conversion. The plank retains the elongated tapering shape of its parent log with breadths increasing from forward. Both edges are generally normal to the plank faces; the ends are butts with the stem post, with bow bottom plank BP1, and the corresponding timbers astern.

This plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was aft – the converse of S1 in this respect. The grain generally flows along the plank's length. Some sapwood (five rings) had been left at the edges of the after part of this plank; there was more further forward where the upper end of the parent log was narrower. The plank dimensions are: length *c* 7.18m; breadth aft, 0.295m tapering to 0.238m forward; thickness *c* 60 mm. Such a plank would have weighed *c* 97kg.

Boatbuilding features

Plank/frame fastenings

Floor timbers F4, F6, F8, F9, F11, F13, F14, F16, and F17 were fastened to this plank-keel by two nails each. One of the nails through F4 (and probably F17) also passed through the post. F15 was fastened by one nail.

Half-frames F5, F7, F10, F12, and F15 (port and starboard) were each fastened to P1 by one nail.

Plank-keel/post/frame fastenings

At the forward end of this plank near the seam with S1, a rectangular recess, 0.15 to 0.17m in length and 0.11 to 0.13m athwartships, had been worked in the inner face to a depth of *c* 25mm. In conjunction with a similar feature on S1, this housing formed a half-lap scarf (with sides) with a corresponding recess in the outer face of the lower, horizontal end of the post (5024). A notch worked in the fore-and-aft direction across the outer face of F4 was set into a recess in the upper face of the stem post, forming a double-notch joint directly above the plank-keel/post scarf. Two nails, one each through P1 and S1, fastened plank-keel to post to frame (Fig 6.10). There were probably similar arrangements at the stern.

Caulking

Both edges of the plank in the seams with P2 and S1 were caulked with macerated hazel and/or willow held in place by small iron nails some 28mm in length, with a head 11mm in diameter and a near-rectangular shank, which were driven (in a curved direction?) into the plank edges. Similar caulking was used between the end of this plank and the stem post and the butted end of the port bow bottom plank (BP). There was comparable use at the stern.

Builders' marks

Blind holes some 12mm in diameter had been bored vertically 6 to 10mm into the inner face of this plank in a line close to the seam with S1; near the bow these holes are actually at this seam. There are none of these holes underneath floor timbers F4, F6, F13, and F17. As this edge of the plank is damaged in the vicinity of F7Pt and St and slightly damaged near F8, it is not now clear whether there were such holes under these three timbers. Where there are such holes their spacing is irregular, varying from 50 to 300mm, the mean being *c* 136mm with a large standard deviation of 65mm.

Signs of use

The inner face of the plank has been especially worn down in two regions: between F5St and F6 by 22 to 31mm (see also P2, S1 and S2); between F16 and F17

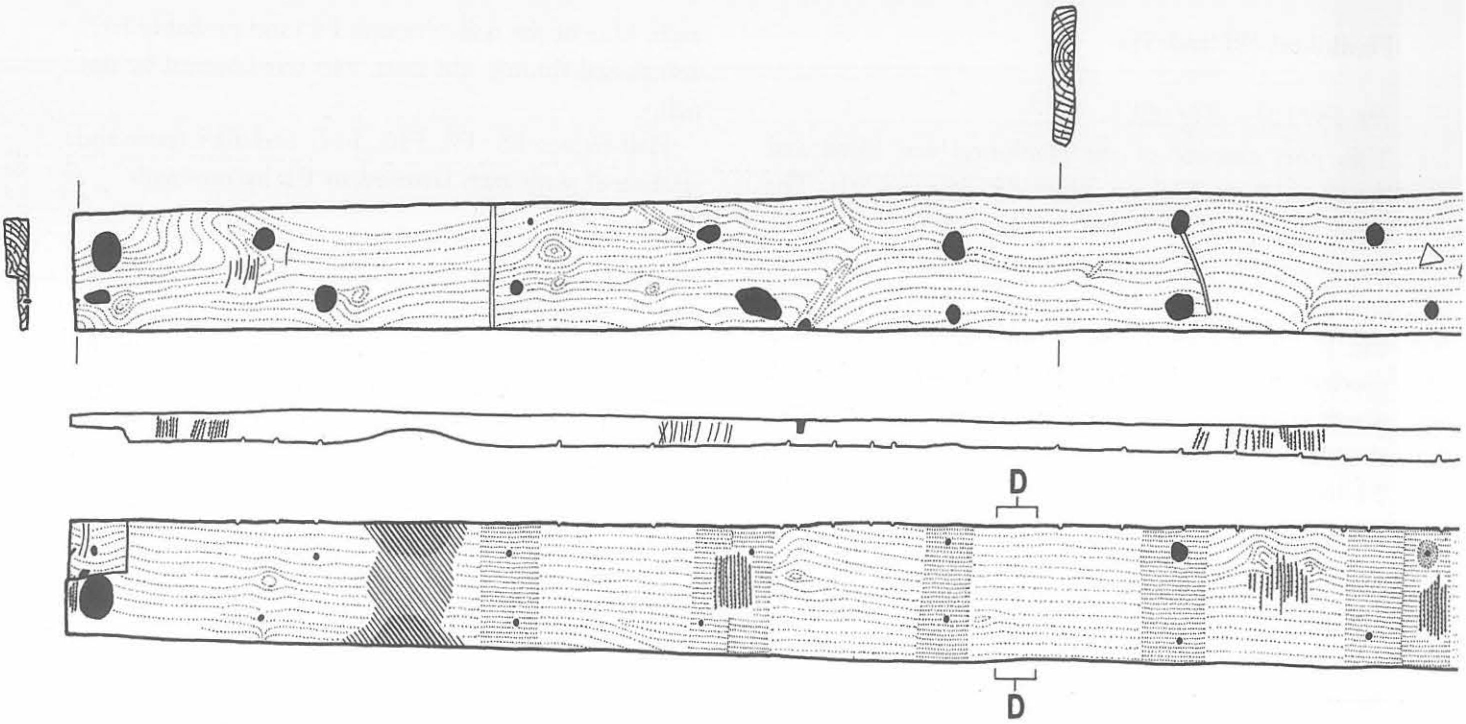


Figure A2.1 Plank-keel element P1.

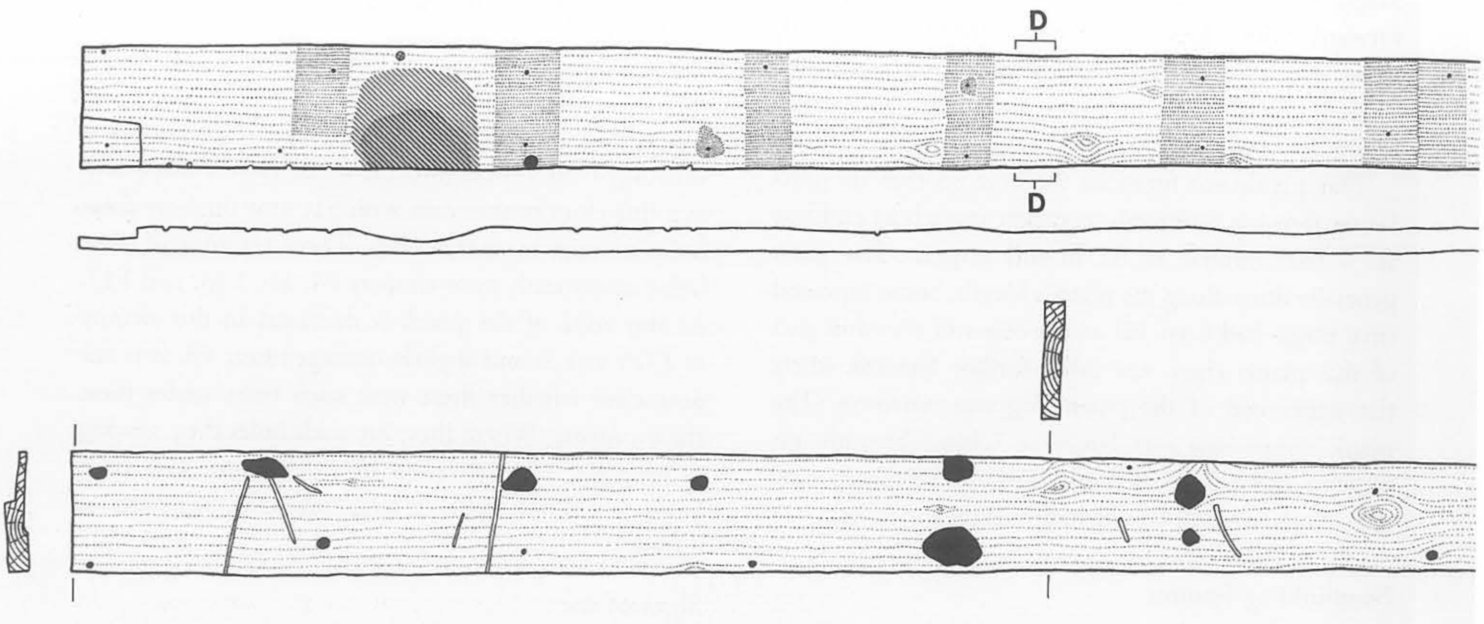
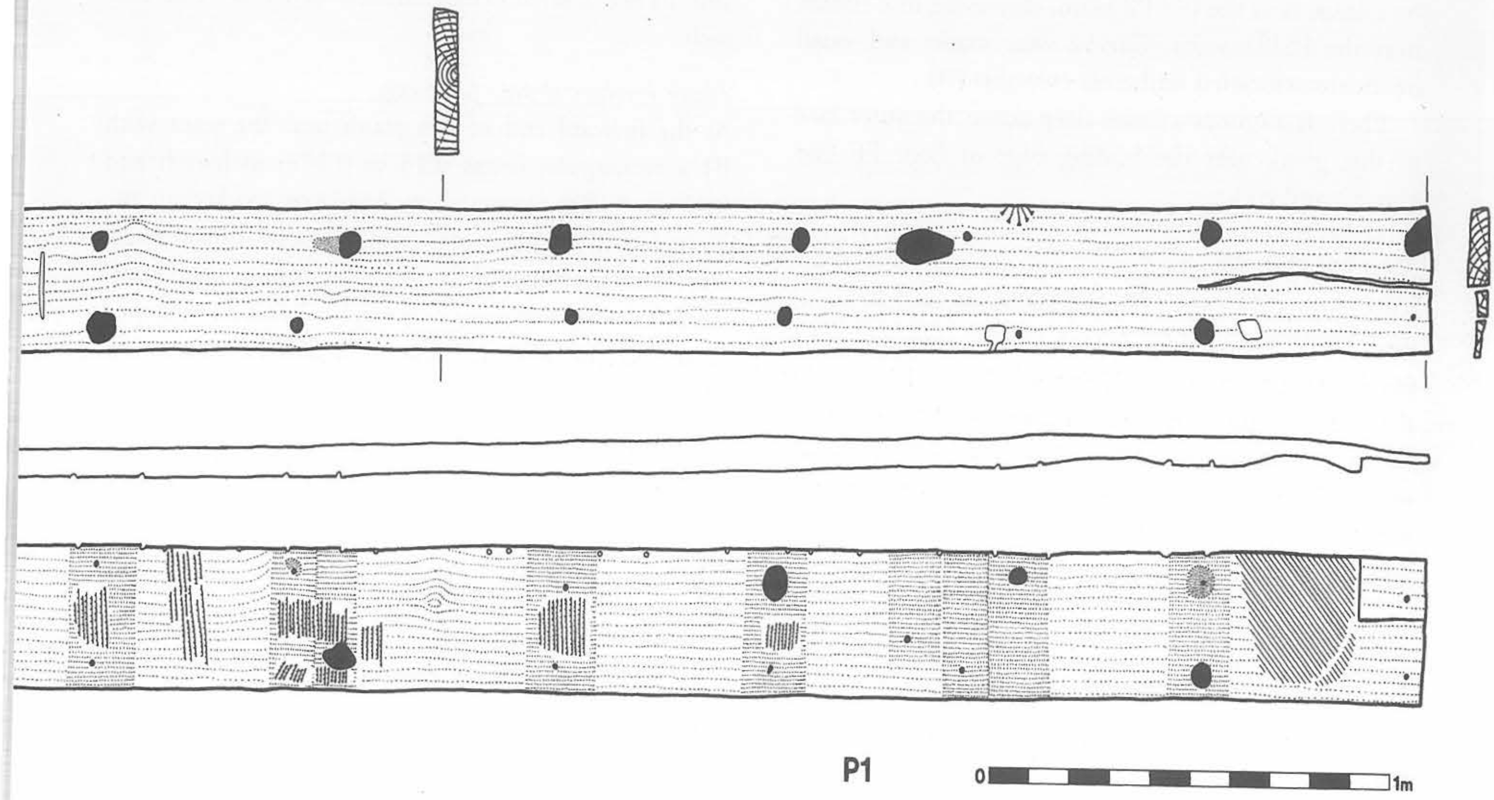
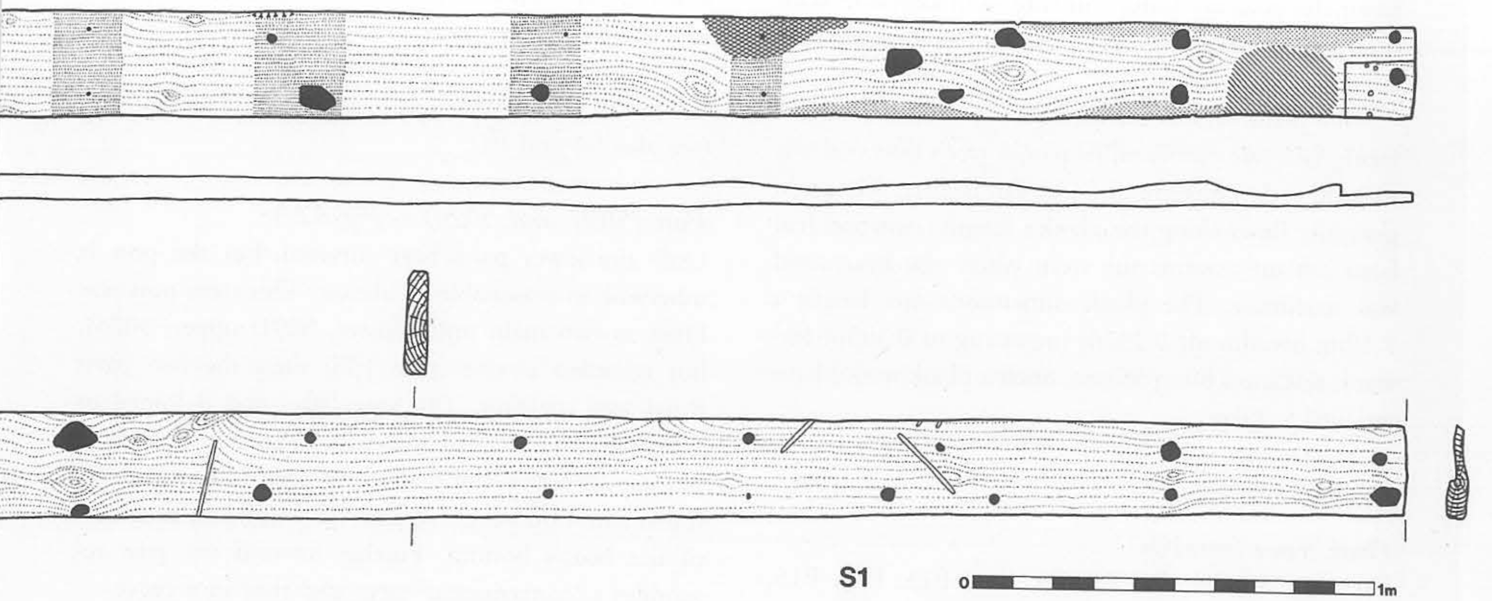


Figure A2.2 Plank-keel element S1.



P1



S1

by *c* 4mm near the P1/ P2 seam, increasing to *c* 16mm near the P1/S1 seam. Curved wear marks and small dents are associated with this (see also S1).

There is a groove *c* 2mm deep across the outer face of this plank near the leading edge of floor F6 (see also S2 and S1).

S1 (5113) – Fig A2.2

This starboard element of the plank-keel was lifted and drawn in three sections (plans 85, 86, and 87). The plank extends most the length of the bottom, from the half-lap joint with the stem post under floor timber F4 to a similar joint under F17. It partly butts with the starboard bow bottom plank (BS) and with the starboard quarter bottom plank (now missing). It is in good condition and comparable with P1.

Conversion

This plank was fashioned tangentially close to the pith of a straight-grained oak. (It has not yet proved possible to estimate the growth rate.) In the lower parts of this bole there were a few small branches; further up, branches increased in size and number, with two large branches at the top. This bole was more than 7m tall, had a maximum girth of *c* 1.54m (diameter 0.49m), and would have weighed *c* 763kg. Since this parent log has features similar to P1, these two planks may have been converted from halves of the same log.

Much of the bole had been sawn away during conversion. The plank retains the elongated tapering shape of its parent log with breadths decreasing from forward. Both edges are generally normal to the plank faces; the ends are butts with the stem post and with bow bottom plank BS1 and the corresponding timbers astern.

This plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was forward – the converse of P1 in this respect. The grain generally flows along the plank's length; sapwood had been left on towards the stern where the heartwood was narrowest. The plank dimensions are: length *c* 7.18m; breadth aft 0.232m increasing to 0.303m forward; thickness 60 to 55mm. Such a plank would have weighed *c* 90kg.

Boatbuilding features

Plank/frame fastenings

Floor timbers F4, F6, F8, F9, F11, F13, F14, F15, F16, and F17 were fastened to this plank-keel by two nails each. One of the nails through F4 (and F17) also passed through the post. Half-frames F5, F7, F10, F12, and F15Pt and St were fastened to S1 by one nail each.

Plank-keel/post/frame fastenings

At the forward end of this plank near the seam with P1 a rectangular recess 0.15 to 0.17m in length and 0.11 to 0.13m athwartships had been worked in the inner face to a depth of *c* 24mm (see also P1). There were similar arrangements at the stern plank-keel/ post scarf. Two nails, one each through P1 and S1, fastened plank-keel to post to frame (Fig 6.3.7). There were probably similar arrangements at the stern.

Caulking

Caulking with embedded nails was found in the seam with P1.

Builders' marks

Towards the forward end, on the S1/P1seam, there is a sequence of blind holes matching those on P1; the foremost two holes are entirely on S1. These holes mark the centreline of the boat.

Repair?

A treenail *c* 42mm in length and 11 × 14mm in section had been driven from the inner face between F5St and F6 into the seam next to S2 where its end was shaped to fit the plank edge. There is no sign of this on the corresponding edge of S2.

Signs of use

The inner face of the plank has been especially worn down: between F5St and F6 by 30 to 40mm, especially towards P1 (see also P1, P2, and S2); between F16 and F17 by *c* 20mm (see also P1); between F16 and F15St by *c* 25mm.

There is a groove 1 to 2mm deep across the *outer* face of this plank near the leading edge of floor F6 (see also S2 and P1).

***Post** (5091 and 5024) – Fig A2.3*

Only the lower parts have survived, but the post is otherwise in reasonable condition. This stem post was lifted as two main units (lower, 5091; upper, 5024), but recorded as one (plan 136) since the two parts fitted well together. The lower/after end is joined to the plank-keel P1 and S1 and the horizontal portion of the post forward of that joint (some 1.2m in length) forms with bow bottom planks BP and BS an extension of the boat's bottom. Further forward the post resembles a 'conventional' stem and rises in a curve.

Conversion

This post was fashioned from a natural oak crook,

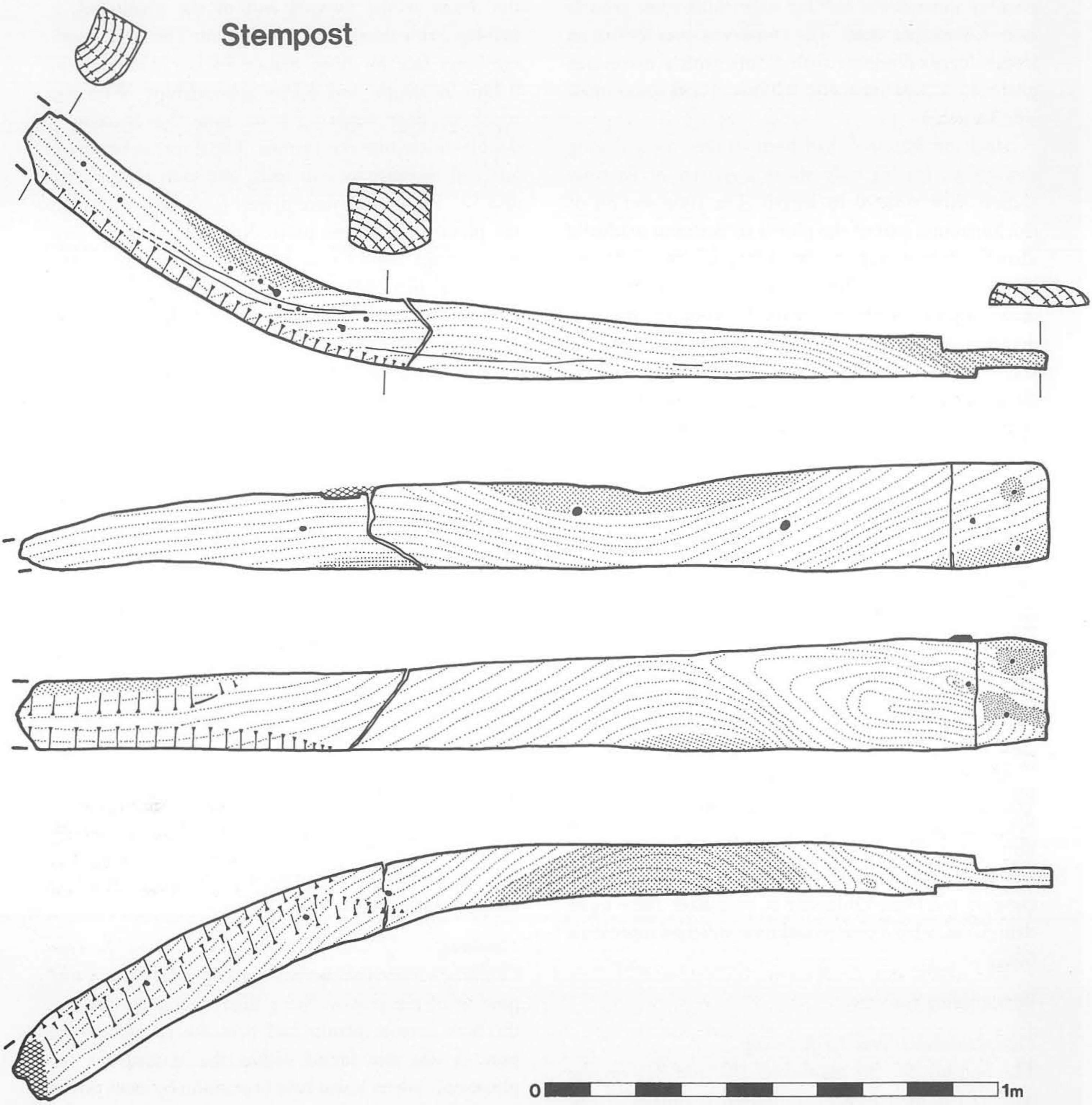


Figure A2.3 The Post.

possibly through the half-log stage, with a fast growth rate (6.8mm per year). The crook was over 2.15m in length (originally more than 3.5m), with a maximum girth of *c* 2.36m (diameter 0.75m); it had some small side branches.

Much of the crook had been worked away during conversion, leaving only about a quarter of its cross section over most of its length. The cross section of the horizontal part of the post is rectangular, gradually changing from *m/s* aft of *c* 88/242 (ie 0.36) to *c* 140/180 forward (ie 0.78). The forward portion of the post resembles a 'conventional' stem: it curves upwards with a radius of *c* 1.15m or more to reach a height of *c* 0.68m above the outer face of the bottom planking. At the upper surviving end its angle to the horizontal is 33°. The cross section of this forward/upper portion is rectangular with a rounded outer face (similar to that of Blackfriars 1). Over this section the *m/s* increases from *c* 150/183 (ie 0.86) to *c* 150/120 (ie 1.25) near the tip.

The sides of the post are normal to its faces; in the upper surviving portion there are rabbeted grooves on both sides to receive the ends of the side strakes (P/S3–7). At the after/lower end rectangular recesses for the plank-keel (below) and floor timber F4 (above) have been worked on both inner and outer faces.

The post was fitted in the boat so that its pith-facing face was outboard. Its parent tree's butt end was probably aft. The grain generally follows the curve of the upper surviving part of the post, but with some short grain. There is sapwood in places on both faces and both sides. The overall surviving length along the curve is *c* 2.15m. Originally it may have been more than 3.5m. Such a post would have weighed more than 60kg.

Boatbuilding features

Post/plank-keel/frame F4 fastenings

The housing for the plank-keel (P1 and S1) on the outer face of the post is *c* 22mm deep, 0.14m in length, and 0.24m athwartships. With this housing set into the recess at the forward end of the plank-keel, a half-lap (with sides) scarf was formed. The housing on the inner face for floor timber F4 is *c* 22mm deep, 0.23m in length, and 0.24m athwartships. With the notch in floor timber F4 set into this housing a double-notch joint was formed. The three timbers were fastened together by two nails, one each through P1 and S1. These nails were driven from below through the plank-keel and the protruding tongue of the post and through floor F4, to be clenched by turning the point through 180° into the inner face of that floor timber. These two nails thus fastened the post/plank-keel scarf to the post/floor timber double-notch joint. A third nail forward of the other two further fastened post and floor timber.

Floor timbers F1, F2, and F3 were each fastened to the post by one nail.

Bow bottom planks/post fastenings

The tip of each bow bottom plank (BP1 and BS1) is fastened to the post just below the lower end of the rabbets for the side planking (see below) by a nail (probably used as a spike) driven through the plank edges. These bow planks were not otherwise fastened to the post.

Side planking post fastenings

The forward ends of the side strakes (P/S 3 to 7) were fastened by nails (probably used as spikes) into a rabbet worked along the port and starboard faces of the upper post parallel to its curved leading edge. As the plank ends are fragmented and the sides of the post eroded, it is not possible to say precisely how many nails were used for each strake.

Caulking

Caulking survived along the outer edge of the horizontal portion of the post within a slight indentation where the bow bottom planks had been forced against the post. It was also found within the housing for the plank-keel, where it was held in position by tacks driven from below.

Framing

Floors

F1 (5076, 5077, and probably 5138) – Fig A2.4

This foremost floor timber was lifted in two main units, but recorded as one (plan 128). The upper part of the port arm is missing; the starboard arm is also incomplete, but fragment 5138 (Plan 164) may be the tip. This floor was positioned on the post, *c* 1.35m forward of the forward post/keel joint; it now extends from strake P3 to S3. The lower arms of this floor flare out at an angle of *c* 65° to the vertical, then *c* 45°. The chine breadth of the boat to the inside of the planking at this station is 0.15m; the breadth at strake 3 is *c* 0.33m.

Conversion

This floor was fashioned from an oak crook, with the pith in the middle in its horizontal element. The crook was formed from a main limb (starboard arm and horizontal element) with a side branch (port arm) and had a moderate growth rate (2.38 to 2.9mm per year). It was over 0.8m in length, with a girth of *c* 0.79m (diameter 0.25m), and had a number of other side branches.

Much of the crook had been worked away during conversion, leaving, for example, only half its cross section in the arms.

The floor was fitted in the boat with its parent tree's butt end to starboard. There is short grain in both arms where timber has been worked away to match the flare of the sides; there is sapwood on the outer face. The ends were probably wedge shaped originally. The cross section amidships is 'squared off' with *m/s* of 85/110 (ie 0.77); $m \times s$ is 9350. The port arm has a half-log section; to starboard it is more rectangular. This floor may originally have extended from P4 to S4. Such a timber would have weighed *c* 7kg.

Boatbuilding features

Fastenings

This floor was fastened to the post by one nail. Bow

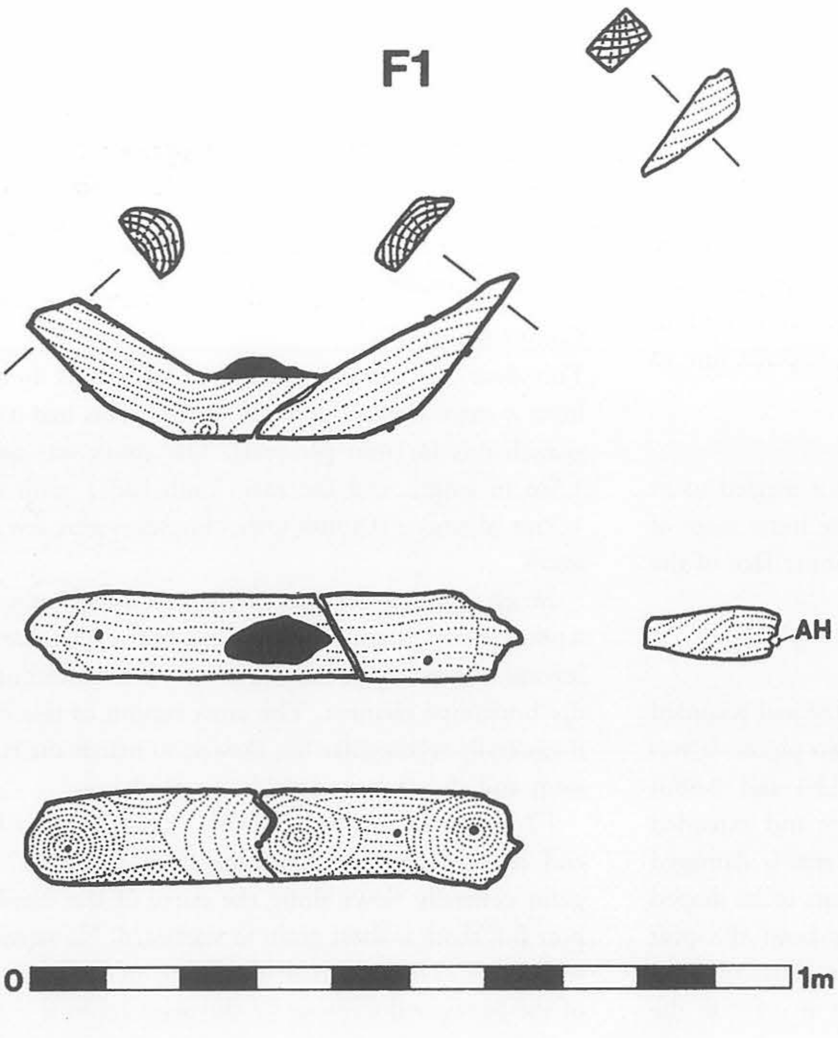


Figure A2.4 Floor F1. (Scale 1:10)

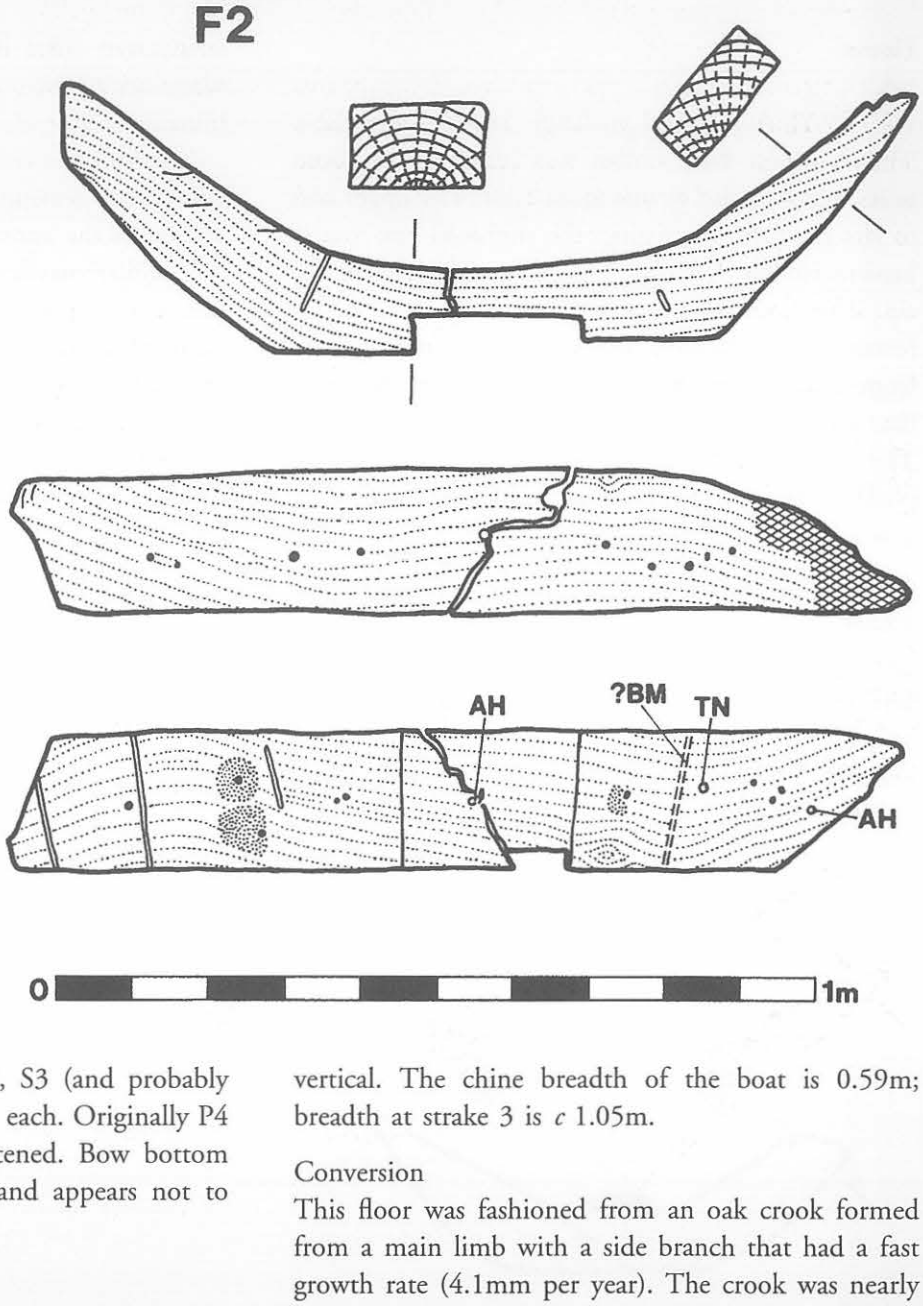


Figure A2.5 Floor F2.
(Scale 1:10)

bottom plank BS and strakes P3, S3 (and probably S4) were fastened to it by one nail each. Originally P4 may also have been similarly fastened. Bow bottom plank BP is not as long as BS and appears not to extend as far forward as F1.

Notch for the post

Unlike F2, F3, and F4, this floor is not joggled to fit the post. By this station, therefore, the inner faces of the planking must be flush with the inner face of the post.

F2 (5075) – Fig A2.5

The second floor from forward was lifted and recorded as one unit (plan 126); it is now in two pieces. It was positioned in the boat *c* 47m aft of F1 and 0.88m forward of the forward post/keel joint and extended from strake P4 to S3. The starboard arm is damaged but its cross section near the end appears to be shaped to match planking converging at the bow; the port arm appears complete – its tip is 0.36m above the base of this floor. The lower arms flare out at *c* 45° to the vertical. The chine breadth of the boat is 0.59m; breadth at strake 3 is *c* 1.05m.

Conversion

This floor was fashioned from an oak crook formed from a main limb with a side branch that had a fast growth rate (4.1mm per year). The crook was nearly 1.5m in length and the main limb had a girth of *c* 1.35m (diameter 0.43m). Other branches were few and small.

Much of the outer part of the crook had been was worked away to get the shape needed at this station, leaving, for example, less than half its cross section in the horizontal element. The cross section of this floor is generally rectangular but skewed to match the rising stem and the converging sides in the bows.

F2 was fitted in the boat with its parent tree's butt end to port and its pith-facing face outboard. The grain generally flows along the curve of the crook to port but there is short grain to starboard. No sapwood was noted. The moulded dimension of the port side of the horizontal element (ie the main limb) is *c* 20%

greater than that of the starboard side (the branch). The *m/s* to port is *c* 110/185 (ie 0.594); to starboard it is *c* 90/175 (ie 0.514).

Corresponding $m \times s$ are: port, 20,350; starboard, 15,750. Thus this was not a symmetrical floor and notches cut in the two bow bottom planks to house it had to be deeper to port (BP) than to starboard (BS), so that the floor's inner face would be horizontal. The overall length of this floor is 1.3m. Such a timber would have weighed *c* 17kg.

Boatbuilding features

Fastenings
This floor was fastened by one nail to the post. Strakes P4, possibly S4, and the bow bottom planks BP and BS were fastened to it by one nail each. Lowest side strakes P3 and S3 were each fastened to it by two nails.

Post notch
This floor is joggled to fit over the post, the notch being 210 × 48 to 33mm, reducing in depth forward as the post begins to rise.

Builders' marks or tool marks
There are shallow grooves 1mm deep cut across the outer face of this floor at seams S2/S3, near P3/P4, near P4/P5, and possibly by P2/3. The marks at the chine do not extend right across the breadth of the floor.

F3 (5074) – Fig A2.6

The third floor from forward was lifted and recorded as one unit (plan 125). Strictly speaking it should be classified as a half-frame, since it appears to be complete yet does not extend up the starboard side. There is no sign on the bottom planking of a partner half-frame aft and to starboard, however, as is the pattern elsewhere in this boat (at stations 5, 7, 10, 12, and 15). On the other hand the fragmentary timber SF3St (5101) may have been at station 3 rather than aft of it, the two timbers together forming a frame at this station. Being fragmented the starboard planking cannot throw further light on this problem.

This floor was positioned in the boat *c* 0.43m aft of F2 and *c* 0.45m forward of the forward post/keel scarf; it extended from P4 to S3. The port arm flares

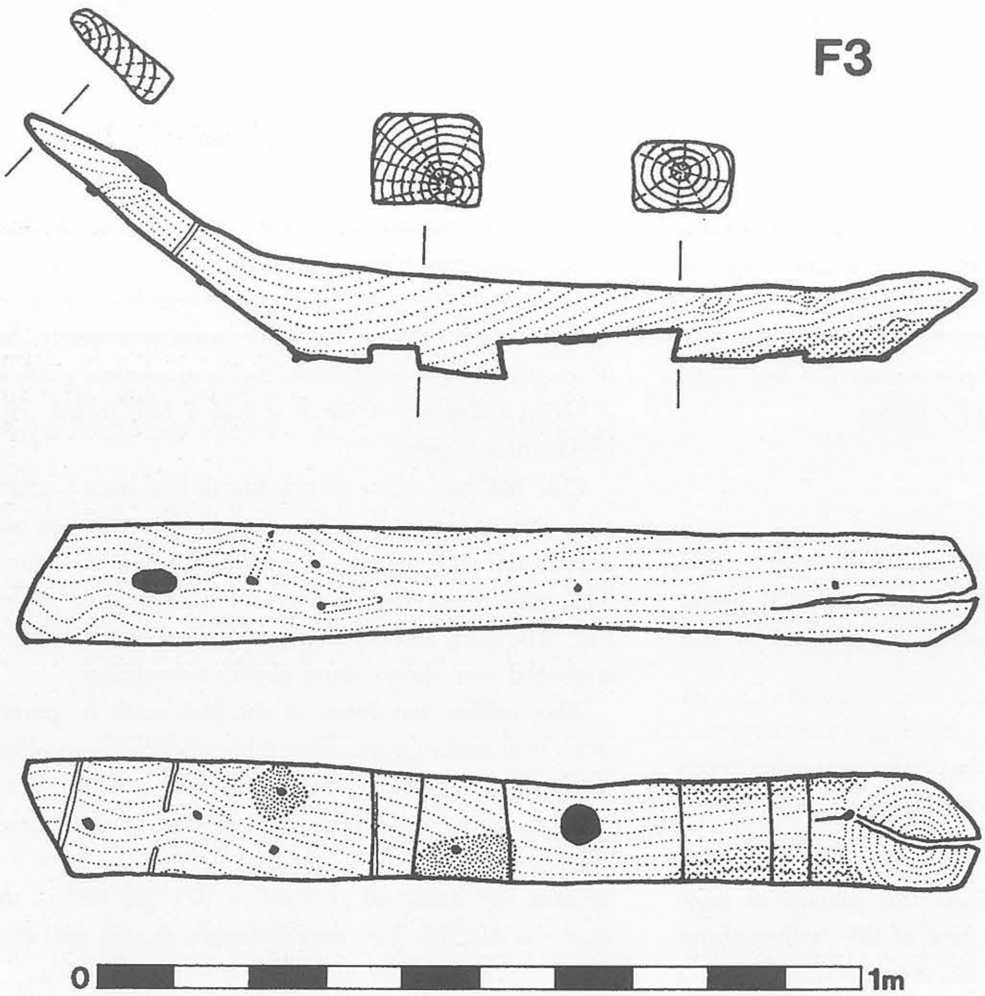


Figure A2.6 Floor F3. (Scale 1:10)

out at *c* 50° to the vertical; its tip is *c* 0.33m above the floor's base. The starboard end is shaped to take against lowest side strake S3. The chine breadth of the boat is *c* 0.76m; breadth at strake 3 is *c* 1m.

Conversion

This timber was fashioned from an oak crook formed from a main limb (the port arm) with a side branch (the horizontal element); it had a moderate growth rate (2.1mm per year). This crook was *c* 1.3m in length and the main limb had a girth of *c* 1.23m (diameter 0.39m).

Although a large part of the branch's cross section survives in the horizontal element, some of it has been worked away where the branch joins the main limb. Towards the other end, this branch had insufficient wood to give the horizontal element of this timber a constant moulded dimension. Much of the outer part of the main limb has been worked away to form the port arm. The cross section is generally rectangular, but that of the arm is skewed to match the convergence of the bow.

This timber was fitted in the boat with its parent tree's butt end to port. The grain generally flows along this timber, but there is short grain near the chine. There is sapwood (twelve rings) on the outer face of the horizontal element and along one edge of the arm. The moulded dimensionof the port side of the floor section is some 25% greater than that of the starboard side (see F2). The *m/s* to port is 120/145 (0.83); to starboard it is 90/125mm (0.72). Corresponding $m \times s$ are: port, 17,400; starboard, 11,250. Like F2 this is not a symmetrical timber: to make the floor's inner face horizontal a notch was cut in BP but not in BS. The overall length of this timber is 1.3m. Such a timber would have weighed *c* 12 kg.

Boatbuilding features

Fastenings

This timber was fastened by one nail to the post. Strakes P4 and S3 and bow bottom plank BP were fastened to it by one nail each and strake P3 by two nails.

Post notch

This floor is joggled to fit over the post, the notch being *c* 215 × 45mm (starboard) and × 35mm (port).

Limber holes

Longitudinal notches to ensure free passage of bilge water were cut in the outer face of this timber above bow bottom planks BP and BS; cross sections were 55 to 60 × 20 to 23mm (port) and × 10mm (starboard). These are the furthest forward limber holes.

Builders' marks or tool marks

There are shallow grooves cut across the outer face of this timber in the vicinity of the P3/P4 seam – this appears to continue around to the forward face and in the vicinity of the P4/P5 seam.

F4 (5073) – Fig A2.7

The fourth floor from forward, which had been displaced aft of its station when excavated, was lifted and recorded as one unit (plan 123). The port arm appears to be almost complete; the starboard arm is broken and incomplete. This floor and the corresponding one aft (F17) are key timbers in the boat's structure, since they are essential elements of the joints by which the posts are fastened to the plank-keel. Floors F4 and F17 must have been among the earliest framing timbers to be positioned. Floor F4 is incomplete to starboard; it now extends from P5 to S4. The curve of both arms of this floor is actually more graceful than can be shown in a measured drawing. The bilge curves of this floor have a radius of *c* 0.78m.

The chine breadth of the boat is *c* 0.8m.; breadth at strake 4 is *c* 1.53m. The tip of the port arm is 0.29m above the outer face of this floor; the starboard tip was more than 0.31m.

Conversion

This timber was fashioned from an oak crook formed from a main limb (the port arm and horizontal element) with a branch (the starboard arm); three other branches had to be trimmed away. This crook was nearly 2m in length and the main limb had a maximum girth of *c* 1.63m (diameter 0.52m); it had a fast growth rate (5.35mm per year).

One half and more of this crook had been worked away during conversion. It is conceivable that this was mainly done by sawing along the curving centreline. The other half crook may then have been used for F17. The cross section is generally rectangular, but the starboard arm shows some plank convergence.

This timber was fitted in the boat with its parent tree's butt end to port. The grain generally flows along the horizontal element of this timber, but there is short grain in both arms. There is sapwood at the chines. The main limb *m/s* is 130/220 (0.59), the $m \times s$ is 28,600; the starboard arm *m/s* is 105/188 (0.56), the $m \times s$ is 19,740. The overall length of this timber is 1.8m. Such a timber would have weighed *c* 30kg.

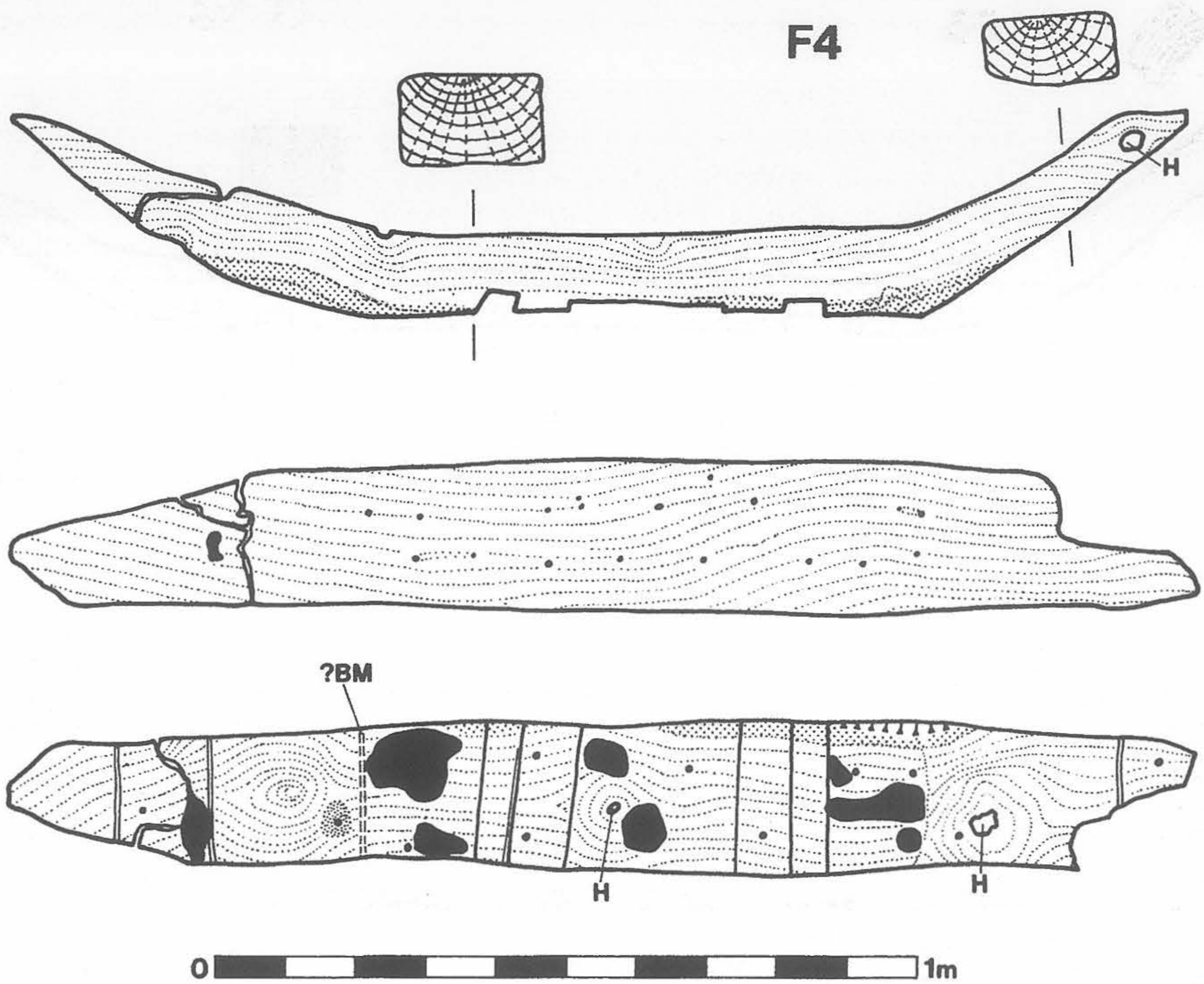


Figure A2.7 Floor F4. (Scale 1:10)

Boatbuilding features

Fastenings
This timber was fastened to the post by three nails; one of these also passes through P1 while another also passes through S1. It was also fastened to plank-keels P1 and S1 by two nails each (one to port and one to starboard of these four nails also pass through the post). Outer bottom planks P2 and S2 and lowest side strakes P3 and S3 were fastened to it by one nail each. Bow bottom planks BP and BS and side strake P4 were fastened by two nails each and probably also S4 (although only one such fastening has survived).

Post notch
This floor is joggled to fit over the post, the notch being *c* 240 × 23mm. This joggled notch and the housing cut in the inner surface of the post form a double-notch joint.

Limber holes
Limber holes were cut above P1 and BP and above S1 and BS. The cross sections of these two limber holes are 48 × 23mm (port) and 53 × 14mm (starboard).

Builders' marks or tool marks
There are shallow grooves *c* 2mm deep cut across the outer face of this timber at the port chine, in the vicinity of the P3/P4 seam, the P4/P5 seam (almost a ledge here), near the S3/S4 seam, and possibly at the starboard chine.

F6 (5070) – Fig A2.8

Floor F6, the fifth floor from forward, was lifted and recorded as one unit (plan 124). It is incomplete to starboard and extends from P5 to S4. The curve around the port bilge has a radius of *c* 0.78m. The starboard curve initially matches the port, but then the timber appears to be distorted. The upper part of this floor

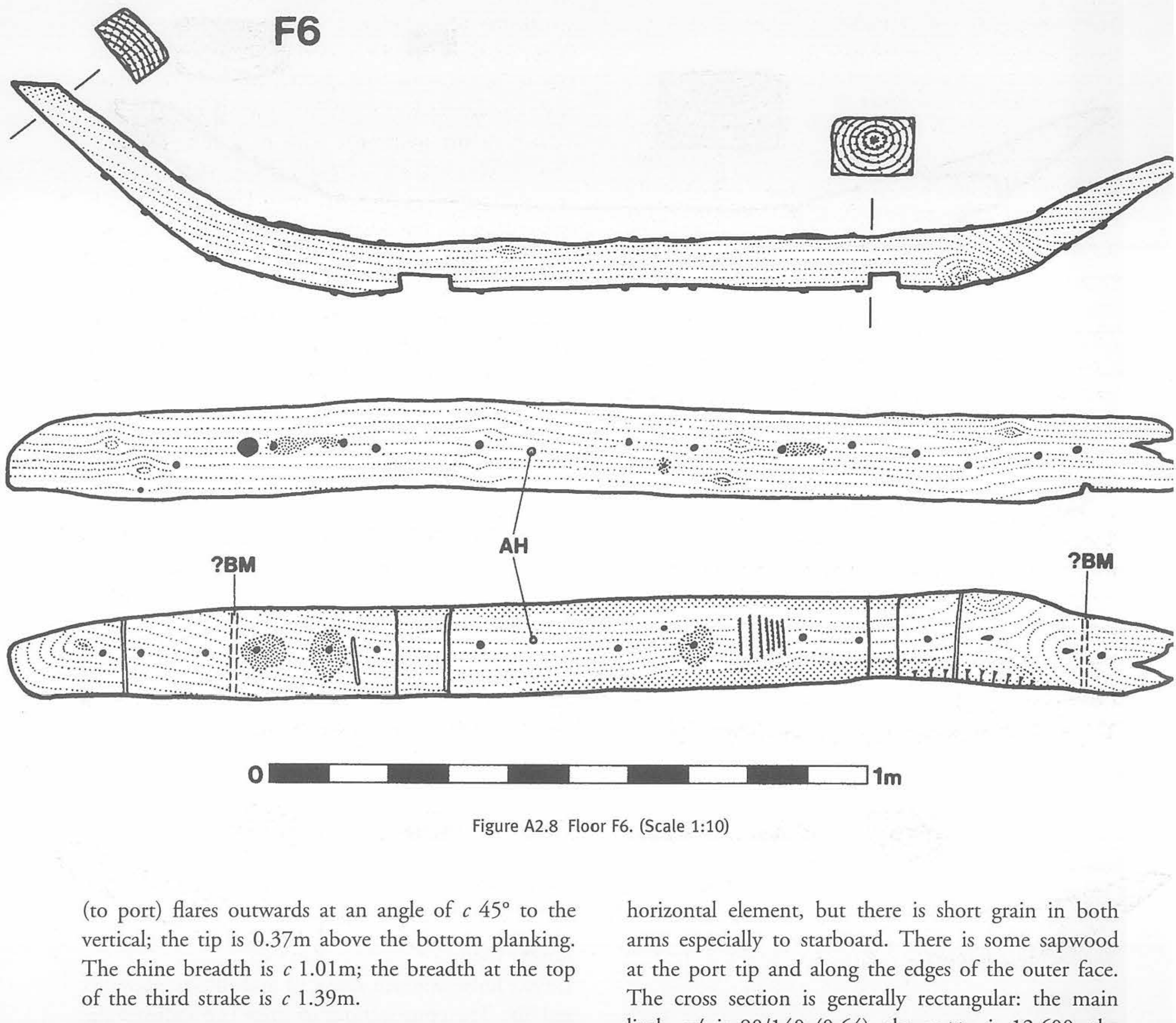


Figure A2.8 Floor F6. (Scale 1:10)

(to port) flares outwards at an angle of *c* 45° to the vertical; the tip is 0.37m above the bottom planking. The chine breadth is *c* 1.01m; the breadth at the top of the third strake is *c* 1.39m.

Conversion

This timber was fashioned from an oak crook formed from a main limb (the port arm and the horizontal element) with a branch (the starboard arm). Other branches had to be trimmed away. This crook was at least 2.08m in length and probably originally over 2.3m. The main limb had a girth of *c* 1.07m (diameter 0.34m); it had a fast growth rate (3.56mm per year).

The greater part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but more than half of the cross section had been worked away to get the necessary curve for the rising arms.

This timber was fitted in the boat with its tree-butt end to port. The grain generally flows along the horizontal element, but there is short grain in both arms especially to starboard. There is some sapwood at the port tip and along the edges of the outer face. The cross section is generally rectangular: the main limb *m/s* is 90/140 (0.64), the $m \times s$ is 12,600; the port arm *m/s* is 55/110 (0.50), the $m \times s$ 6050. With an original overall length of *c* 2.3m such an oak timber would have weighed *c* 21kg.

Boatbuilding features

Fastenings

This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strakes P4, P3, and S3 were fastened to it by two nails each. P5 was fastened to this floor by one nail; S4 is similarly fastened, but there may have been a second in now missing parts. The mast-step timber was fastened by a spike driven from above which pierced floor F6 and slightly entered plank-keel S1.

Limber holes
The cross sections of the limber holes are 57 × 21mm (port) and 49 × 21mm (starboard).

Builders' marks or tool marks
There are shallow grooves 1 to 2mm deep cut across the outer face of this timber near the port chine (incomplete), near the starboard chine, in the vicinity of the P4/5 seam, and possibly P3/4 and S3/4. There is a groove 5mm wide within the inner angle of the port limber hole.

F8 (5067) – Fig A2.9
Floor F8, the sixth floor from forward, was lifted and recorded as one unit (plan 113). It is complete to port with a horizontal surface worked at the top of this arm; towards the other end, beyond the starboard limber hole, it is broken into several pieces, but these fit together and the end is very nearly complete. This floor extends from P4 (not fastened) to S4. The sides flare outwards at an angle of *c* 60° from the vertical; the port tip is 0.16m, the starboard *c* 0.2m above the outer horizontal face. The chine breadth is *c* 1.25m; the breadth at the top of the third strake is *c* 1.58m.

Conversion
This timber was fashioned from an oak crook that was at least 1.95m in length. The main limb had a girth of *c* 0.94m (diameter 0.3m); it had a fast growth rate (3.56mm per year). Some medium-sized branches had first to be removed. A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but some of the cross section was worked away to get the necessary curve for the rising arms. The grain generally flows along the floor element, but there is short grain in both arms especially to port. Some sapwood had been left along the forward face on the port side.

The cross section is generally rectangular: the main limb *m/s* is 75/125 (0.60), the *m* × *s* is 9375. With an original overall length of *c* 1.95m, such an oak timber would have weighed *c* 12kg.

Boatbuilding features

Fastenings
This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strakes P3, S3, and S4 were fastened to it by two nails each.

Limber holes
The cross sections of limber holes are 55 × 20mm (port), and 55 × 16mm (starboard).

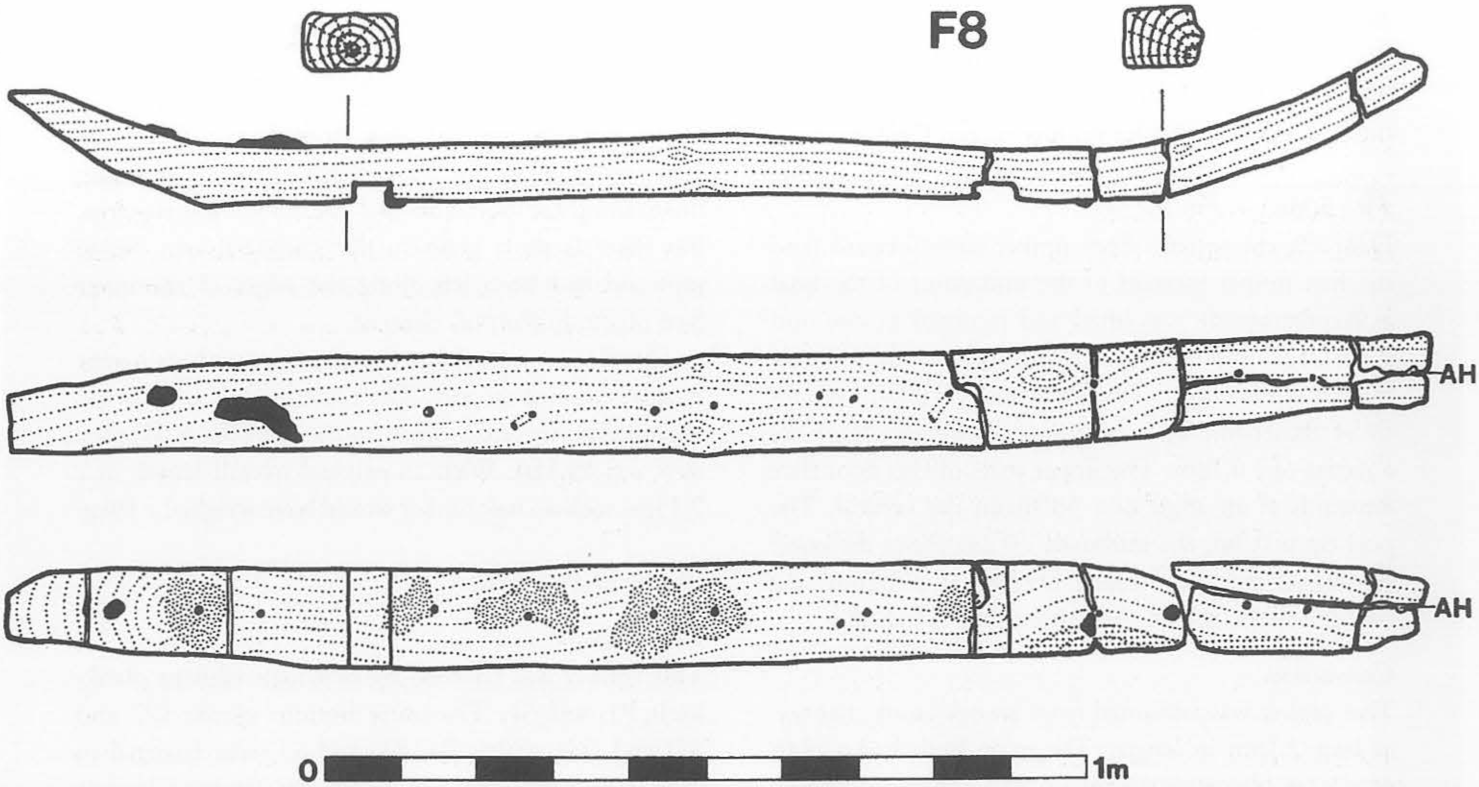


Figure A2.9 Floor F8. (Scale 1:10)

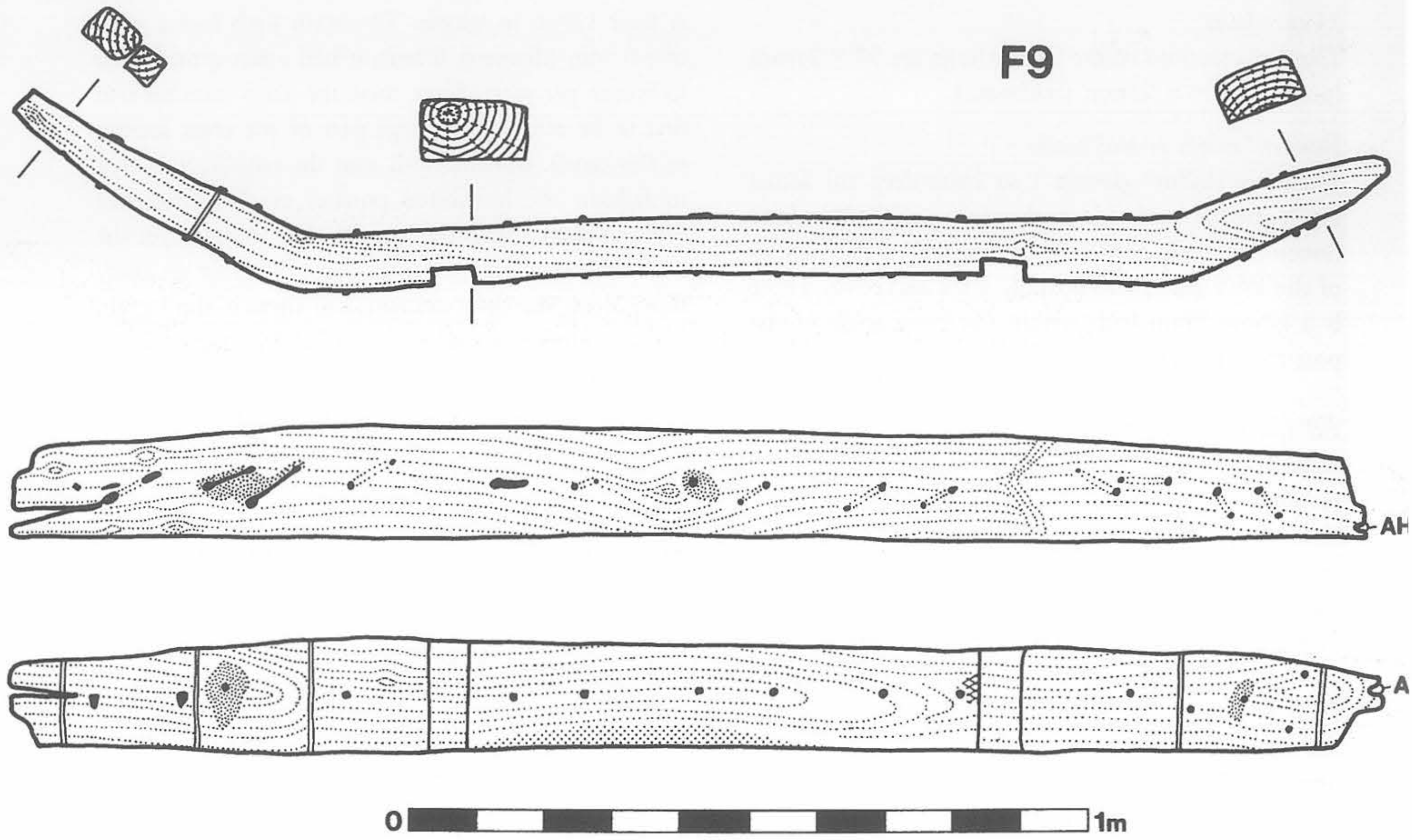


Figure A2.10 Floor F9.

Builders' marks or tool marks
There are shallow grooves 1 to 2mm deep cut across the outer face of this timber near the port chine (incomplete) and in the vicinity of the P3/4 seam.

F9 (5066) – Fig A2.10

Floor F9, the seventh floor timber from forward (and the first timber forward of the mid-point of the boat as reconstructed), was lifted and recorded as one unit (plan 112). This is an almost complete timber slightly broken at the ends; it extends from P5 (slight overlap) to S4 (fastened). The curve around the port bilge has a radius of *c* 0.78m. The upper parts of this floor flare outwards at an angle of *c* 50° from the vertical. The port tip is 0.3m, the starboard *c* 0.2m above the outer horizontal face. The chine breadth is *c* 1.26m; the breadth at the top of the third strake is *c* 1.68m.

Conversion

This timber was fashioned from an oak crook that was at least 2.15m in length. The main limb had a girth of *c* 1.1m (diameter 0.35m); it had a medium growth rate (2.24mm per year). Some small branches had first to be removed. A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but some of the cross section had been worked away to get the necessary curve for the rising arms. The grain generally flows along the port arm and the horizontal element, but there is short grain in the starboard arm. Some sapwood had been left along the edges of the outer face of the horizontal element.

This floor was positioned in the boat with its parent limb's butt end to port. The cross section is generally rectangular: the main limb *m/s* is 89/150 (0.59), the $m \times s$ is 13,350. With an original overall length of *c* 2.15m, such an oak timber would have weighed *c* 19kg.

Boatbuilding features

Fastenings
This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strakes P4, S3, and S4 were fastened to it by two nails each. Strake P3 was fastened by one nail.

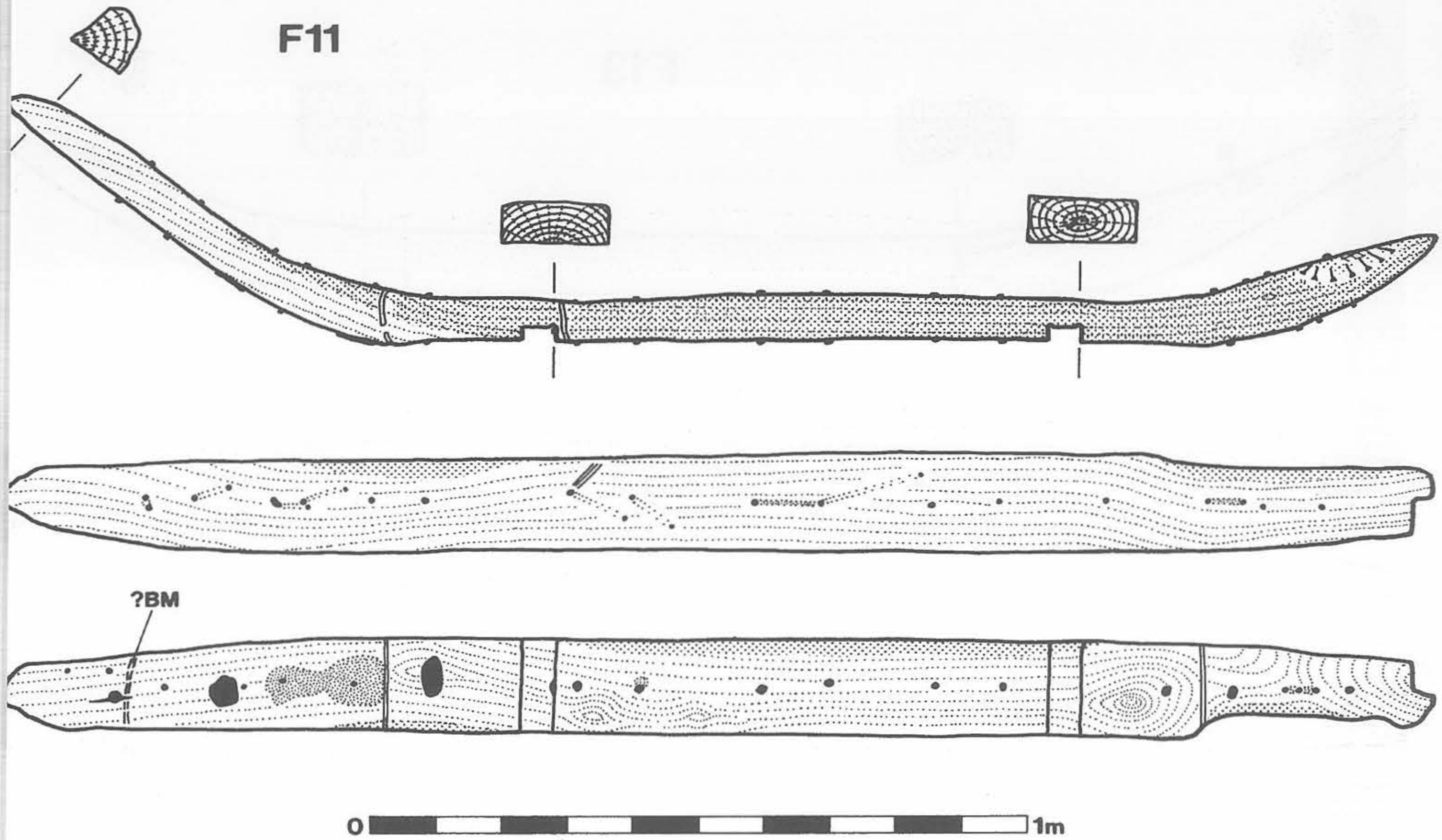


Figure A2.11 Floor F11.

Limber holes
The cross sections of limber holes are 56 × 17mm (port) and 61 × 19 (starboard).

Builders' marks or tool marks
There are shallow grooves cut across the outer face of this timber near both chines and in the vicinity of the seams P3/4, P4/5, and S3/4. These grooves are generally 1mm deep but that near seam P4/5 is 4mm deep. There is another shallow groove across the after face by seam P3/4.

F11 (5063) – Fig A2.11

Floor F11, the eighth floor timber from forward, was the first framing timber aft of the mid-point of the plank-keel. It was lifted and recorded as one unit (plan 108). This is an almost complete timber, with recent damage to the starboard arm but its tip probably survives; it extends from P5 to S4. The curves around the bilge have a radius of *c* 0.88m. The upper parts of this floor flare outwards at an angle of *c* 50° from the vertical; the port tip is 0.43m, the starboard *c* 0.2m above the outer horizontal face. The chine breadth is *c* 1.26m; the breadth at the top of the third strake is *c* 1.63m.

Conversion
This timber was fashioned from an oak crook that was at least 2.36m. in length. The main limb (port arm and horizontal element) had a girth of *c* 0.82m (diameter 0.26m); it had a fast growth rate (3.61mm per year). The main limb formerly divided into two branches near the starboard chine: one branch was fashioned into the starboard arm; the other was removed. A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but more of the cross section had been worked away to get the necessary shape for the rising arms. The grain generally flows along the horizontal element, but there is short grain in the starboard arm and near the top of the port arm.. Some sapwood had been left along the lower edges of the outer face of the horizontal element.

This floor was positioned in the boat with its parent limb's butt end to port. The cross section is generally rectangular: the main limb *m/s* is 89/170 (0.52), the

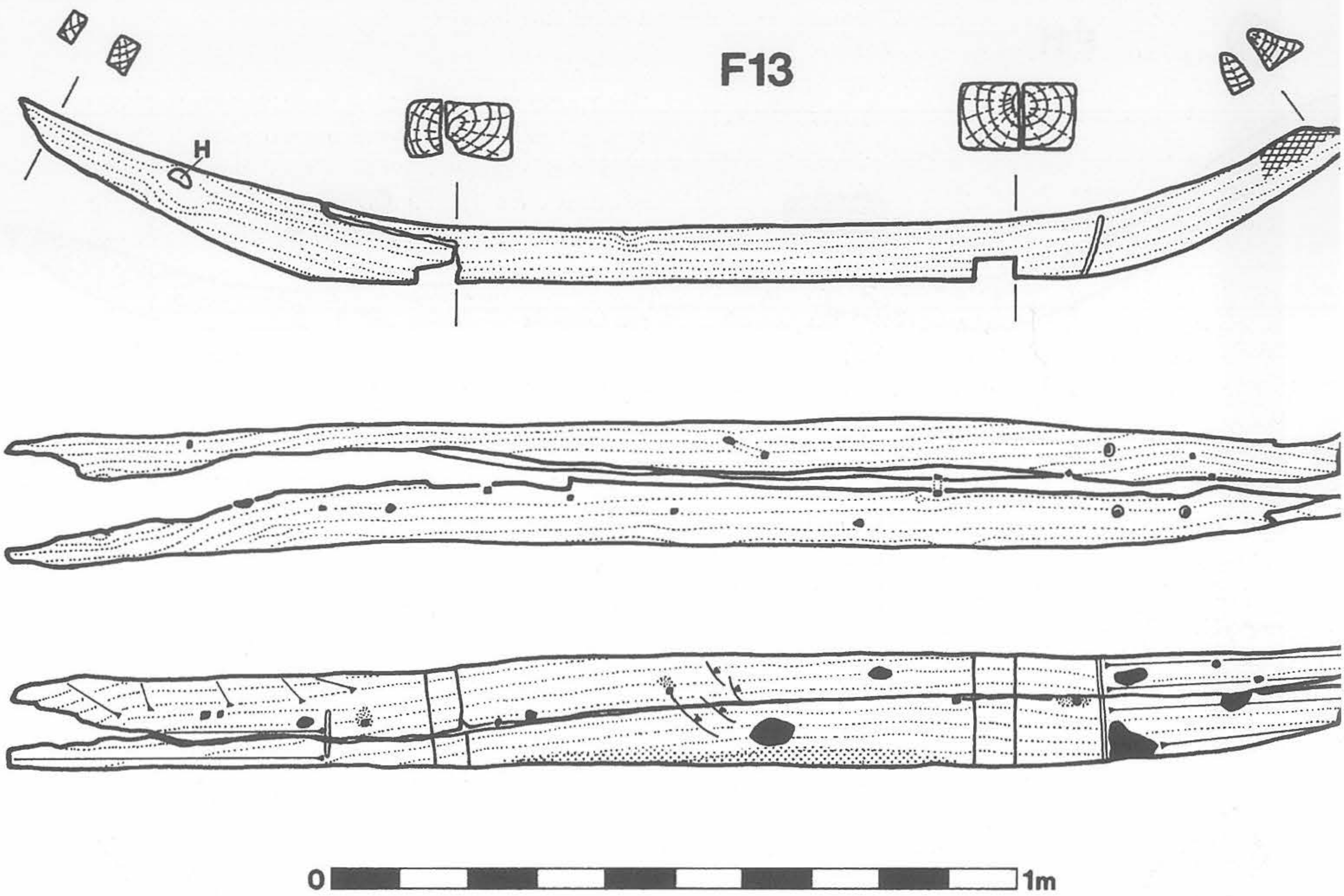


Figure A2.12 Floor F13. (Scale 1:10)

$m \times s$ is 15,130; with an original overall length of *c* 2.34m, such an oak timber would have weighed *c* 25kg.

Boatbuilding features

Fastenings
This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strakes P3, P4, and S3 were fastened to it by two nails each. The butt joint in P5 was fastened by two nails in each plank, while strake S4 was fastened by one nail

Limber holes
The cross sections of limber holes are 58 × 26mm (port) and 51 × 27mm (starboard).

Builders' marks or tool marks
There are shallow grooves *c* 1mm deep cut across the outer face of this timber near both chines and possibly in the vicinity of P4/5 seam. There are also grooves on the *after* face near the P2/3 seam and near the port limber hole. On the *inner* face near the P1/2 seam, three short, feint, parallel lines are scored. In the upper corners of the limber holes there are good examples of auger and saw marks.

F13 (5060 and possibly F5097) – Fig A2.12
Floor F13, the ninth floor timber from forward, was lifted and recorded as one unit (plan 104). This timber, now split lengthways into two, is warped in places and consists of several fragments. The port end is damaged but appears to be close to the original length; the starboard end is incomplete. Timber 5097 may be part of this floor. F13 extends from P5 (touching only) to S4. The curves around the bilge have a radius of *c* 0.8m. The upper parts of this floor flare outwards at an angle of *c* 55° from the vertical; the port tip is 0.29m above the outer horizontal face. The chine breadth is *c* 1.1m; the breadth at the top of the third strake is *c* 1.55m.

Conversion
This timber was fashioned from an oak crook that was

at least 2.03m. in length. The main limb had a natural curve (starboard arm and horizontal element) and a girth of *c* 0.91m (diameter 0.29m); it had a fast growth rate (4.3mm per year). Part of a medium-sized knot in the port arm (the branch) had rotted away before excavation. A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but more of the cross section had been worked away to get the necessary shape for the rising arms. The grain generally flows along this timber, there being little if any short grain. There is a little sapwood on the upper forward edge.

This floor was positioned in the boat with its parent limb's butt end to starboard. The cross section is generally rectangular: the main limb *m/s* is 83/168 (0.49), the *m* × *s* is 13,944. With an original overall length of *c* 2.1m, such an oak timber would have weighed *c* 20kg.

Boatbuilding features

Fastenings
This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strakes P3 and P4 were fastened to it by two nails each. The butt joint in S3 was fastened by two nails in each plank. Strake S4 was fastened by one nail.

Limber holes
The cross sections of limber holes are 65 × 23mm (port) and 57 × 21mm (starboard).

Builders' marks or tool marks
There are shallow grooves *c* 1mm deep cut across the outer face of this timber near both chines.

F14 (5059) – Fig A2.13

Floor F14, the tenth floor timber from forward, was lifted and recorded as one unit (plan 103). The central

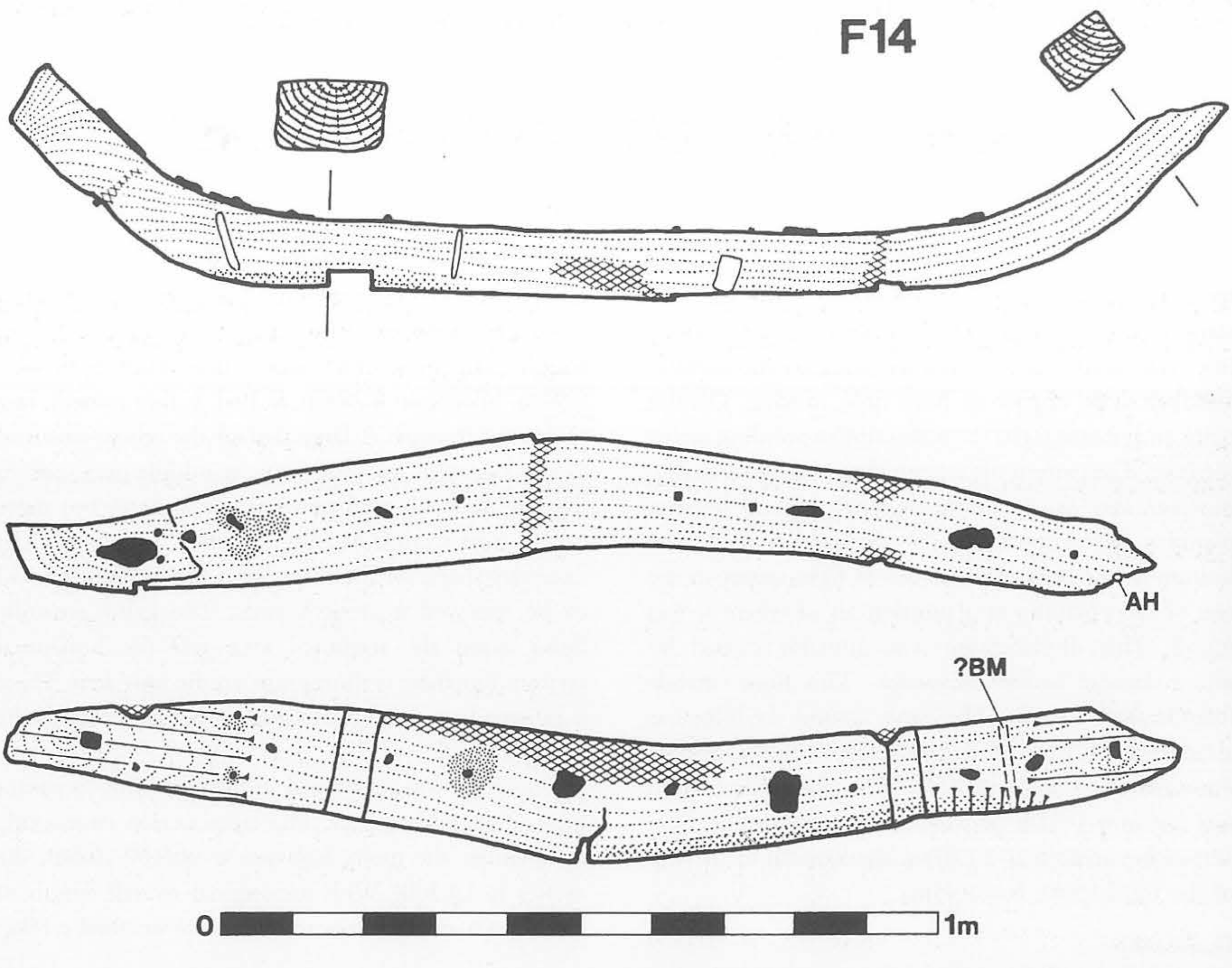


Figure A2.13 Floor F14. (Scale 1:10)

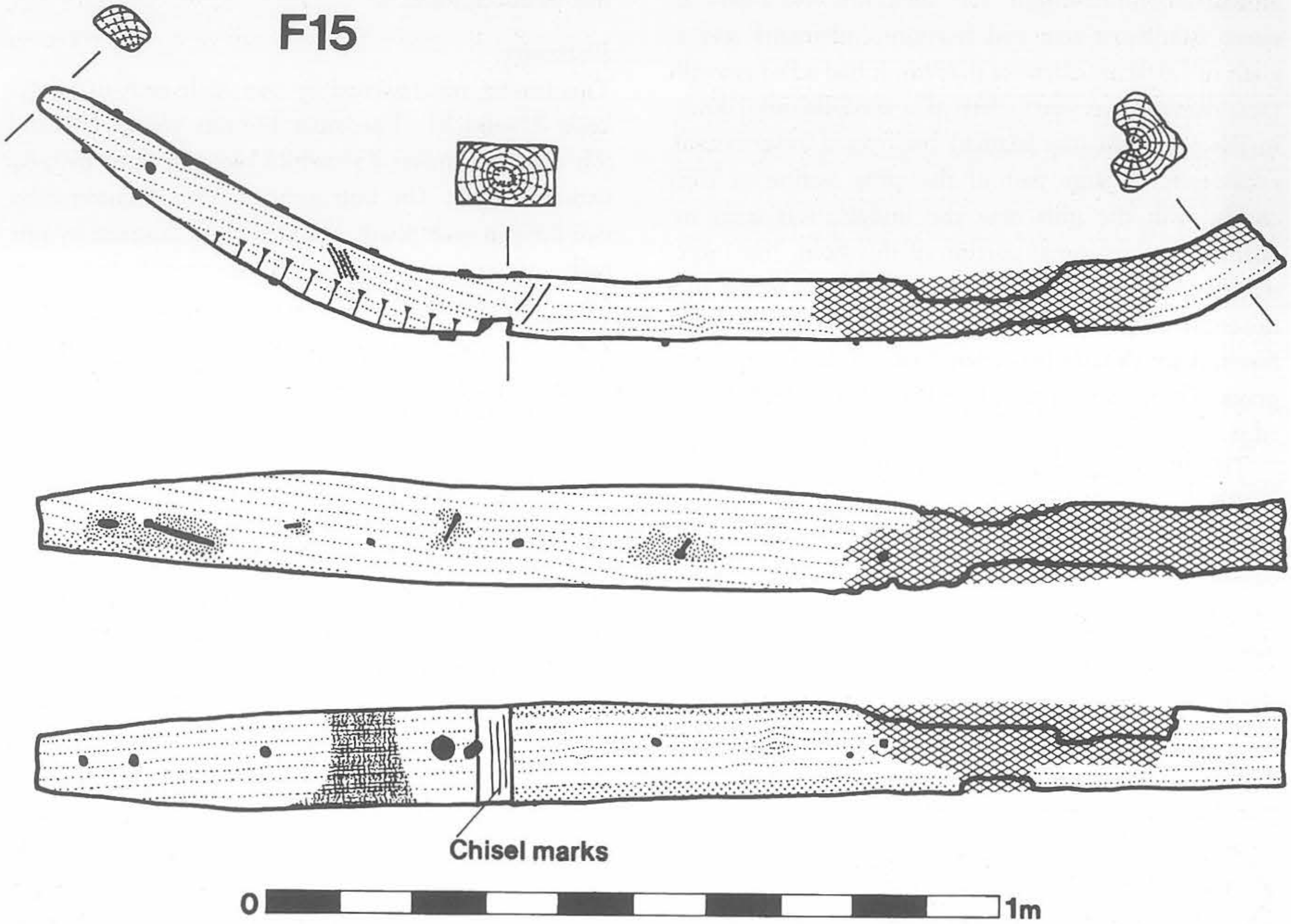


Figure A2.14 Floor (F15). (Scale 1:10)

section of this timber had been pushed forward of its station prior to excavation. This timber is now broken into four major portions and the ends are incomplete, although both appear to have little missing. On-site plans and photographs show this timber winding across the boat. The pattern of fastening holes in the planking, however, and 'ghosts' on the upper faces of the bottom planking demonstrate that it originally spanned the bottom of the boat more or less at right-angles to the run of the planking at a position aft of where it was found. This displacement was probably caused by recent damage before excavation. This floor extends from strake P4 to S4. The curve around the bilge has a radius of *c* 0.78m. The upper parts of this floor flare outwards at an angle of *c* 50° from the vertical; both tips are now 0.31m above the outer horizontal face. The chine breadth is *c* 1.07m; the breadth at the top of the third strake is *c* 1.43m.

Conversion

This timber was fashioned from an oak crook consisting of a main limb (port arm and horizontal section) and a branch (starboard arm) that was at least 1.95m in length. The main limb had a maximum girth of *c* 0.91m (diameter 0.29m); it had a fast growth rate (3.3mm per year). A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but more of the cross section had been worked away to get the necessary shape for the rising arms. Large branches had to be removed near both ends. The grain generally flows along the starboard arm and the horizontal section, but there is short grain on the port arm. There is sapwood on the forward and inner faces towards the starboard end.

This floor was positioned in the boat with its parent limb's butt end to port. The cross section is generally rectangular: the main limb *m/s* is 90/150 (0.60), the $m \times s$ is 13,500. With an original overall length of *c* 2m, such an oak timber would have weighed *c* 18kg.

Boatbuilding features

Fastenings
This timber was fastened by two nails each to plank-keels P1 and S1. The outer bottom planks (P2 and S2) and side strake S3 were fastened to it by two nails each, P4 and S4 by one nail each. The butt joint in P3 was fastened by two nails in each plank.

Limber holes
The cross sections of limber holes are 50 × 20mm (port) and 45 × 18mm (starboard).

Builders' marks or tool marks
There is a shallow groove *c* 1mm deep cut across the outer face of this timber near S2/3 seam.

F15 (5058) – Fig A2.14

Floor F15, the eleventh floor timber from forward, was lifted and recorded as one unit (plan 102). This floor now extends from P5 to S3. From outer bottom plank S2 out to starboard it is badly damaged and the end is missing. Half-frame F15Pt lies aft of and immediately adjacent to this timber. The curve of F15 around the port bilge has a radius of *c* 0.8m, while the upper part flares outwards at an angle of *c* 60° from the vertical; the port tip is 0.35m above the outer horizontal face. The external chine breadth is *c* 1.05m.

Conversion
This timber was fashioned from a curved oak limb that was at least 1.82m in length. This limb had a maximum girth of *c* 0.91m (diameter 0.29m); it had a slow growth rate (1.81mm per year). A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal element of this floor, but more of the cross section had been worked away to get the necessary shape for the port arm. The grain generally flows along the port arm and the horizontal section. There is sapwood and some bark on the outer face and on the forward face at the chines.

This floor was positioned in the boat with its parent limb's butt end to port. The cross section is generally rectangular and there is no sign of plank convergence: the main limb *m/s* is 80/132 (0.61), the $m \times s$ is 10,560. With an original overall length of *c* 2m, such an oak timber would have weighed *c* 15kg.

Boatbuilding features

Fastenings
This timber was fastened by one nail to plank-keel P1 and by two to S1. The outer bottom planks (P2 and S2) were fastened to it by two nails each and side strakes P3, P4, and P5 by one nail each. It is not clear how S3 was fastened to it.

Limber holes
The cross section of the port limber hole is 42 × 23mm (port).

Signs of use
The boat's framing sequence and spacing suggest that floor F15 was an afterthought fitted adjacent to and forward of the paired half-frames F15Pt and St to reinforce the framing at that station.

F16 (5055) – Fig A2.15

Floor F16, the twelfth floor timber from forward, was lifted and recorded as one unit (plan 99). The port end of this timber is complete though damaged; the starboard end is incomplete and decayed. When excavated this floor was found to have been recently damaged and distorted and its central and starboard sections displaced aft of their original position. This floor now extends from P5 to S4. The lower, curving portion of the port arm has a radius of *c* 0.85m, while the upper part flares outwards at an angle of *c* 45° from the vertical; the port tip is 0.54m above the outer horizontal face. The chine breadth is more than 0.85m. The breadth at the upper edge of the third strake is 1.32m.

Conversion
This timber was fashioned from an oak crook formed of a main limb (starboard arm) and a branch (horizontal portion and port arm) that was at least 2.07m in length. The main limb had a maximum girth of *c* 1.54m (diameter 0.49m); it had a fast growth rate (3.05 mm per year). A large part of the cross section of this crook, with the pith near the middle, was used to fashion the horizontal portion of this floor, but more of the cross section had been worked away to get the necessary shape for the arms. The grain generally flows along the port arm and the horizontal section, but it is confused in the starboard arm and there is short grain. There is some sapwood on the forward and after faces.

This floor was positioned in the boat with its parent limb's butt end to starboard. The cross section is generally rectangular and there is no sign of plank convergence. The horizontal section *m/s* is 95/125 (0.76) and the $m \times s$ is 11,875; the port arm *m/s* is 85/75 mm (1.13) and the $m \times s$ is 6375. With an original overall length of *c* 2.1m, such an oak timber would have weighed *c* 17kg.

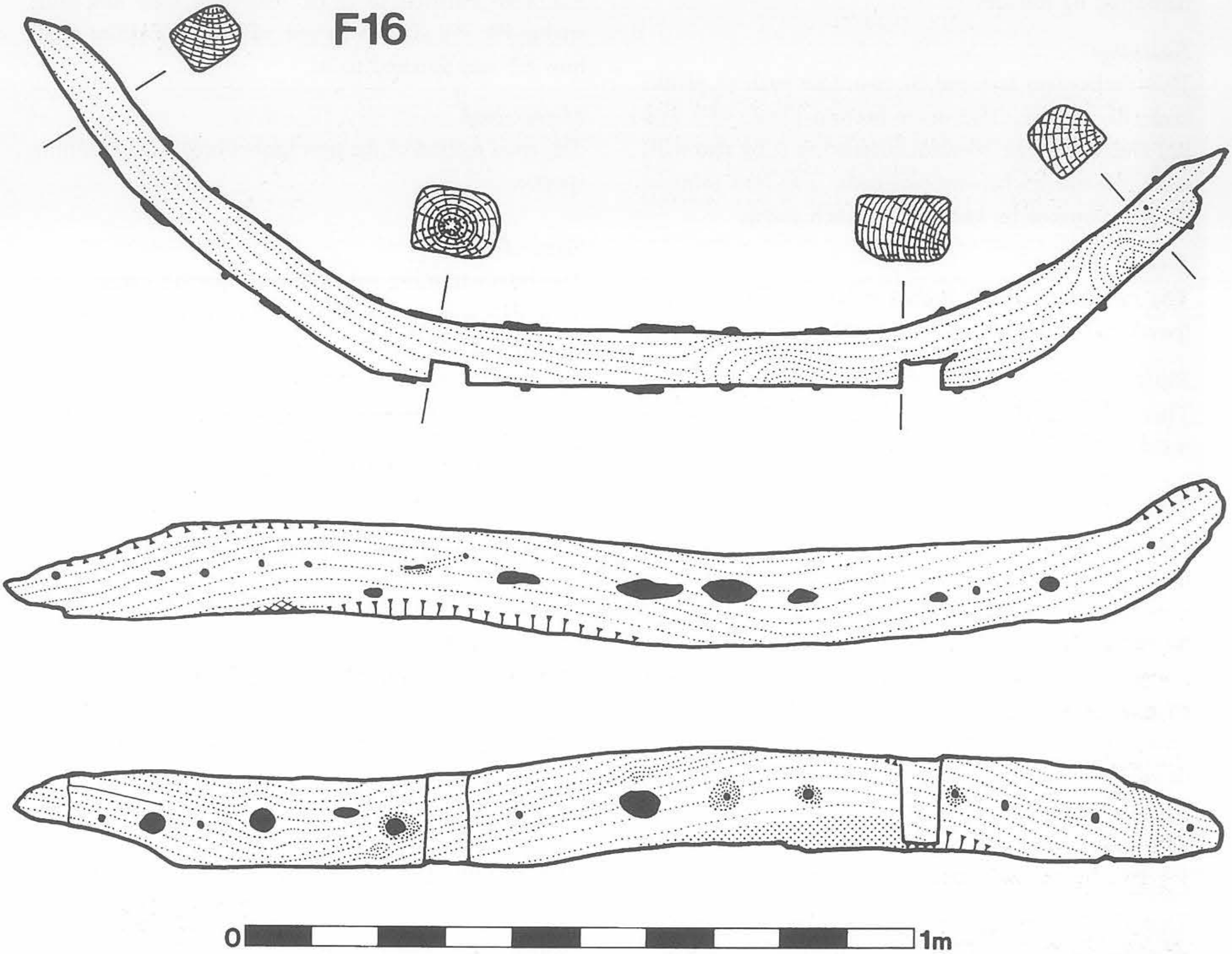


Figure A2.15 Floor F16. (Scale 1:10)

Boatbuilding features

Fastenings

This timber was fastened to the plank-keel (P1 and S1) by two nails each. The outer bottom planks (P2 and S2) were fastened to it by one nail each, side strakes P3, P4, P5, and S3 by two nails each, and S4 by one possibly two nails. It is not clear how the after plank (P5D) in the butt joint in side strake P5 was fastened to F16, as that plank has not survived and the floor timber is damaged at that point. By analogy with other butts, two further nails would have been used.

Limber holes

The cross sections of the limber holes are 57 × 26mm (port) and 60 × 30mm (starboard).

F17

This timber had not survived to be excavated, but fastening holes in P1, P2, P3, S1, and S2, demonstrate that it was originally positioned over the stern post/plank-keel scarf in a double-notch joint with the stern post (see Post and F4). This timber was fastened by two nails to each of the plank-keels (P1 and S1). Outer bottom planks P2 and S2 were fastened to it by one nail each and side strake P3 by one nail possibly two. Other strakes would also have been fastened to it (see F4).

This was one of the key timbers in this boat's structure. It and F4 must have been two of the earliest framing timbers to be positioned and fastened, thereby locking the posts to the plank-keels.

Side timbers

SF1Pt

This timber had not survived to be excavated but one fastening hole each in side strakes P6 and P7 (plans 153 and 98) suggest that it was originally fitted forward and to port of floor F1. It may also have been fastened to plank P3A*.

SF2Pt (5090) – Fig A2.16

This side timber was lifted and recorded as one unit (plan 129). Both ends are incomplete. It was forward of and adjacent to floor F2 and extended from strake P3 to strake P6. It is in three main fragments.

Conversion

It was fashioned from an oak branch of fast growth rate (3.2mm per year), with the pith in the middle. The branch was about 0.5m in length, with a girth of *c* 0.38m (diameter 0.12m). The cross section is 'squared-off' with *m/s* of 73/85 (ie 0.86); the $m \times s$ is 6205. There is sapwood (twelve rings) on all faces. Such a timber would have weighed *c* 2.5kg.

Boatbuilding features

Fastenings

This side timber and side strakes P3–6 were fastened together by one nail each.

SF2St (5092) – Fig A2.17

This probable side timber is fragmented, but was lifted and recorded as one unit (plan 134). Both ends are incomplete. It was excavated from on top of bow bottom plank BS1, but it would originally have been aft of and adjacent to floor F2; it would have extended from S3 or S4 upwards.

Conversion

It was fashioned from an oak branch of slow growth rate (1.8mm per year), with the pith near the middle. This branch was more than 0.40m in length with a girth of *c* 0.31m (diameter 0.1m). The cross section is 'squared-off', but rounded on the inner face, with *m/s* of *c* 55/80 (ie 0.69); the $m \times s$ is 4400. There is much sapwood (nineteen rings) on all faces. Such a timber would have weighed *c* 1.5kg.

Boatbuilding features

Fastenings

This fragment has one nail hole.

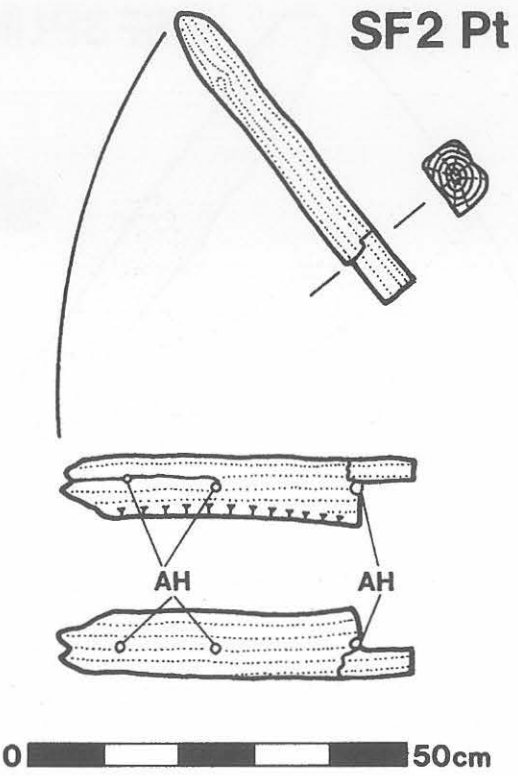


Figure A2.16 Side timber SF2 Pt. (Scale 1:10)

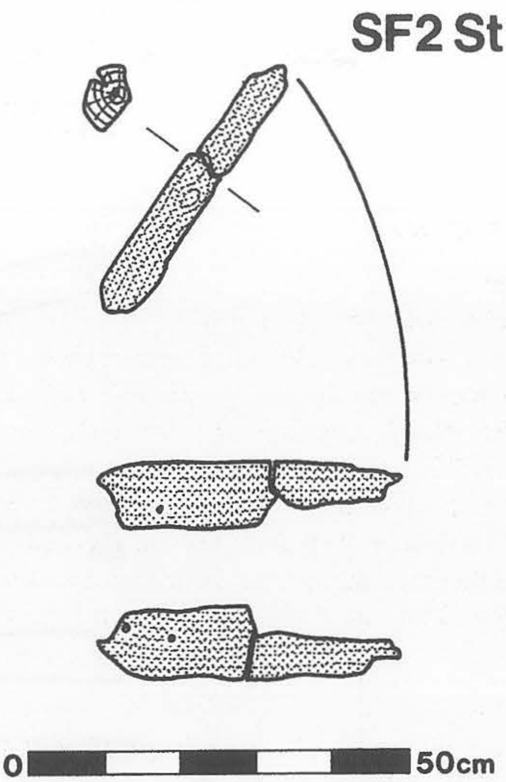


Figure A2.17 Side timber SF2 St. (Scale 1:10)

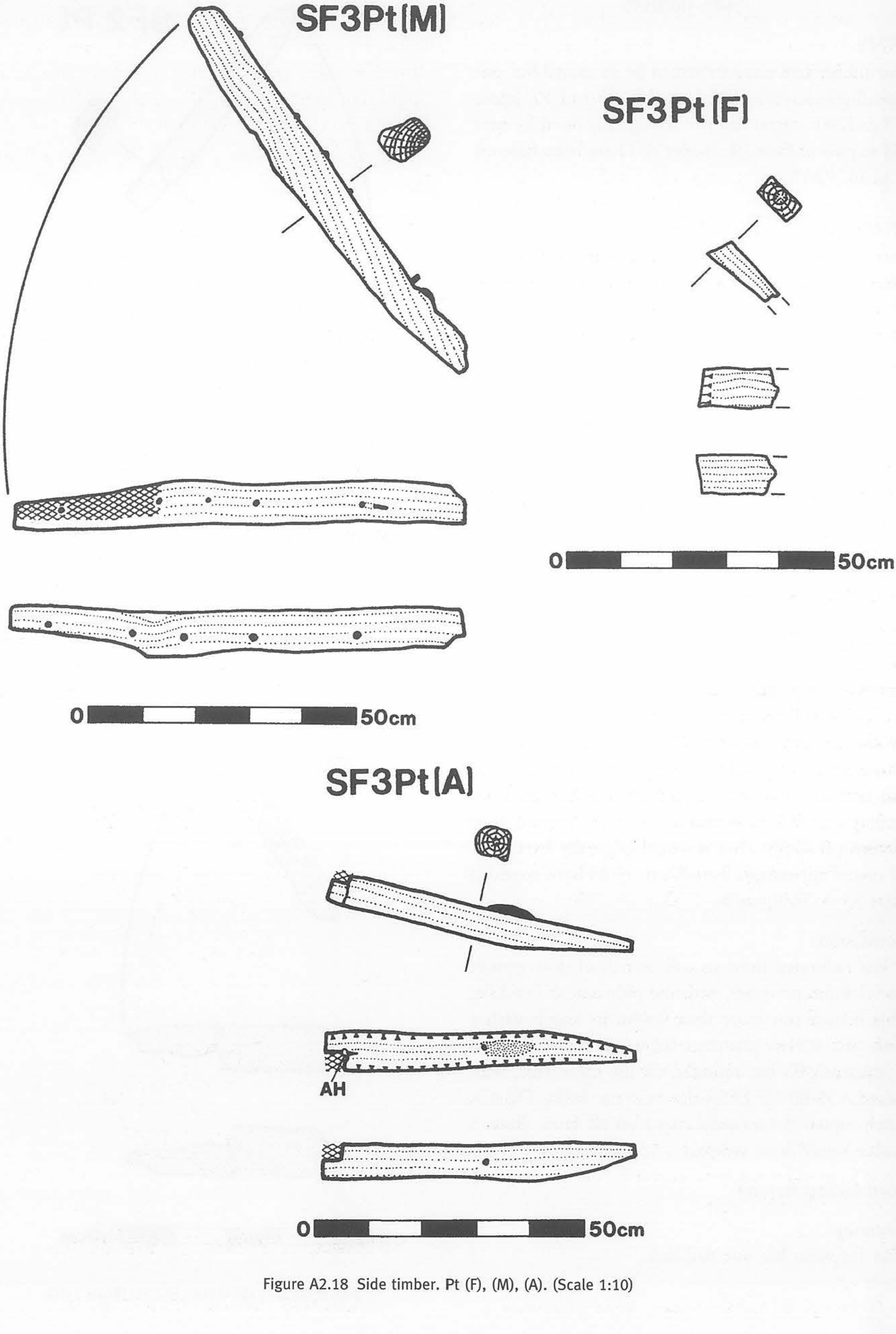


Figure A2.18 Side timber. Pt (F), (M), (A). (Scale 1:10)

SF3Pt (5089, 5088, and 5087) – Fig A2.18

These are three separate timbers, all of them side timbers forward of floor F3. Timber 5087(A; surviving length 0.55m) was adjacent to F3 near the top of that floor; 5088 (M; surviving length 0.84m) was adjacent to F3 lower down; while 5089(F; surviving length 0.15m) was forward of 5088(M). They all overlap F3, 5088(M) having the greatest overlap. Each timber was lifted as one unit and recorded individually, but on the same plan (119). The lower end of (F) is incomplete: originally it probably extended from P4 to P3. The upper end of (M) is incomplete: it extended from P3 to P7. The upper end of (A) is also incomplete: it extended from P6 or P7 to P5 and may also have taken against P4.

Conversion

5089 (F)

This side timber was fashioned from a whole oak branch of fast growth rate (5.4mm per year) that was up to 0.45m in length, with a girth of *c* 0.36m (diameter 0.12m). The side frame's cross section is rectangular, with *m/s* of 45/75 (ie 0.6); the $m \times s$ is 3375. Some sapwood had been left on. Such a timber would have weighed *c* 1.2kg.

5088 (M)

This was the principal side timber at this station. It was fashioned from part of an oak branch with smaller branches removed. Much had been worked away during conversion leaving only *c* 25% of the cross section. This branch had a medium growth rate (2.47mm per year); it was *c* 0.87m in length, with a girth of *c* 0.82m (diameter 0.26m). The side timber's cross section is more or less rectangular with *m/s* of 85/75 (ie 1.13); the $m \times s$ is 6375. Such a timber would have weighed *c* 4.5kg.

5087 (A)

This side timber seems to have been wedged between 5088(M) and floor F3. It was fashioned from a whole oak branch of slow growth rate (1.3mm per year). This branch was *c* 0.6m in length, with a girth of *c* 0.31m (diameter 0.1m). The side timber's cross section is square but with the after face still rounded, with *m/s* of 55/65 (ie 0.85) and $m \times s$ 3375. Much sapwood was left on and some bark on the inner face. Such a timber would have weighed *c* 1.7kg.

Boatbuilding features

Fastenings

No fastenings are visible in the surviving fragment of 5089 (F) and there is no guidance from the planking. Strakes P7, P5, and P4 and 5088 (M) were fastened together by one nail each, P6 by two nails. 5088 is shaped to take against P3 but is not fastened to it. Strake P6 (probably also P7) and 5087 (A) were fastened together by one nail. 5087 was shaped to take against P5 but does not appear to have been fastened to it.

SF3St (5101, 5094, and 5096) – Fig A2.19

The fragment 5101, which may have been associated directly with F3 to form a composite frame rather than as a side timber aft of it, was lifted and recorded as one unit (plan 134). The fragment 5094 (plan 50), which may also be part of this side timber, was not individually recorded. 5096 is a minor fragment. SF3St probably extended from strake S3 upwards.

Conversion

This timber (5101) was fashioned from an oak branch of slow growth rate (1.9mm per year). The branch was at least 0.3m in length, with a girth of *c* 0.72m (diameter 0.23m). Much of this had been worked away to leave only a quarter of its cross section in the surviving fragment. This timber was fitted in the boat with its pith-facing face outboard. The grain generally flows along the length and there is sapwood (nine rings) in places. The cross section is generally rect-

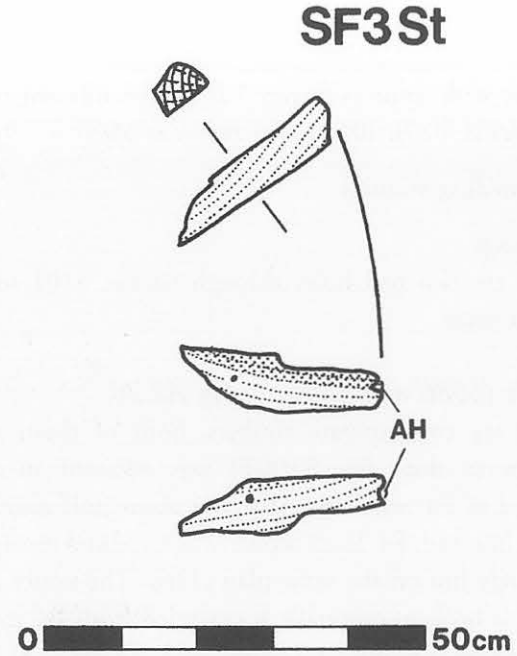


Figure A2.19 Side timber SF3 St. (Scale 1:10)

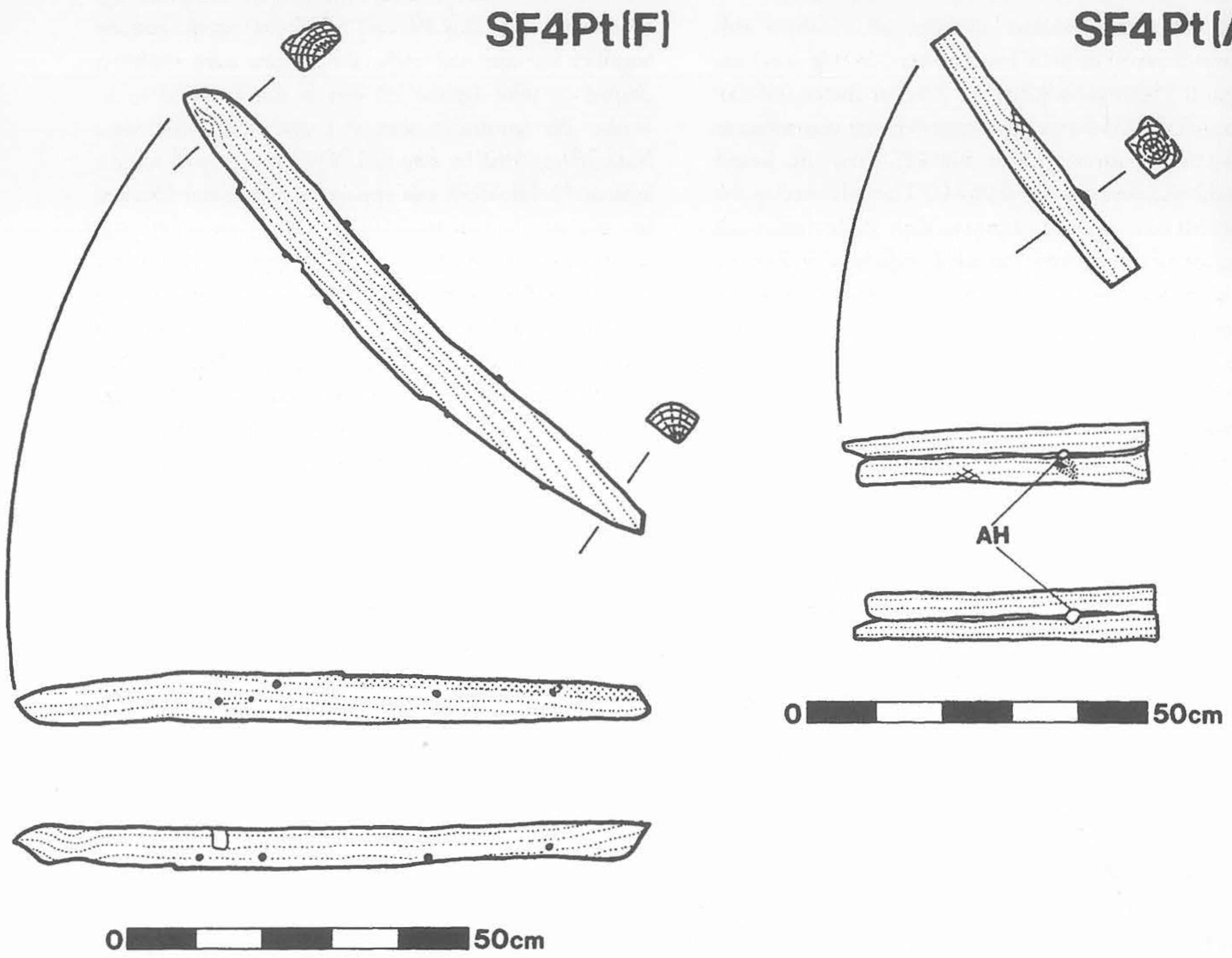


Figure A2.20 Side timber SF4 Pt (F), (A). (Scale 1:10)

angular with some curvature left on the inboard face. The *m/s* is 50/70 (0.71) and $m \times s$ is 3500.

Boatbuilding features

Fastenings
There are two nail holes through timber 5101 some 0.17m apart.

SF4Pt (5086 and 5085) – Fig A2.20

These are two separate timbers, both of them side timbers to floor F4: 5086(F) was adjacent to and forward of F4, while 5085(A) was above and more or less in line with F4. Each timber was lifted and recorded separately but on the same plan (116). The upper end of (F) is broken; originally it extended from P4 to P7 overlapping F4 on strakes P4 and P5 by *c* 0.3m. The upper end of (A) is also incomplete; it probably extended from P5 to P7; this timber was adjacent to and aft of (F).

Conversion

5086 (F)
This timber was the principal side timber at this station. It was fashioned from an oak limb of medium growth rate (2.05mm per year) that was *c* 1m in length, with a girth of *c* 0.72m (diameter 0.23m). The side timber's cross section is generally rectangular, but some of the limb's curvature with sapwood has been retained on the inner face. The *m/s* is 80/65 (1.23) and $m \times s$ is 5200. The outer face has been worked longitudinally to the transverse curvature of the hull at this station, leaving less than half the limb's cross section in the side timber; this has also resulted in some short grain at the lower end. Such a timber would have weighed *c* 4kg.

5085 (A)

This timber was fashioned from a whole oak branch of slow growth rate (1.65mm per year) that was *c* 0.5m in length, with a girth of *c* 0.38m (diameter 0.12m). This auxiliary side timber's cross section is generally rectangular, with an *m/s* of 55/70 (0.79), and $m \times s$ of 3850. There is much sapwood (eleven rings) on all faces and also some short grain at the lower end. Such a timber would have weighed *c* 1.5kg. This timber was fitted in the boat with its parent branch's butt end lowest.

Boatbuilding features

Fastenings

Strakes P4 and P5 were fastened to side timber 5086 (F) by one nail each and strake P6 by two nails. Strake P7 was also probably fastened to this side timber: the full breadth of P7 seems to have been overlapped by 5086(F). P6 and possibly P7 were fastened to 5085 (A) by one nail each.

SF6.5Pt (5080) – Fig A2.21

Side timber SF6.5Pt, midway between the floor timber F6 and the half-frames F7Pt and St, was lifted and recorded as one unit (plan 117). Its upper end is broken and incomplete; the outer face is slightly curved longitudinally; its lower end is shaped to take against strake P5 and the upper part of P4. This timber appears to have been broken in antiquity near the upper edge of strake P7: the upper fragment measures *c* 0.13m; the lower fragment measures 0.82m and extends from

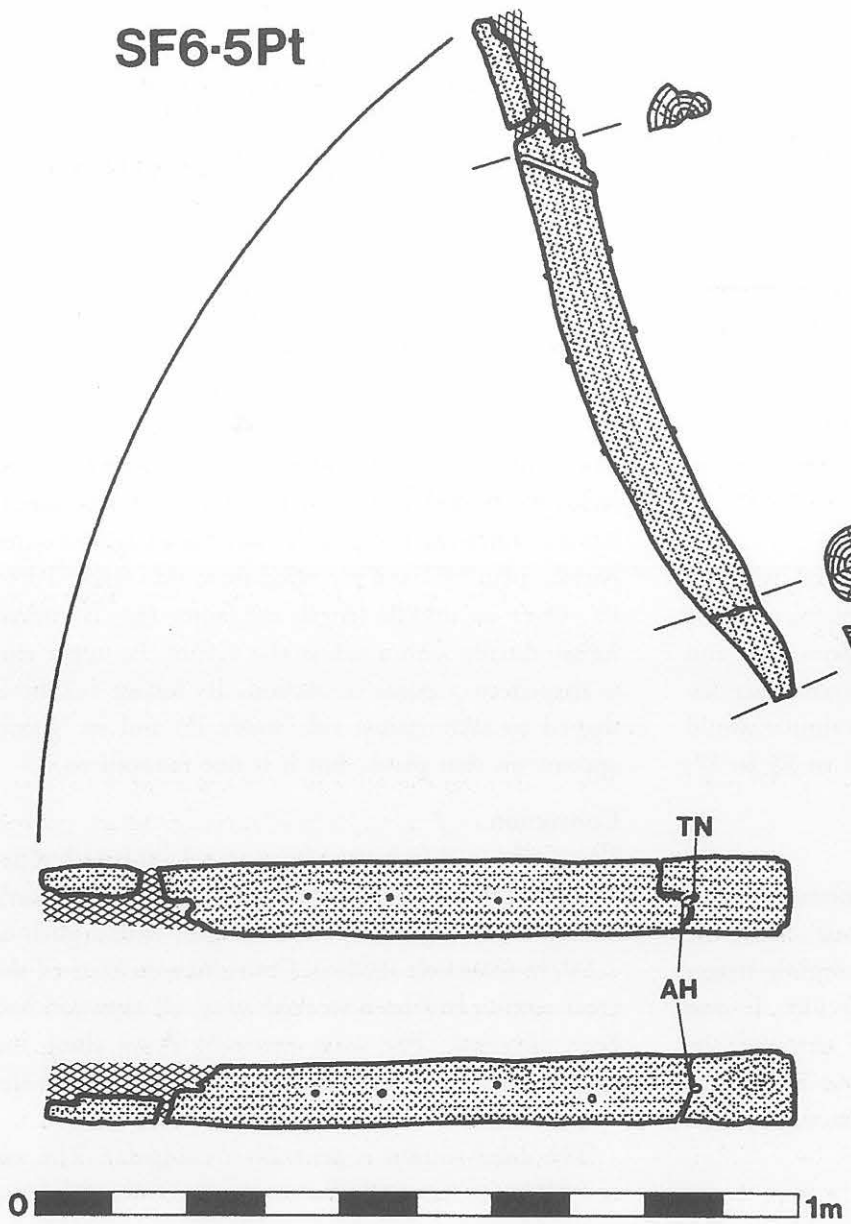


Figure A2.21
Side timber SF6.5 Pt. (Scale 1:10)

P4 (part) to P7. This side timber probably protruded above the sheerline by at least 0.13m.

Conversion
This timber was fashioned from an oak branch of slow growth rate (1.8mm per year). The branch was at least 1m in length, with a girth of *c* 0.41m (diameter 0.13m). The greater part of the cross section, with the pith near the middle, was used, except towards the lower end where about a half had been worked away. Much sapwood (fifteen rings) had been left on all faces particularly those forward and aft. The grain generally flows along the length.

The cross section is generally rounded with some flattening of the inner and outer faces. The *m/s* is 88/95 (0.93) and the $m \times s$ is 8360. With an original length of *c* 1m such a timber would have weighed *c* 5kg.

Boatbuilding features

Fastenings
This side timber was fastened to strake P5 by two nails. Strake P6 was fastened to it by two nails and strake P7 by one possibly two nails.

Signs of Use
Towards the top of this timber, near the top edge of strake P7, a 10mm groove angled downwards from outboard has been worked in the after face. The upper, outer end of this groove appears to be aligned with a sub-rectangular hole, 50 × 30mm through strake P7. This may have been a lead for a line, possibly rigging.

SF6.5St (5082) – Fig A2.22
This small fragment, 0.17m in length and with no sign of fastenings, is probably all that remains of a side timber positioned opposite SF6.5Pt. It was lifted and recorded as one unit (plan 168). Both ends are incomplete. By analogy with SF6.5Pt, this timber would originally have extended from strake S4 or S5 to S7; it may also have had a rigging function.

Conversion
This timber was fashioned from an oak branch of slow to medium growth rate (2.2mm per year), with the pith near the middle. This branch was slightly bigger (girth 0.53m) than that used for SF6.5Pt. It was otherwise similar, with four rings of sapwood. Its conversion into a side timber would have been comparable, except that less of the cross section of the branch was used.

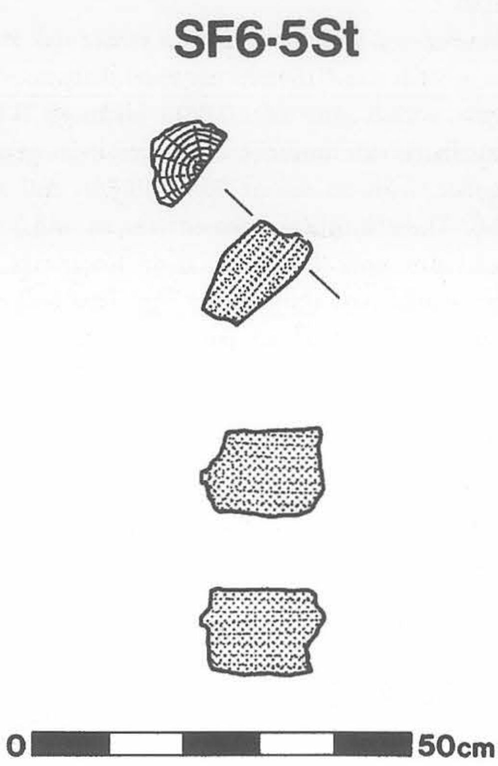


Figure A2.22 Side timber SF6.5 St. (Scale 1:10)

SF8Pt (5079) – Fig A2.23
Side timber SF8Pt overlapped floor timber F8 by *c* 0.36m. It was lifted and recorded as one unit (plan 114), although there are broken elements halfway along its length. Its upper end is slightly broken and damaged, but it is otherwise complete. It was butted against outer bottom plank P2 and extended from side strake P3 to P7. Over its middle length the outer face is curved longitudinally with a radius of *c* 1.15m. Its upper end is shaped to a point in section. Its lowest 0.23m is shaped to take against side strake P3 and its 'ghost' appears on that plank, but it is not fastened to it.

Conversion
This timber was fashioned from an oak limb with some side branches and of fast growth rate (4.5mm per year). The limb was at least 1.3m in length, with a girth of *c* 2.07m (diameter 0.66m). Over three-quarters of the cross section had been worked away; all sapwood had been removed. The grain generally flows along the middle length of this timber, but with irregularities due to knots; there is short grain at both ends

The cross section is generally rectangular. The *m/s* is 90/110 (0.82) and the $m \times s$ is 9900. With an

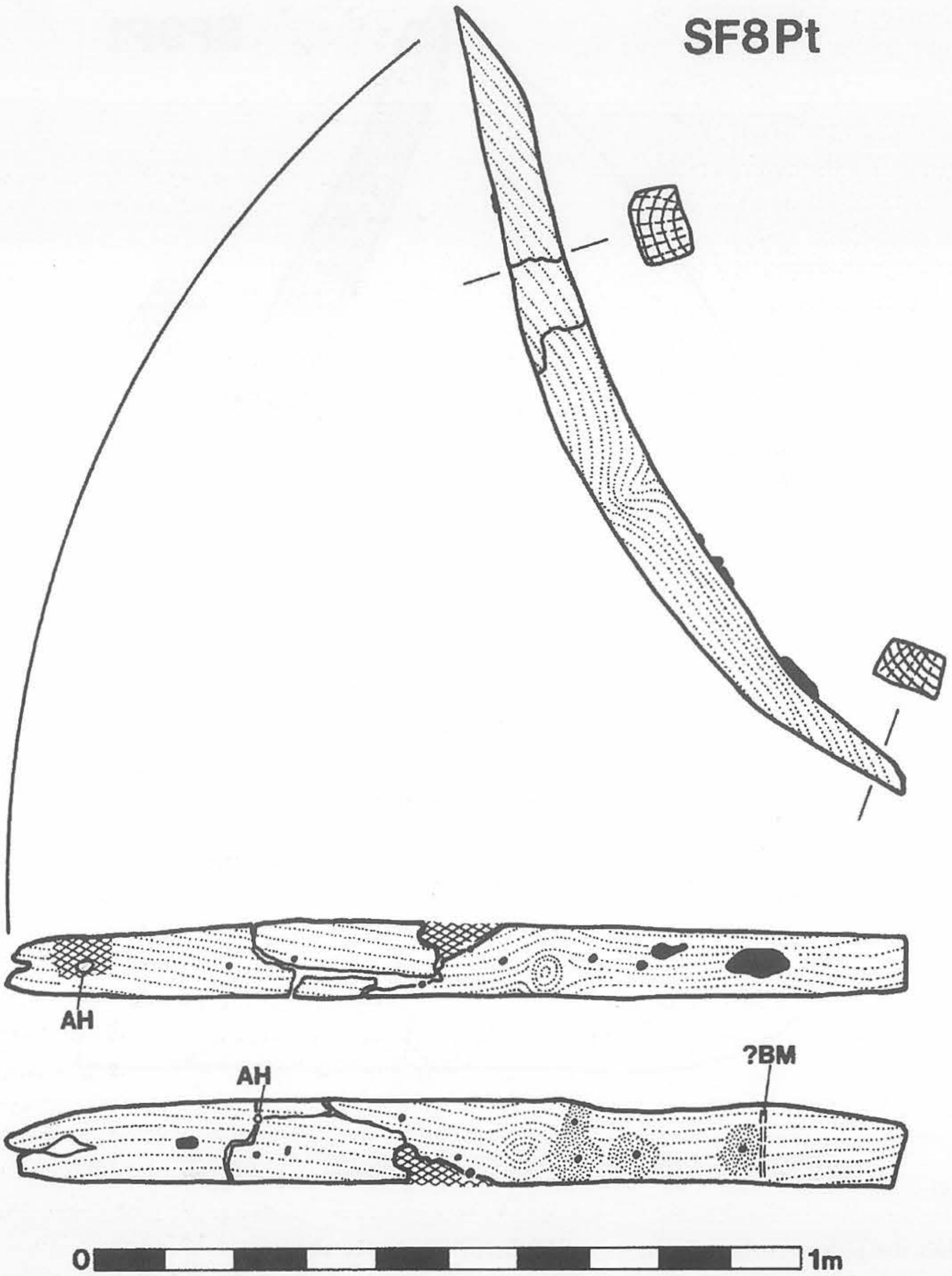


Figure A2.23
Side timber SF8 Pt.
(Scale 1:10)

original length of *c* 1.3m such a timber would have weighed *c* 9kg.

Boatbuilding features

Fastenings
This side timber was fastened to strake P4 by two nails. Strakes P5 and P7 were fastened to it by two nails. The butt joint in strake P6 was fastened to it by two nails in each plank.

Builders' marks or tool marks
There is a possible shallow groove cut across the outer face of this timber near seam P2/3.

SF9Pt (5078) – Fig A2.24

Side timber SF9Pt overlapped floor timber F9 by *c* 0.23m. It was lifted and recorded as one unit (plan 115), although it is in three large fragments. Its upper end is slightly damaged. It is otherwise complete and extends from side strake P4 to P7. The outer face is curved longitudinally.

Conversion
This timber was fashioned from an oak limb with some minor branches and of medium growth rate (2.5mm per year). This limb was at least 1.05m in length, with a girth of *c* 0.5m (diameter 0.16m). Most of the cross

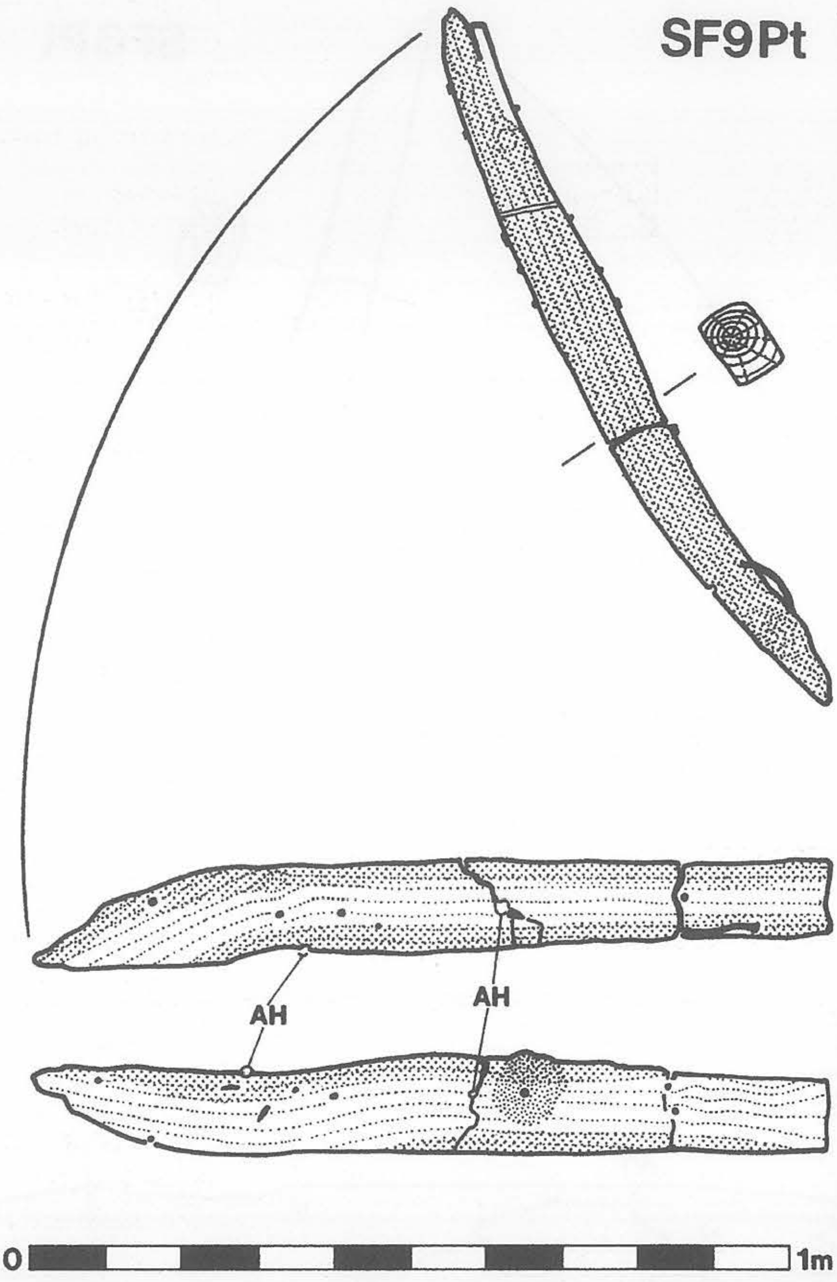


Figure A2.24
Side timber SF9 Pt. (Scale 1:10)

section had been used, with the pith near the middle. Much sapwood (twelve rings) had been left on, especially on the after face. The grain generally flows along the length of this timber, but there is short grain towards the upper end.

The cross section is generally rectangular. The *m/s* is 80/120 (0.67) and the *m* × *s* 9600. With an original length of *c* 1.05m such a timber would have weighed *c* 7kg.

Boatbuilding features

Fastenings
This side timber was fastened to strake P4 by one nail. Strakes P5, P6, and P7 were fastened to it by two nails each.

SF9St (5083) – Fig A2.25
The minor fragment of side timber SF9St that survived was lifted and recorded as one unit (plan 110). It measures 0.34m: its upper end is broken; its lower end is also broken but appears almost complete; it now extends from S3 to S4, but originally probably extended much higher. It overlapped floor timber F9 by at least 0.34m.

Conversion
This timber was fashioned from an oak bole that seems to have had a greatest girth of 2.83m (diameter 0.90m) and a fast growth rate (4.6mm per year). The surviving fragment has short grain along most of its length.

The cross section is generally rectangular. The *m/s*

SF9St

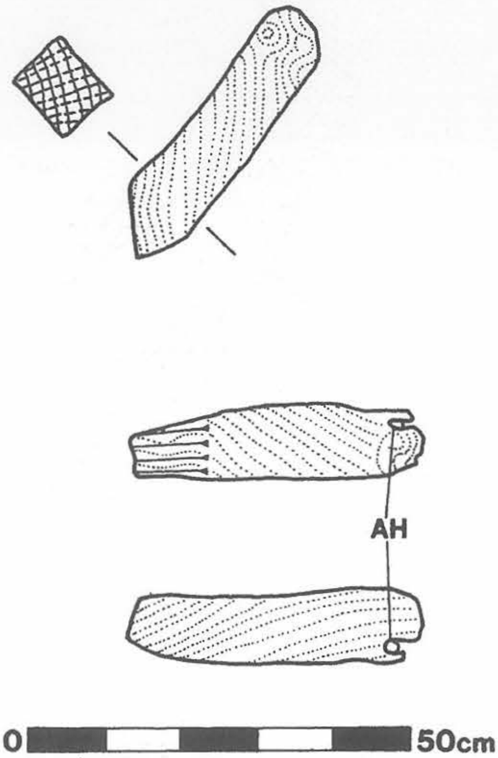


Figure A2.25 Side timber SF9 St. (Scale 1:10)

SF13Pt

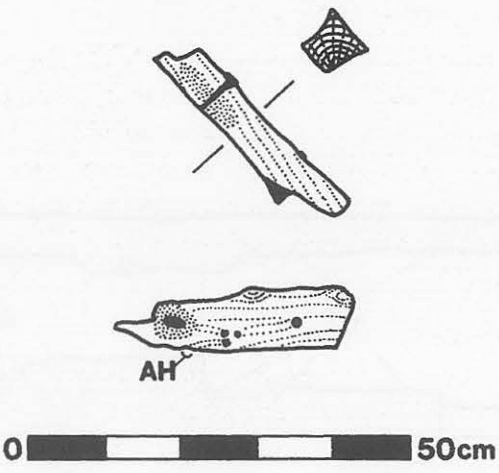


Figure A2.26 Side timber SF13 Pt. (Scale 1:10)

is 82/65 (1.26) and the $m \times s$ 5330. If its original length was 1m, such a timber would have weighed *c* 5kg.

Boatbuilding features

Fastenings
This side timber was fastened to strake S3 by one nail.

SF11St (5103/4/5)

These three fragments appear on the archaeological site plan 57 as loose timbers on strakes S4 and S3 aft of floor timber F11. There is no measured drawing of them and their whereabouts is now unknown. A fastening hole through strake S4 (Plan 176) suggests that there was a starboard side-timber (SF11St) aft of F11: such a timber would accord with the general framing pattern. No remains of an equivalent timber to port have been identified, however, and there seem to be no fastening holes through strakes P3–5 in the position where an SF11Pt would have been.

SF13Pt (5099) – Fig A2.26

The surviving fragment of side timber SF13Pt that overlapped floor timber F13 by *c* 0.25m was lifted and recorded as one unit (plan 105). It is only *c* 0.3m in length: its lower end is complete, its upper end damaged. It extends from side strake P3 (not fastened) to P5.

Conversion

This timber had been fashioned from an oak limb of maximum girth 0.66m (diameter 0.21m), with some minor branches and a fast growth rate (3.7mm per year). Much of this limb had been worked away, leaving only about a quarter of the cross section. No sapwood had been left on the surviving fragment. The grain generally flows along the length of this timber, but there is short grain at the lower end where the timber is shaped to take against strake P3.

The cross section is generally rectangular. The moulded depth is 25mm. As both after and forward faces are broken, no sided dimension can be given.

Boatbuilding features

Fastenings
Side strake P5 was fastened to this side timber by two nails. The butted planks in side strake P4 were each fastened by one nail, while a third nail seems to have been driven more or less through the butt. Although this timber was shaped to take against lowest side strake P3, it does not appear to have been fastened to it. It

is thus difficult to visualise how and when the butted planks in strake 4 were fastened to SF13Pt, unless this was after this side timber had been fastened to a higher strake, such as P5.

SF13St

This timber has not survived, but a fastening hole near the lower edge of side strake S4, aft of the position of floor timber F 13, suggests that there was formerly a side timber here. Such a timber would 'balance' SF13Pt.

SF14Pt

This timber has not survived, but two fastening holes each in side strakes P5 and P4 forward of the position of floor timber F14 suggest that there once was a side timber there. This timber would have overlapped F14 by *c* 0.2m. Since it was not fastened to strake P3, it can only have been added to the hull after a higher strake, such as P4, was in position.

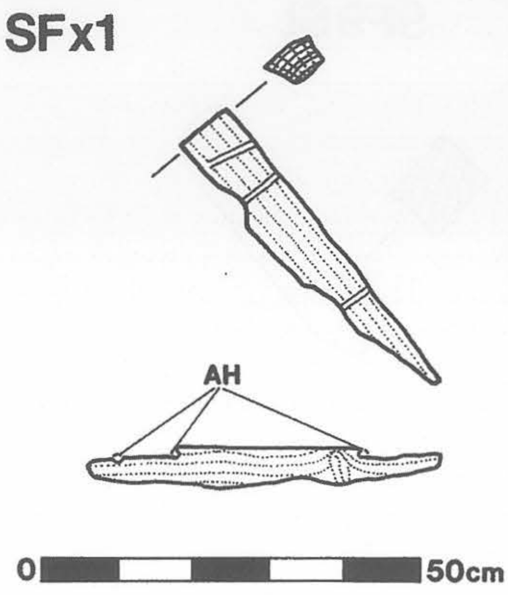


Figure A2.27 Side timber SFX1. (Scale 1:10)

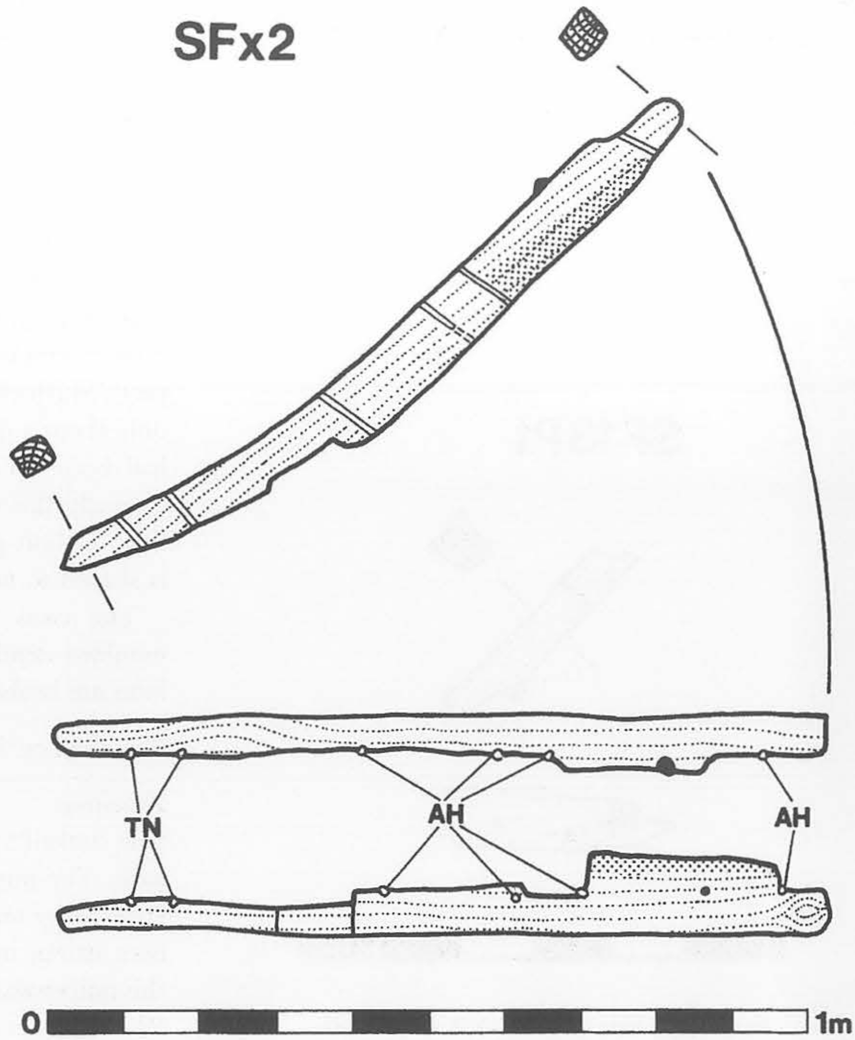


Figure A2.28
Side timber SFX2. (Scale 1:10)

SF17Pt

This timber had not survived to be excavated, but two holes in side strake P3 suggest that it was originally positioned forward of floor timber F17.

SFX1 (5098) – Fig A2.27

This side timber was excavated from the area astern of the boat. It was lifted and recorded as one unit (plan 178). This timber has been split roughly down the middle and only one part has survived. It is now *c* 0.46m in length: one end (upper?) appears to be complete; the other may have been shaped to take against a (lower?) strake.

This timber was fashioned from an oak limb of medium growth rate (2.2 mm per year), with a girth of more than 0.72m (diameter 0.23m). Less than half the cross section was used. No sapwood had been left on the surviving fragment. The grain flows along the length. The cross section of this side timber was probably rectangular; the moulded dimension was 50mm.

There are the remains of three fastening holes through this timber; SFX1 may have spanned one strake and parts of two others.

SFX2 (5037) – Fig A2.28

This side timber was excavated from the area astern of the boat. It was lifted and recorded as one unit (plan 157). This timber had been split roughly down the middle and only one part has survived. Its length is now 1.02m, which seems to be close to the original length. The outer face has been shaped longitudinally to match the curvature of the boat's side.

This timber was fashioned from an oak limb of fast growth rate (3.2 mm per year), with a girth greater than 0.94m (diameter 0.3m). Less than half the cross section was used. Sapwood had been left on either the forward or the after face. The grain flows along the upper (?) part of this timber, but there is short grain near the other, more curved end. The cross section was probably rectangular; the moulded dimension is *c* 40mm.

There are the remains of seven fastening holes through this timber: SFX2 probably spanned three strakes and parts of two others. It seems more suited to a position in the boat away from the bow and stern.

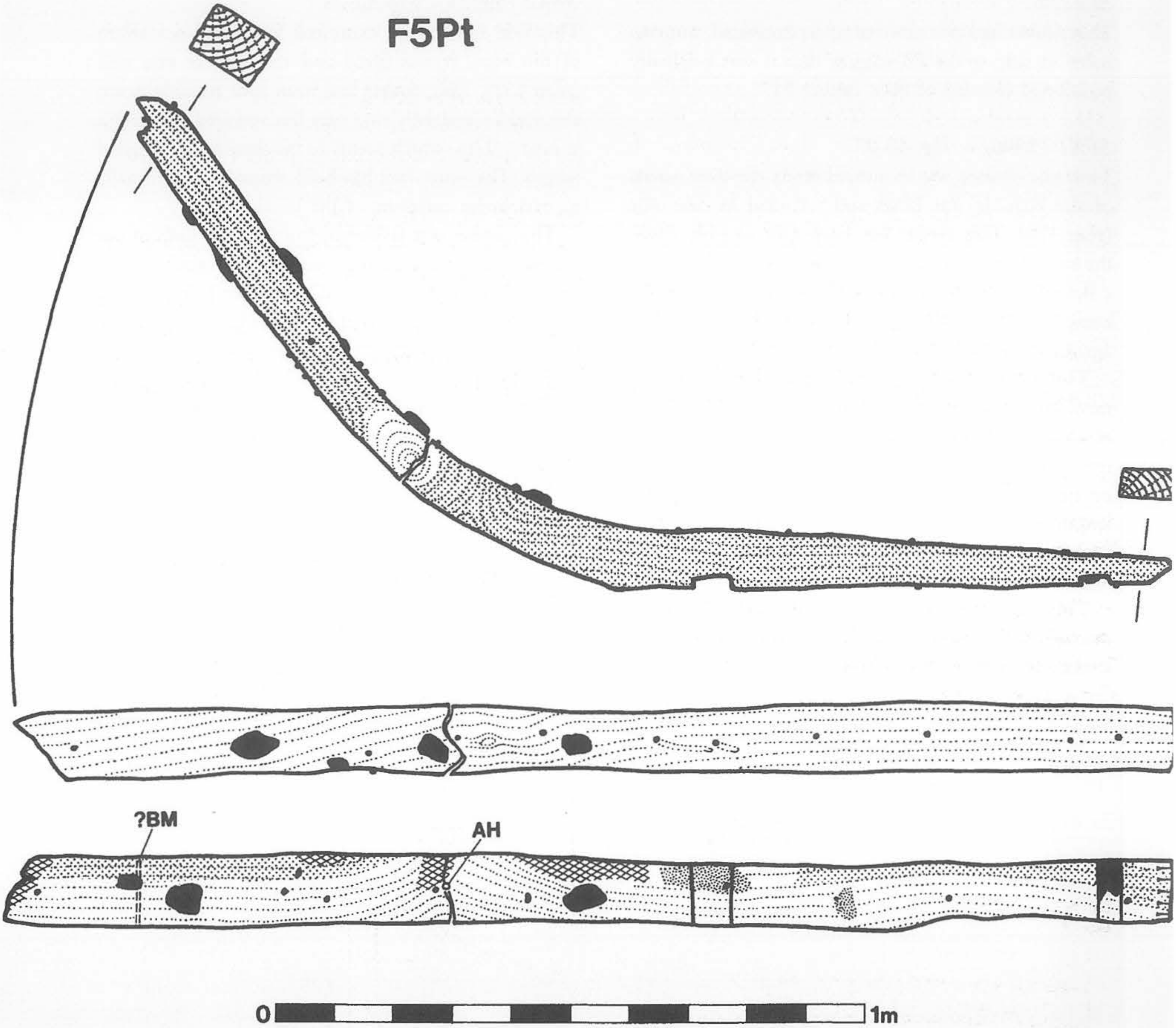


Figure A2.29 Half frame F5 Pt. (Scale 1:10)

Half-frames

F5Pt (5072) – Fig A2.29

Half-frame F5Pt is the port member of the first pair of half-frames from forward. Though broken at the level of strake 4 into two pieces, it was lifted and recorded as one unit (plan 122). Its upper end is slightly damaged, but it is otherwise complete and extends from P7 to S2, its lower end shaped to take against S3. Its outer face has a graceful curve around the turn of the port bilge, with a radius of *c* 0.85m; the upper part of the frame flares outwards at an angle of *c* 33° to the vertical. The chine breadth is *c* 0.92m and the tip of the port arm is 0.85m above the outer face of the horizontal arm.

Conversion

This timber was fashioned from an oak crook formed from a main limb with a branch. Other branches had to be trimmed away. This crook was 2.20m along its curved length, with a greatest girth of *c* 1.26m (diameter 0.4m); it had a fast growth rate (3.7mm per year).

Much wood had been worked from this crook during conversion leaving, for example, about one quarter of its cross section towards the ends of the crook. The grain generally flows along the length of this timber; there is sapwood (seven rings) on the inner and after faces.

The cross section is generally rectangular and no planking convergence can be detected. The *m/s* of the rising arm is 90/120 (0.75) and the $m \times s$ is 10,800; the horizontal arm *m/s* is 90/105 (0.86) and the $m \times s$ 9450. The overall length is 2.2m. Such a timber would have weighed *c* 17kg.

Boatbuilding features

Fastenings
This half-frame was fastened to plank-keels P1 and S1 by one nail each. Outer bottom plank P2 was fastened to this timber by one nail and S2 by two nails. Side strakes P6, P4, and P3 were fastened by two nails and P7 by one. The scarf in P5 was fastened by two nails through each plank.

Limber holes
The cross sections of limber holes are 58 × 20mm (port) and 50 × 15mm (starboard).

Builders' marks or tool marks
There is a possible shallow groove *c* 2mm deep across the outer face in the vicinity of seam P6/7.

F5St (5071) – Fig A2.30

Half-frame F5St is the starboard member of the first pair of half-frames from forward. Although broken into two pieces near the S2/S3 seam, it was lifted and recorded as one unit (plan 120). Its upper, starboard end is decayed and incomplete; the lower end is finished in a vertically sawn face which was not in contact with side strake P3. The inner face has been damaged in recent times. This half-frame extends from P2 to S4 and originally extended higher. There is the beginning of a graceful curve around the turn of the starboard bilge. The chine breadth is *c* 0.91m.

Conversion
This timber was fashioned from an oak crook – possibly a single curved branch – that was at least 1.3m along its curved length, with a greatest girth of *c* 0.6m (diameter 0.19m); it had a moderate growth rate (*c* 2.7mm per year). Much wood had been worked away during fashioning the horizontal element, leaving less

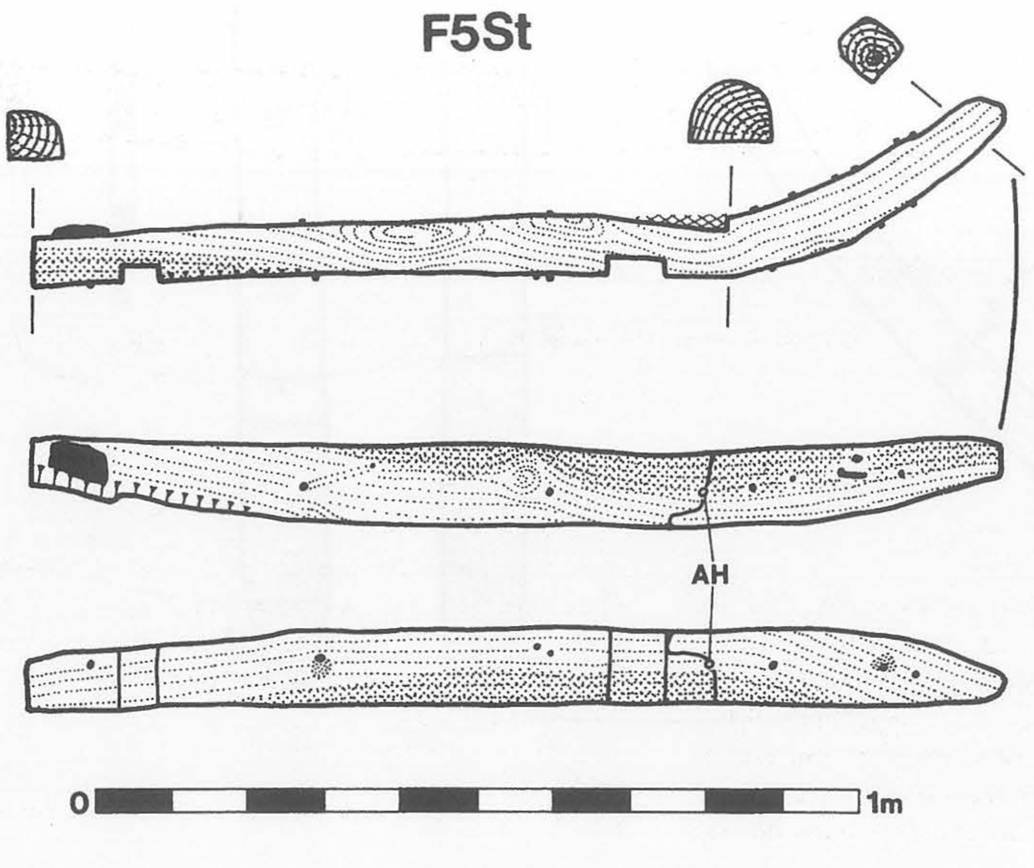


Figure A2.30
Half frame F5 St.
(Scale 1:10)

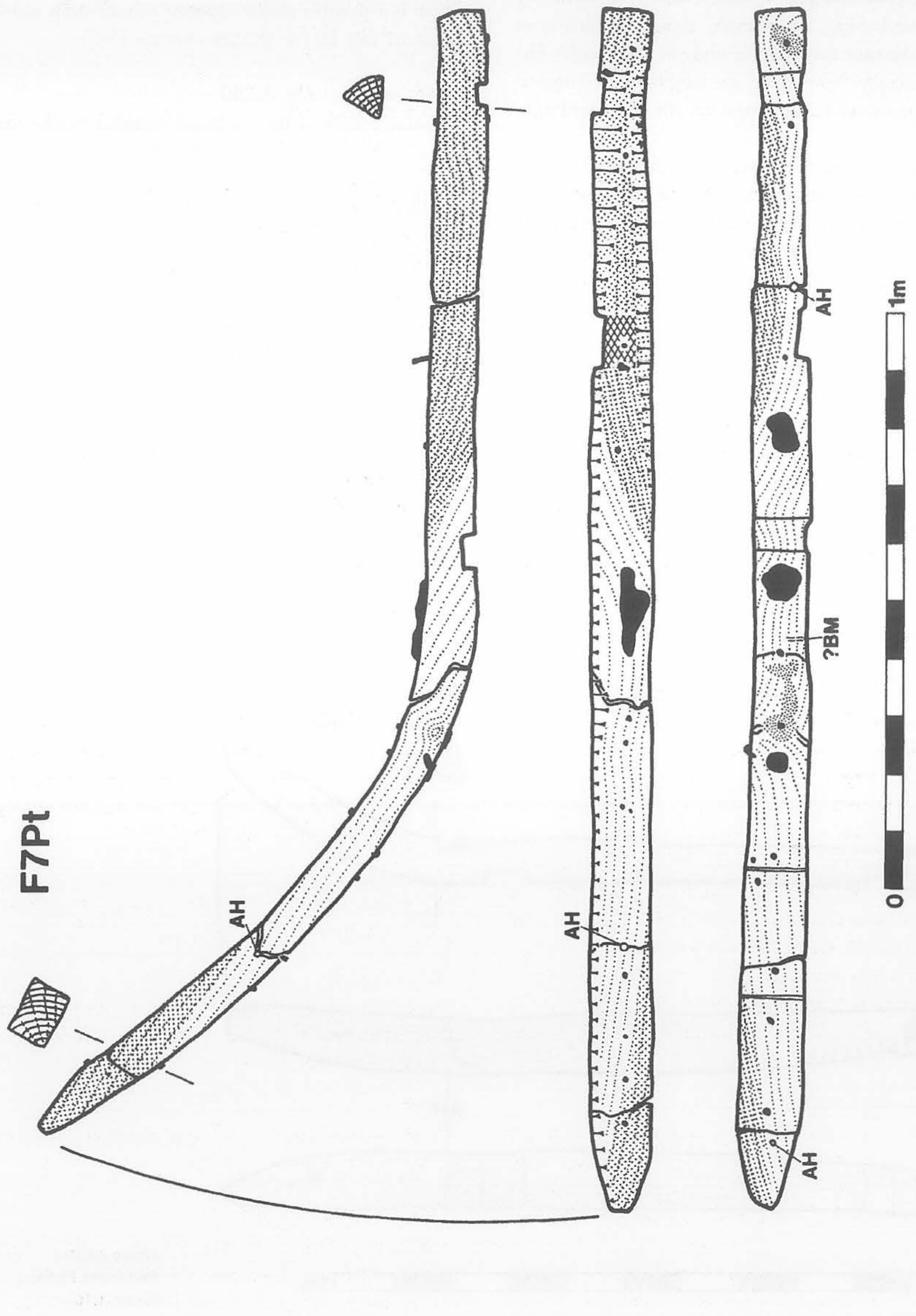


Figure A2.31 Half frame F7 Pt. (Scale 1:10) than half the cross section of the parent limb. The rising arm was fashioned more symmetrically, with the pith nearer the centre of the timber. What was to be the horizontal arm of this half-frame was curved and much sapwood (ten rings) had been left on when the timber was given a 'squared-off' appearance. The grain follows this (undesirable) curvature across the boat as well as the (desirable) curvature around the bilge.

The cross section is generally rectangular, although where there is sapwood on the horizontal section, the original roundness of the limb is retained. The *m/s* of the rising arm is 75/65 (1.15) and the $m \times s$ is 4875; the horizontal arm *m/s* is 80/105 (0.76), the $m \times s$ 8400. Its original length may have been similar to its partner – 2.2m. Such a timber would have weighed *c* 13kg.

Boatbuilding features

Fastenings
This timber was fastened to the plank-keel (P1 and S1) by one nail each. The outer bottom planks (P2 and S2) were fastened to this timber by one nail each, as was side strake S4. Side strake S3 was fastened by two nails.

Limber holes
The cross sections of the limber holes are 52 × 25mm (port) and 75 × 23 (starboard).

F7Pt (5069) – Fig A2.31

Half-frame F7Pt is the port member of the second pair of half-frames from forward. Broken in antiquity into four major fragments and several minor ones, it was lifted and recorded as one unit (plan 121). This timber is complete and extends from P7 to S2. There is a graceful curve around the turn of the port bilge, with a radius of *c* 0.88m; the upper part of the port arm flares outwards at a mean angle of 40° to the vertical. The highest 0.15m of the port arm has been worked to a blunt point in section and in plan. The tip of this arm is 0.75m above the outer surface of the horizontal element of this half-frame. The boat's chine breadth is more than 0.91m.

Conversion
This timber was fashioned from an oak crook formed from a limb with a branch. This crook was 2.2m along its curved length, with a greatest girth of *c* 0.6m (diameter 0.19m); it had a medium growth rate (3.2mm per year).

Much wood had been worked away during conversion, leaving about a quarter of the cross section of the parent crook. The grain generally flows along the length of this timber, but with short grain near the port limber hole and in the upper part of the rising arm. Towards the ends there is sapwood (thirteen rings) on the outer face, more on the inner face, and much more on the after face.

The cross section is generally rectangular, but towards the lower (starboard) end it becomes near-triangular with the after face retaining the curvature of the parent log. The *m/s* of the rising arm is 75/105 (0.71) and the $m \times s$ 7875; the horizontal element *m/s* is 80/100 (0.80) and the $m \times s$ 8000. The overall length is 2.2m. Such a timber would have weighed *c* 13kg.

Boatbuilding features

Plank fastenings
This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom plank P2 was fastened to it by one nail and S2 by two nails. Side strakes P7 and P5 were fastened to it by one nail each and strakes P3 and P6 by two nails each. The butt joint in strake P4 was fastened to F7Pt by two nails in each plank (one of these nails has not yet been traced in the half-frame).

Mast step
A notch was cut in the forward edge of this timber to form part of the after face of the mast step. The mast step timber was fastened to this half-frame by a spike driven from above which just pierced the half-frame without marking P1, the plank-keel below. This nail was thus 0.18m in length. Another spike appears to have been driven from the mast step itself at an angle into the forward edge of F7Pt.

Limber holes
The cross sections of the limber holes are 55 × 23mm (port) and 40 × 19mm (starboard).

Builders' marks or tool marks
There are shallow (1mm) grooves cut across the outer face of this half-frame near seam P4/5 and near seam P5/6 and possibly at the port chine.

Repair ?
There is a small augered hole into the after face of this timber *c* 45mm below the P5/P6 seam.

F7St (5068) – Fig A2.32

Half-frame F7St is the starboard member of the second pair of half-frames from forward. Broken in antiquity and in the recent past, it was lifted and recorded as

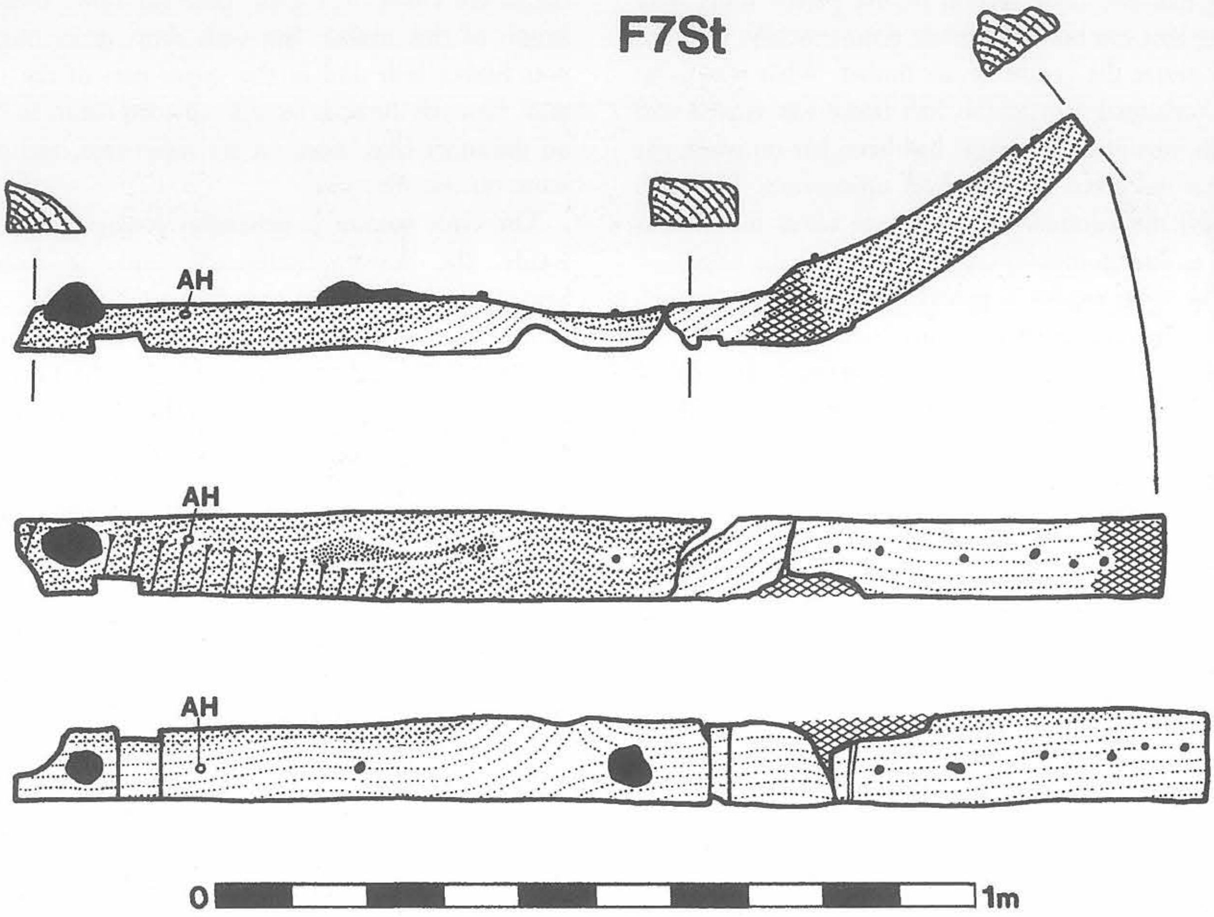


Figure A2.32 Half frame F7 St. (Scale 1:10)

one unit (plan 118). The port (lower) end is complete though damaged; parts are missing from the horizontal section and the upper part of the rising (starboard) arm is also missing, broken off along the short grain. It now extends from strake P2 to S4.

Conversion

This timber was fashioned from an oak crook formed from a main limb (the starboard arm) with a branch (the horizontal section). This crook had a greatest girth of *c* 1.7m (diameter 0.54m); it had a fast growth rate (4.7 to 5.5mm per year).

Much wood had been worked away during conversion, leaving about a quarter of the cross section of the parent crook. The flow of the grain along the length of this timber is disturbed by knots in the horizontal arm and there is short grain near the starboard chine. There is sapwood (eight rings) along the after face and on the port side of the inner face. There is bark at the junction of the after and inner faces on the port side. This timber was fitted in the boat so that the butt end of its parent limb was probably to starboard.

The cross section is generally rectangular, but towards the upper (starboard) end it becomes more triangular with the after face retaining some of the curvature of the parent log. The horizontal arm *m/s* is 55/115 (0.48) and the $m \times s$ 6325. The overall length was possibly 2m or more. Such a timber would have weighed *c* 10kg.

Boatbuilding features

Fastenings

This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom plank P2 was fastened to it by two nails and S2 by one nail. Side strakes S3–5 were fastened to it by two nails each. The mast-step timber was fastened to F7St by a spike driven from above which did not emerge in the outer face of this half-frame.

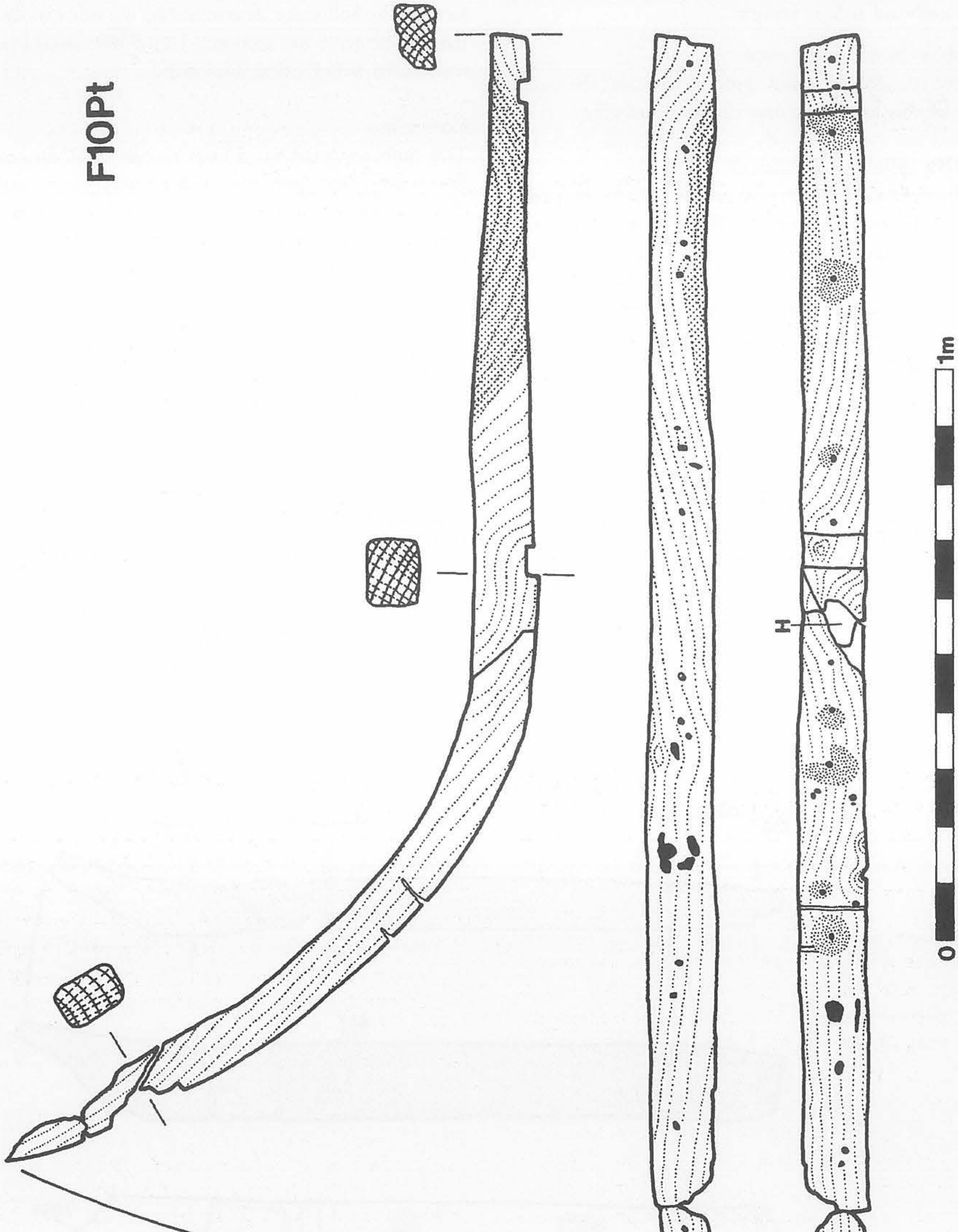


Figure A2.33 Half frame F10 Pt. (Scale 1:10)

Limber holes
The cross section of the port limber hole is 60 × 21mm; the starboard hole is vestigial.

Builders' marks or tool marks
There is a shallow (1mm) groove cut across the outer face of this half-frame near the starboard chine.

F10Pt (5065) – Fig A2.33

Half-frame F10Pt is the port member of the third pair of half-frames from forward. These two half-frames are the next timbers forward of the mid-point of the plank-keel and the next timbers aft of the mid-point of the reconstructed boat. Broken in antiquity into four major fragments, F10PT was lifted and recorded as one unit (plan 111). Fragments are missing from the upper (port) end. The lower end is incomplete, but the 'ghost' recorded on S2 extends across the whole strake. This timber probably extended from P7 to S2. There is a graceful curve around the turn of the port bilge with a radius of *c* 0.86m; the upper part of the port arm flares outwards at an angle of 25–30° to the vertical. The highest 0.15m of the port arm has been worked to a blunt point in section and in plan. This tip is *c* 0.87m above the outer face of the horizontal portion of this timber – this is the highest extending half-frame recorded – and it appears to have protruded above strake P7. The boat's chine breadth is more than 0.96m. A 1:10 model of this half-frame did not conform to the hull shape determined by the other model framing elements (see section 8.1.1). F10Pt should be remeasured before being displayed.

Conversion
This timber was fashioned from an oak crook formed from a main limb (port arm) with a branch (horizontal element). The crook was 2.4m along its curved length, with a greatest girth of *c* 2.17m (diameter 0.69m); it had a fast growth rate (5.9mm per year). Much wood had been worked away during conversion, leaving less than a quarter of the cross section of the parent crook. The grain generally flows along the length of the port arm, but there is variable and short grain in the remainder. There is sapwood (seven rings) towards the lower (starboard) end.

This timber was positioned in the boat so that the butt end of its parent log was to port. The cross section is generally rectangular. The *m/s* of the rising arm is 80/110 (0.73) and the *m* × *s* 8800; the horizontal arm *m/s* is 85/115 (0.74) and the *m* × *s* 9775. With an overall length of 2.4m, such a timber would have weighed *c* 15kg.

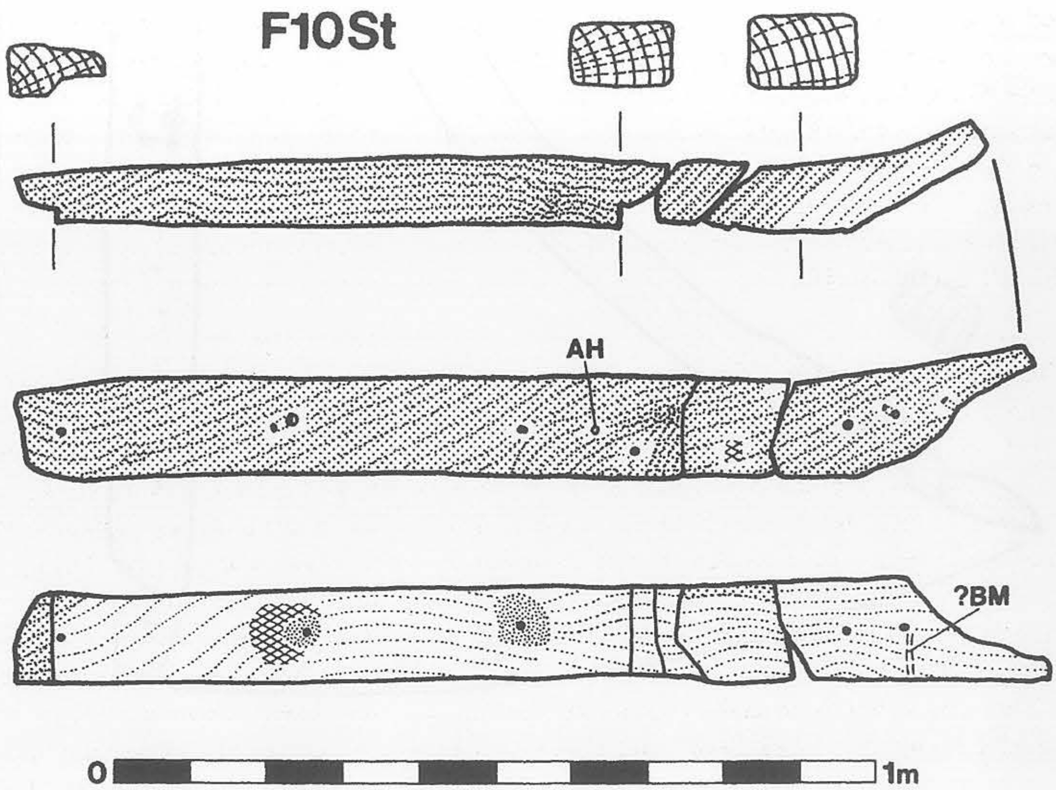


Figure A2.34
Half frame F10 St.
(Scale 1:10)

Boatbuilding features

Fastenings
This timber was fastened to the plank-keel (P1 and S1) by one nail each. The outer bottom planks (P2 and S2) and side strakes P3, P4, P5, P6, and P7 were fastened to it by two nails each.

Repair ?
Another nail appears to have been driven horizontally (as a spike)into the lower (starboard) end of this half-frame as far as the starboard limber hole. Lowest side strake S3 is badly damaged in this region, but two loose nail fragments were found nearby. This suggests that at some stage there was a requirement to fasten this lowest side strake to F10Pt to reinforce the two nails already fastening the strake to adjacent half-frame F10St.

Limber holes
The cross sections of the limber holes are 54 × 25/16mm (port) and 50 × 16mm (starboard).

Builders' marks or tool marks
There are shallow (1mm) grooves cut across the outer face of this half-frame near seam P3/4 and near seam P4/5.

F10St (5064) – Fig A2.34

Half-frame F10St is the starboard member of the third pair of half-frames from forward. Broken in antiquity and in the recent past, it was lifted and recorded as one unit (plan 109). The port (lower) end is broken at the limber hole and nothing survives of this timber outboard; parts are missing from the horizontal section and the upper part of the rising (starboard) arm is also missing. This timber now extends from strake P2 to S4, while a 'ghost' on P2 shows that it once extended the full breadth of that strake.

Conversion
This timber was fashioned from an oak crook with a greatest girth of *c* 1.76m (diameter 0.56m); it had a fast growth rate (5.9mm per year). Much wood had been worked away during conversion, leaving less than a quarter of the cross section of the parent crook. The flow of the grain along the length of this timber is disturbed by large knots in the horizontal arm and there is short grain near the starboard chine. There is sapwood along the after and inner faces.

The cross section is generally rectangular: the horizontal arm m/s is 84/125 (0.67) and the $m \times s$ is 10,500. The overall length may have been *c* 2.4m. Such a timber would have weighed *c* 18kg.

Boatbuilding features

Fastenings
This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom plank P2 was fastened to it by one possibly two nails, S2 by one nail. Side strake S3 was fastened to it by two nails. The butt joint in strake S4 was probably fastened by two nails in each plank.

Limber holes
The cross section of the port limber hole is 50 × 21mm; the starboard hole is ? × 24mm.

Builders' marks or tool marks
There is a possible shallow (1mm) groove cut part-way across the outer face of this half-frame near the starboard chine.

F12Pt (5062) – Fig A2.35

Half-frame F12Pt is the port member of the fourth pair of half-frames from forward. It was lifted and recorded as one unit (plan 107). This half-frame extends from P5 to S2. Apart from a missing fragment, the upper end is probably complete. The lower end has been broken off at the starboard limber hole and is missing. Since there is neither a fastening hole through, nor a 'ghost' of this frame on outer bottom plank S2 outboard of this limber hole, it seems likely that the missing fragment extended only slightly beyond the limber hole. There is a graceful curve around the turn of the port bilge with a radius of *c* 0.9m; the upper part of the port arm flares outwards at an angle of *c* 40° to the vertical. The chine breadth is more than 1m and the tip of the port arm is 0.43m above the outer surface of the bottom.

Conversion
This timber was fashioned from an oak crook formed from a main limb (port arm) with a branch (horizontal element). The crook was 1.9m along its curved length, with a greatest girth of *c* 1.63m (diameter 0.52m); it had a fast growth rate (6.8mm per year). Much wood had been worked away during conversion, leaving less than a quarter of the cross section of the parent crook. The grain generally flows along the length of the port arm, but there is variable and short grain in the remainder. There is sapwood towards the starboard end on the after and inner faces.

This timber was positioned in the boat so that the

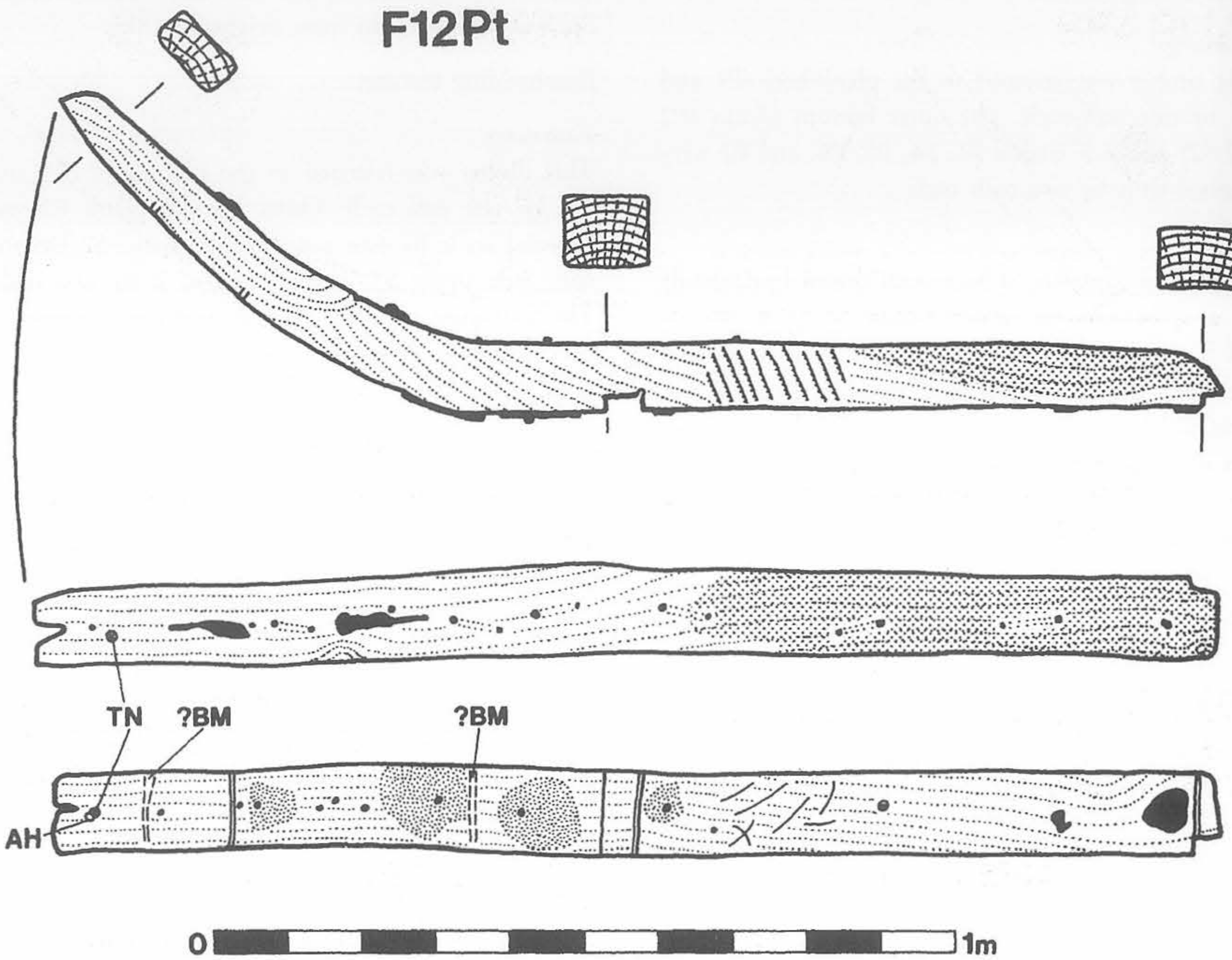


Figure A2.35 Half frame F12 Pt. (Scale 1:10)

butt end of its parent log was to port. The cross section is generally rectangular. The *m/s* of the rising arm is 55/110 (0.5), the $m \times s$ is 6050; the horizontal arm *m/s* is 90/110 (0.82) and the $m \times s$ 9900. The overall length originally was probably *c* 1.9m. Such a timber would have weighed *c* 13kg.

Boatbuilding features

Fastenings
This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom plank P2 and side strakes P3, P4, and P5 were fastened to it by two nails each and outer bottom plank S2 by one nail.

Limber holes
The cross sections of the limber holes are 50 × 20mm (port) and ? × 20mm (starboard). The auger holes at the upper corners of these holes are 5–7mm in diameter.

Builders' marks or tool marks
There is a shallow (1mm) groove cut across the outer face of this half-frame near seam P3/4 and possibly at the port chine and near seam P4/5.

Repair or replacement
The upper nail hole of the two by which strake P5 is fastened to this half-frame has two channels within this frame: the channel that emerges higher up the inner face contains the remains of a nail; the lower one had been plugged.

F12St (5061 and 5084) – Fig A2.36

Half-frame F12St is the starboard member of the fourth pair of half-frames from forward. 5061 (plan 106) forms the greater part of this framing timber: its port end is complete, but its starboard (upper) end is broken and timber is missing. Fragment 5084 (plan 105) is only 0.25m long, but with a parent limb similar to

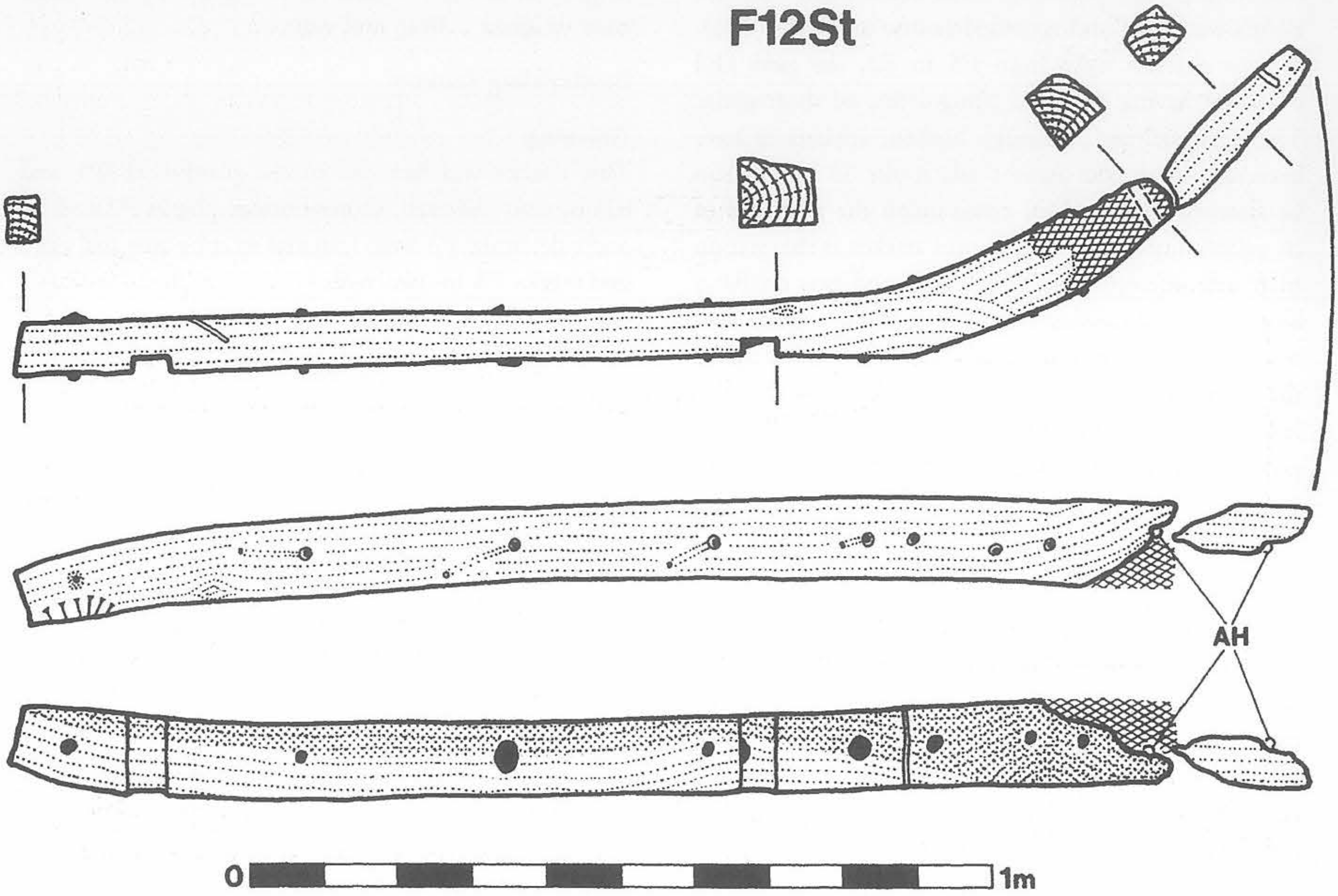


Figure A2.36 Half frame F12 St. (Scale 1:10)

that of 5061 in girth and rate of growth, it may be part of this missing element. This half-frame is now *c* 1.6m in length and extends from strake P2 to S4 and originally probably to S5. The boat's chine breadth is more than 1.2m.

Conversion

This timber was fashioned from an oak crook consisting of a main limb (horizontal element, unusually) and a branch (starboard arm) with a greatest girth of *c* 0.72m (diameter 0.23m). The crook had a fast growth rate (5061: 3.4mm per year; 5084: 3.9mm per year). Much wood had been worked away during conversion, leaving about a quarter of the cross section of the parent crook. The grain generally flows along the length of this timber but is disturbed near the chine. There is short grain in the starboard arm. There is sapwood along the after face and on the outer face to starboard.

This timber was positioned in the boat so that the butt end of its parent log was to port. The cross section is generally rectangular: the horizontal arm *m/s* is 60/100 (0.60) and the *m* × *s* is 6000. The overall length may have been *c* 1.9m. Such a timber would have weighed *c* 8kg.

Boatbuilding features

Fastenings

This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom plank P2 was fastened to it by one nail and S2 by two nails. Side strakes S3 and S4 were fastened to it by two nails each.

Limber holes

The cross section of the port limber hole is 50 × 20mm; the starboard hole is 51 × 18mm.

Builders' marks or tool marks

There is a shallow (1mm) groove cut part-way across the outer face of this half-frame near the starboard chine.

F15Pt (5057) – Fig A2.37

F15Pt is deduced to be the port member of the fifth pair of half-frames from forward: the position of this pair is aft of and adjacent to floor timber F15, but that timber was probably fitted after them. Timber F15Pt was lifted and recorded as one unit (plan 101). It now extends only from P3 to S2, the port end evidently having fractured along a line of short grain. The starboard end, although broken, appears to have been shaped to take against side strake S3 rather than be fastened to it (see for comparison the port end of its paired timber F15St). On port strakes at this station there are: one fastening hole on P3 and two on P4; a large fragment missing from P5; and P6 and P7 had not survived to be excavated. This strongly suggests that there was a port arm to this timber and that this half-frame originally extended from S3 to P5 and possibly higher. The chine breadth of the boat at this station is more than 0.96m.

Conversion

This timber was fashioned from an oak crook that was well over 1m long, with a greatest girth of *c* 1.45m (diameter 0.46m); it had a fast growth rate (7.0mm per year). Much wood had been worked away during conversion, leaving about a quarter of the cross section of the parent crook. The grain is somewhat spiral and confused by knots and there is short grain towards the port end.

The cross section is generally rectangular: the *m/s* is 92/107 (0.86) and the *m* × *s* is 9844. The original length was possibly at least 1.5m. Such a timber would have weighed *c* 10kg and more.

Boatbuilding features

Fastenings

This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom planks P2 and S2 and side strake P3 were fastened to it by one nail each and strake P4 by two nails.

Limber holes

The cross sections of the limber holes are 51 × 24mm (port) and 55 × 30mm (starboard).

F15St (5056) – Fig A2.38

F15St is deduced to be the starboard member of the fifth (and last) pair of half-frames from forward. This timber was lifted and recorded as one unit (plan 100). It now extends only from P3 to S2. The starboard end is incomplete, however, and appears to have fractured along a line of short grain. The port end survives and has been shaped to take against side strake P3 (here with a flare angle of *c* 65°), rather than be fastened to it. The corresponding sections of the starboard-side strakes had not survive to be excavated. By analogy with the rest of the framing pattern in this boat, it seems probable that F15St originally extended up the starboard side to S5 and possibly higher.

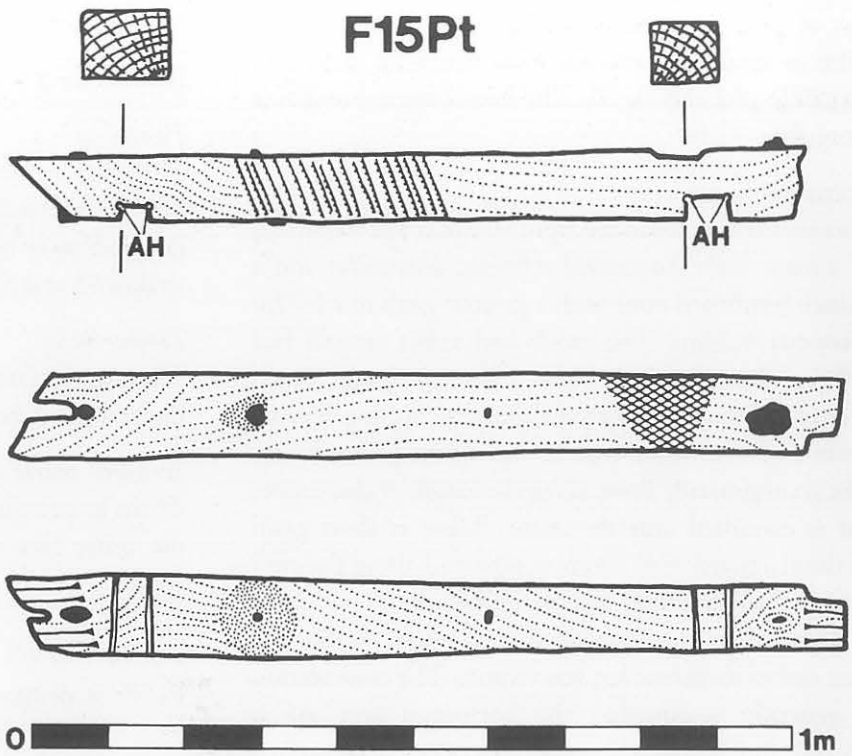


Figure A2.37
Half frame F15 Pt. (Scale 1:10)

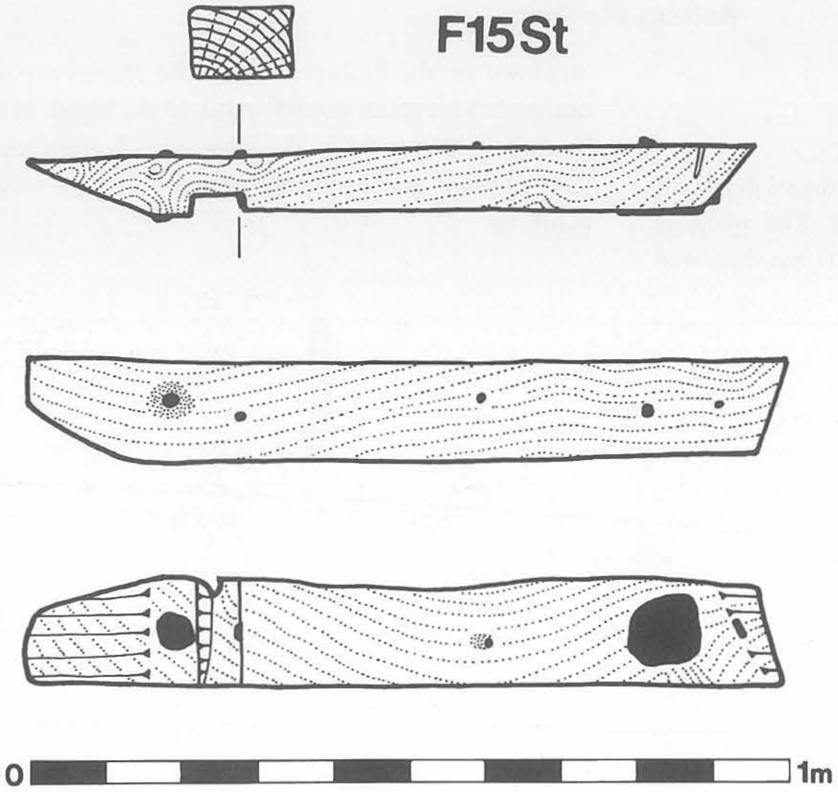


Figure A2.38
Half frame F15 St. (Scale 1:10)

Conversion

This timber was fashioned from an oak crook that was over 1m long, with a greatest girth of *c* 1.41m (diameter 0.45m); it had a very fast growth rate. Much wood had been worked away during conversion, leaving about a quarter of the cross section of the parent crook. The grain is somewhat spiral and confused by knots; there is short grain towards the starboard end.

The cross section is generally rectangular: the *m/s* is 92/130 (0.71) and the $m \times s$ is 11,960. The original length was possibly 1.5m or more. Such a timber would have weighed *c* 13kg.

Boatbuilding features

Fastenings

This timber was fastened to the plank-keel (P1 and S1) by one nail each. Outer bottom planks P2 and S2 were fastened to it by two nails each: one of the nails through P2 had been driven from inboard and clenched by turning the point through 90° outboard of P2.

Limber holes

The dimensions of the port limber holes are 55 × 24mm.

Bottom Planking

Outer bottom planks

P2 (5111) – Fig A2.39

This port outer bottom plank was lifted and drawn in three sections (plans 91, 92, and 93). The plank is generally in a similar condition to P1, but here the 'shadows' of the limber holes in the frames are also outlined. This plank extends most of the length of the bottom and butts with the port bow bottom plank (BP) forward and originally probably with a similar plank aft.

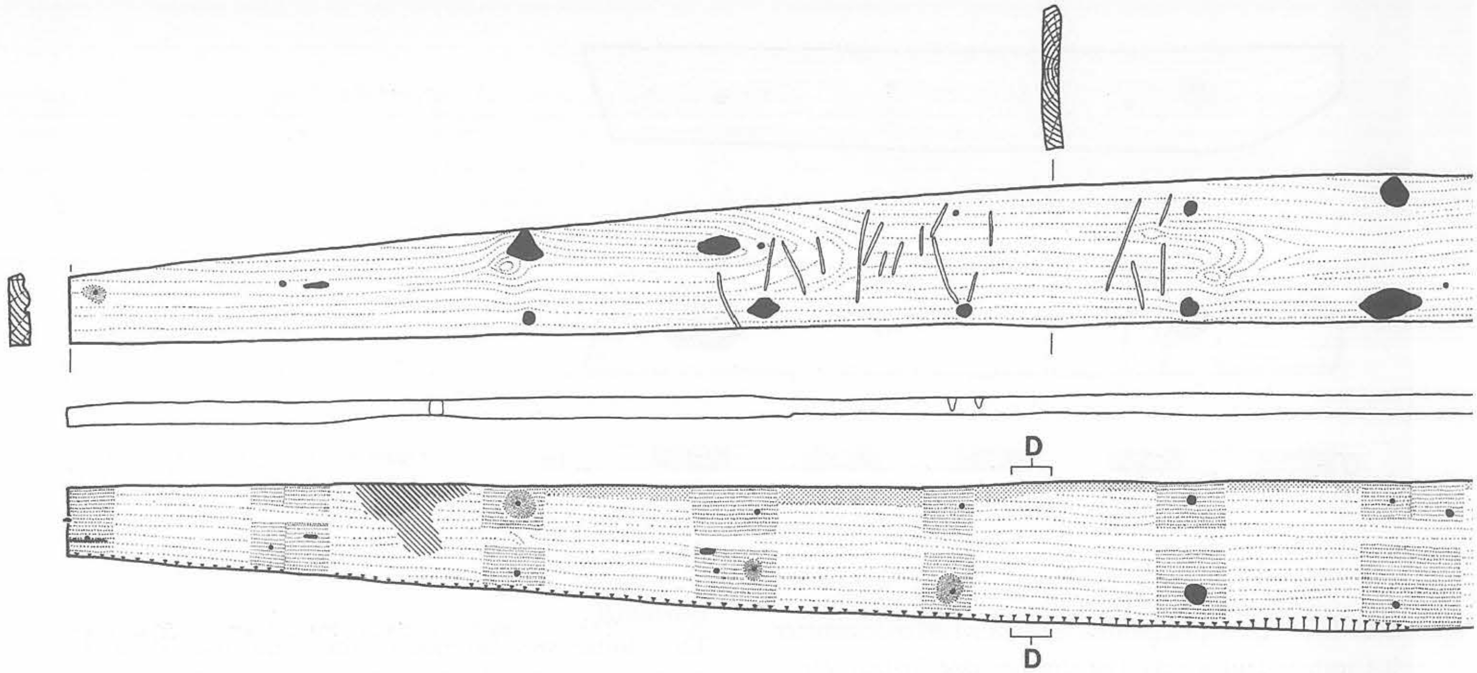


Figure A2.39 Outer Bottom Plank P2. (Scale as shown)

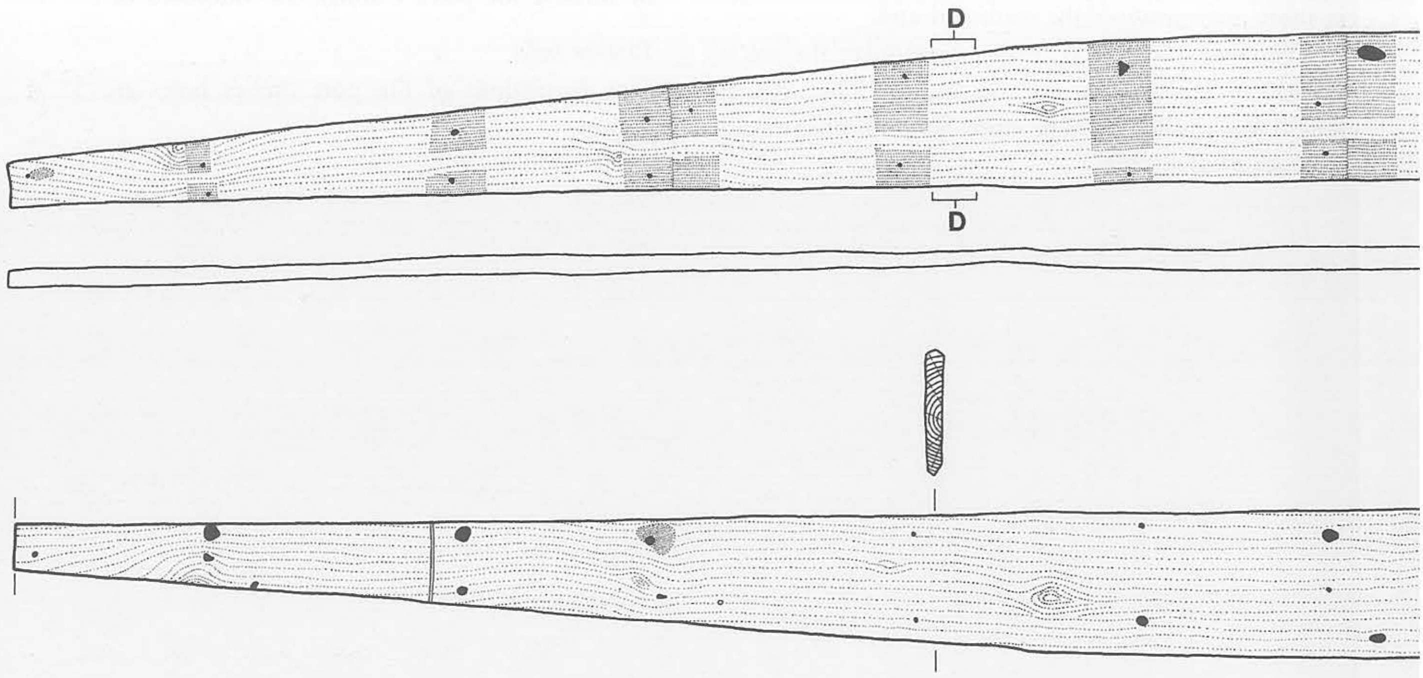
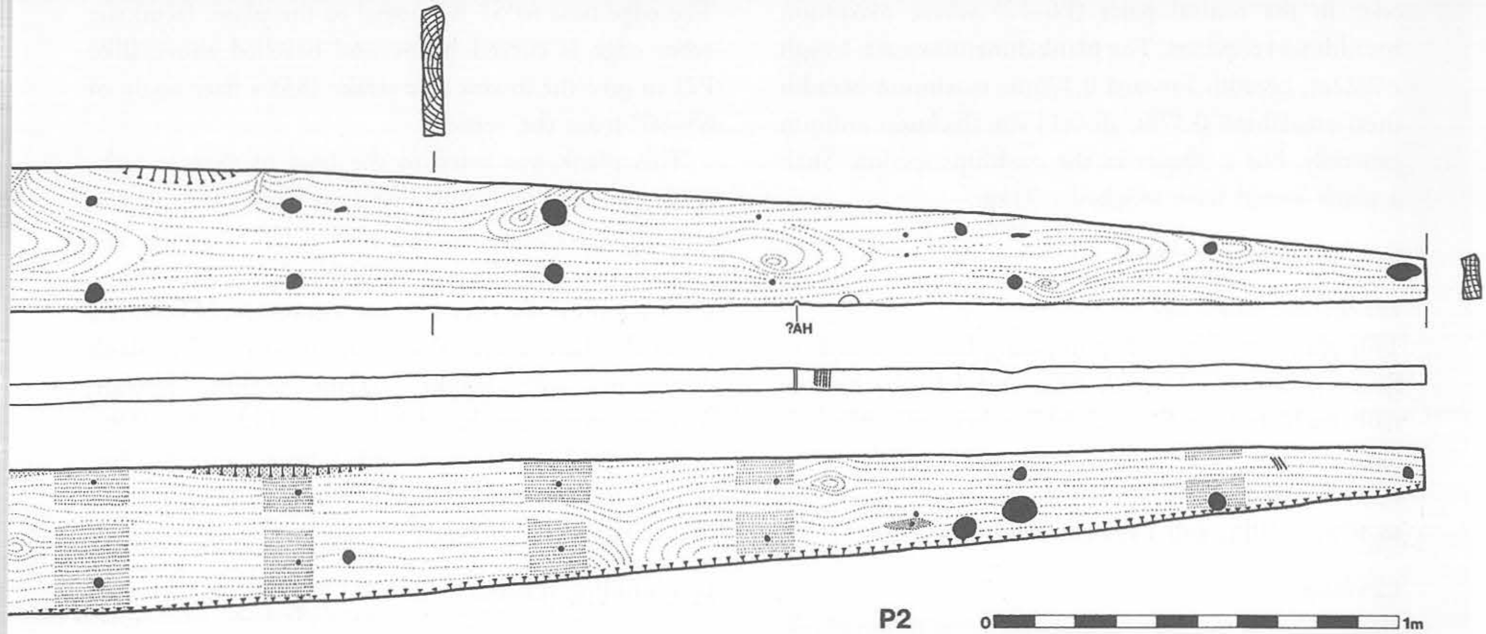


Figure A2.40 Outer Bottom Plank S2. (Scale as shown)

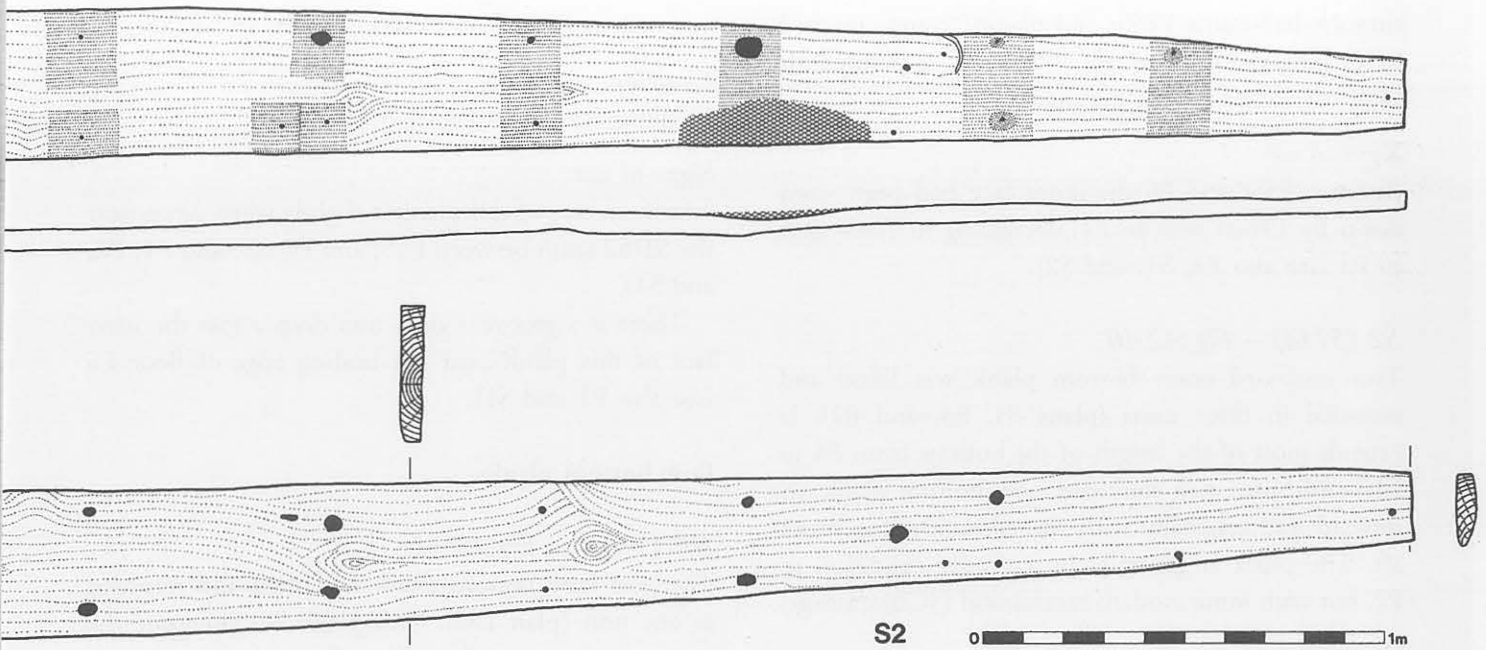
Conversion

The felling of the parent tree of this plank has been dated by dendrochronology to AD 283–328. This plank was fashioned tangentially close to the pith from a straight-grained oak of medium growth rate (2.6mm per year). Branches on the parent tree increased in size and number with height. The bole was more than 7m tall, with a maximum girth of *c* 1.63m (diameter 0.52m) and would have weighed *c* 1.05 tonnes. It is similar to the parent bole of S2; these two planks may have been converted from the same log.

This plank does not have the regularly converging edges of P1, but has been worked along one edge to the curved shape in plan needed to form the outer edge (chine) of the boat's bottom. The ends of this plank and its inner edge (next to P1) are normal to



P2



S2

the plank faces, whereas the outer edge is curved below and bevelled above: this bevel will take a plank 30mm thick with a 70° flare angle from the vertical (see also lowest side strake P3).

This plank was fitted in the boat so that its parent tree's butt end was forward and its pith-facing face outboard. The grain generally flows along the length of this plank, but there is short grain towards the ends. Sapwood (nine rings) had been left along the outer edge in the central parts (F6–12) where maximum breadth was required. The plank dimensions are: length *c* 7.22m; breadth forward 0.175m; maximum breadth (near amidships) 0.37m; aft 0.114m; thickness *c* 40mm generally, but *c* 50mm in the midships section. Such a plank would have weighed *c* 71kg.

Boatbuilding techniques

Plank/frame fastenings
This plank was fastened, pith-facing face outboard: to floor timbers F6, F8, F9, F11, and F13–16 by two nails each, but to F4 and F17, where this plank is narrowest, by one; to half-frames F5Pt, F5St, F7Pt, F10St, F12St, F15Pt, and F15St by one nail each, but to F7St, F10Pt, and F12Pt by two nails each.

Caulking
No caulking remains were found adhering to this plank, but impressions of small nails were noted in the edge next to P1 by frames F6, F13, and F14.

Repair
An additional nail had been driven from inboard through half-frame F15St and plank P2 and clenched by turning the tip through 90° so that it pointed aft along the outer face of the plank.

Signs of use
Between F5St and F6 the inner face had been worn down by 13mm next to P1, decreasing to 7mm next to P3 (see also P1, S1, and S2).

S2 (5114) – Fig A2.40

This starboard outer bottom plank was lifted and recorded in three units (plans 84, 83, and 82). It extends most of the length of the bottom from F4 to F17 and butts with starboard bow bottom plank SB forward and originally with the corresponding plank aft. The plank is generally in a similar condition to P2, but with some modern mechanical (JCB) damage.

Conversion
This plank was fashioned tangentially near the pith from a generally straight-grained oak. It has not yet proved possible to estimate the growth rate. The bole was more than 7m in height with branches in its higher portions. The maximum girth was *c* 1.82m (diameter 0.58m); its weight would have been *c* 1.13 tonnes. It is similar to the parent bole of P2; these two planks may have been converted from the same log.

The curve of this plank's starboard edge that forms the starboard chine is just about a mirror image of the port edge of P2. Both ends of this plank are butted. The edge next to S1 is normal to the plank faces; the other edge is curved below and bevelled above (like P2) to give the lowest side strake (S3) a flare angle of 65–80° from the vertical.

This plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was aft – in this respect the opposite of P2. Generally the grain flows along the length of the plank, but there is short grain on the curves; some sapwood had been left forward where there is least heartwood. The plank dimensions are: length 7.22m; breadth forward 0.105m; maximum breadth (near amidships) 0.359m and aft 0.175m; thickness 45–50mm generally, but thinner towards the lowest side strake S3. Such a plank would have have weighed *c* 70kg.

Boatbuilding features

Fastenings
This plank was fastened to floor timbers F6, F8, F9, F11, and F13–15 by two nails and by one nail to F4, F16, and F17. It was fastened by two nails to half-frames F5Pt, F7Pt, F10Pt, F12St, and F15St and by one nail to F5St, F7St, F10St, F12Pt, and F15St.

Caulking
Caulking was found along both edges.

Signs of use
The inner face of this plank is slightly worn down near the S1/S2 seam between F5St and F6 (see also P1, P2, and S1).

There is a groove 1 or 2 mm deep across the *outer* face of this plank near the leading edge of floor F6 (see also P1 and S1).

Bow bottom planks

BP (5123) – Fig A2.41

The port bow bottom plank was lifted and recorded as one unit (plan 130). This plank lies alongside the stem post from near floor F1 to floor F4 where it butts with outer bottom plank P2 and part of plank-keel P1. The foremost part of the lowest side strake (planks

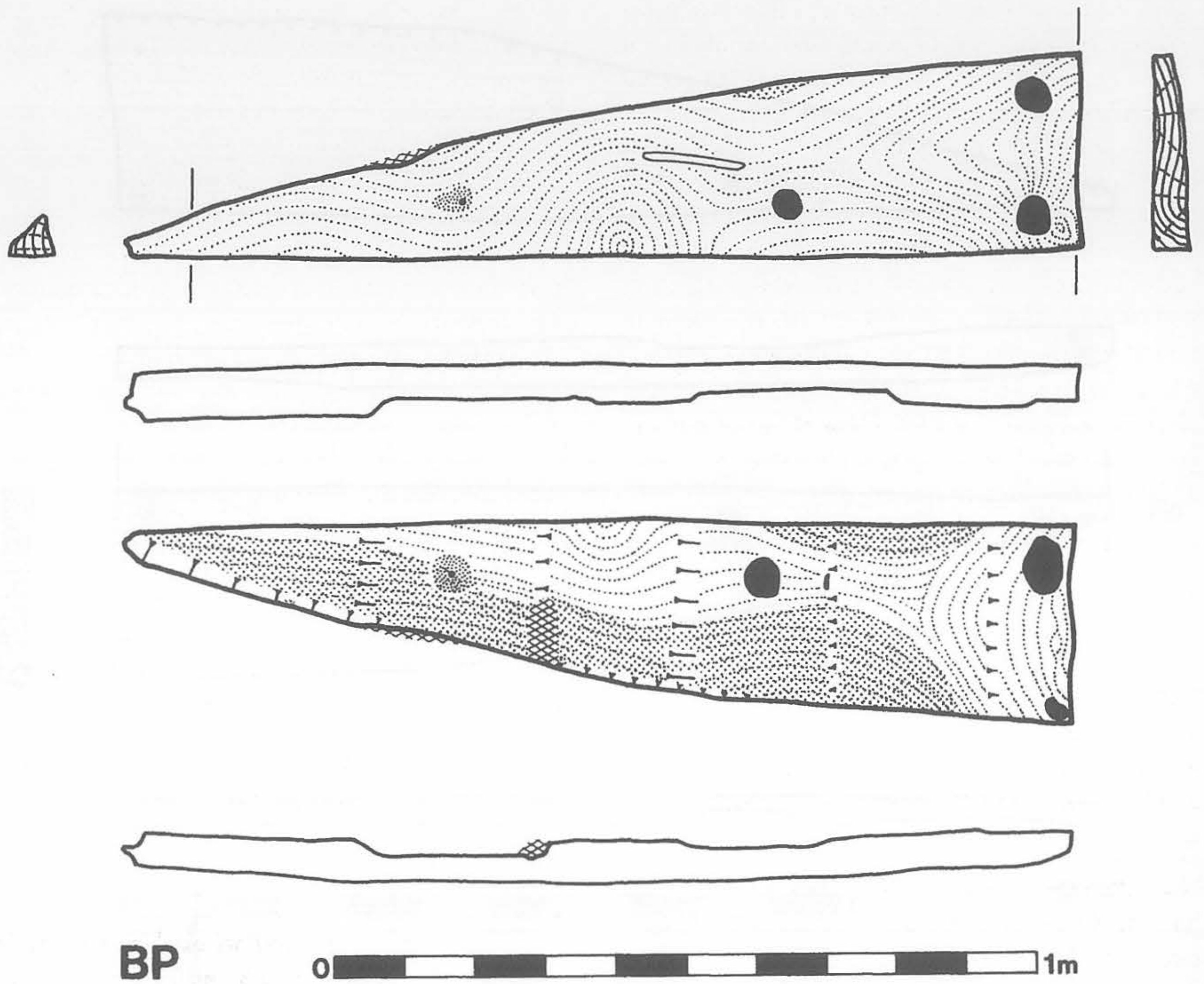


Figure A2.41 Bow Bottom Plank BP. (Scale 1:10)

P3B, P3A, and P3A*) lies outboard of it. Plank BP is in reasonable condition although eroded in parts.

Conversion

This plank was generally fashioned tangentially, but towards the bow an upcurve was worked which crossed the pith. The parent tree was an oak with a fast growth rate (3.8mm per year). The 1.5m length of bole chosen had some large branches.

Much of the bole had been worked away during conversion. The plank breadth increases regularly from the bow. Forward of floor F2 the plank turns up gracefully in a hewn curve matching the rising stem post. The forward end of this plank is broken, but was originally thick enough to take one fastening to the post; the after end is a butt with P2 and P1. The edge next to the post is normal to the plank faces; the other edge is curved in plan and thus continues the curve of the outer edge of P2 to the post, with a bevel of 5–12° from the vertical, giving the adjoining lowest side strake (P3) a corresponding deadrise.

This plank was fitted to the boat so that the face that was most pith-facing was unusually *inboard* (see also P5B and P6B); its parent tree's butt end was probably aft. The grain is variable, with some short grain towards the bow; there is some sapwood along both edges. The plank dimensions are: length 1.36m; breadth from, say, 30mm at the bow to 0.28m at F4; thickness 70 to 50mm. The weight of such a plank would have been *c* 10kg.

Boatbuilding features

Fastenings

The forward tip of this plank was fastened by a spike driven through the plank's edges into the port side of

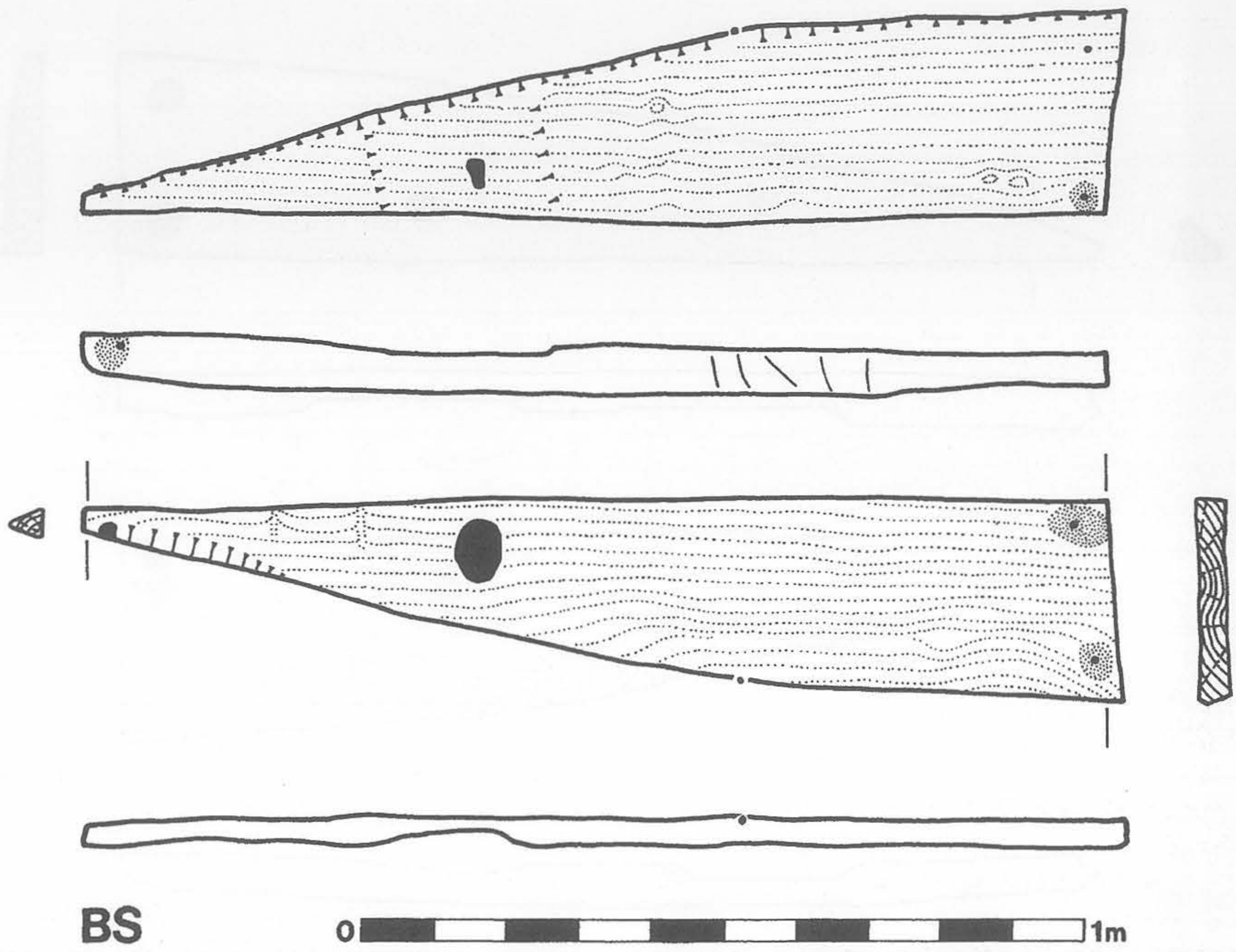


Figure A2.42 Bow Bottom Plank BS. (Scale 1:10)

the post, just aft of the lower end of the rabbet. It was also fastened to bow floors F2 and F3 by one nail each and to F4 by two.

Frame housings
Housings to a depth of *c* 25mm were worked across this plank to take bow floors F2 and 3. These were not a tight fit and designed to lower the inner face of these floor timbers, rather than add strength to the nailed joint between frame and plank. A similar housing for the forward 100mm of floor F4 was a tighter fit designed to reinforce the vital double-notch joint between frame and stem post.

BS (5125) – Fig A2.42

The starboard bow bottom plank was lifted and recorded as one unit (plan 131). This plank lies alongside the stem post from near floor timber F1 to floor F4 where it butts with outer bottom plank S2 and part of plank-keel S1. It is in a reasonable condition.

Conversion
This plank was fashioned tangentially near the pith from an oak of medium growth rate (2.3mm per year). The limb chosen was 1.5m in length and divided into two medium-sized branches at its upper end.

Much had been removed from the limb during conversion. The plank's breadth decreases regularly from aft, continuing the incurving outer edge of the boat's bottom towards the post. Forward of floor F2 the plank curves upwards matching the rising stem post. The forward end is square cut where it is fastened to the post; the after end is a butt with S2 and S1. The edge next to the post is normal to the plank faces; the outer edge has a bevel of *c* 10° from the vertical, giving the adjoining lowest side strake (S3) a corresponding flare of *c* 80°. Close to the bow the outer face of this plank has been chamfered next to the post for a distance of *c* 0.25m probably to match the curve of the sides.

This plank was fitted in the boat with its pith-facing face probably outboard; its parent tree's butt end was probably aft. The grain generally flows along the length of the plank, with some short grain towards the bow caused by the curved outer edge. No sapwood had been left on this plank. The plank dimensions are: length 1.42m; breadth from 30mm at the bow to 0.287m aft; thickness aft, 50mm next to the post and forward of the plank-keel S1, decreasing to 40mm at its outer edge and forward of the outer bottom plank S2; further forward it increases to *c* 70mm, to match the post, reducing to *c* 50mm as it curves upwards. It is generally thinner on its outer edge where it meets the lowest side strake S3. The weight of such a plank would have been *c* 12kg.

Boatbuilding features

Fastenings
The forward end was fastened by one spike driven from the outer face of the plank through the inner edge into the starboard side of the post, just aft of the lower end of the rabbet. It was also fastened to floor timbers F1 and F2 by one nail and to F4 by two. A nail fastening bow floor F3 to the lowest side strake S3 has clipped the outer edge of this plank.

Frame housings
A housing to a depth of *c* 15mm was worked across this plank to take floor timber F2. As with bottom plank BP this was not a tight fit. There is also a shallow depression aft to receive F4.

Side Planking

Port side

P3A (5122) and P3A (formerly part of 5118) – Fig A2.43*

The short length (*c* 0.7m) of timber P3A that extends aft from the post to side-frame SF2Pt was originally known as BP2 as it was considered to be ancillary to the port bow bottom plank BP (5123). Further reflection suggests that it is best thought of as a joint-foremost element, possibly a repair, in strake P3 set into the lower edge of P3B (5110) where it curves around floor timber F1 (5076/7) to meet the stem post (5091) near the lower end of the post's rising arm. P3A was lifted and recorded as one unit (plan 133). Subsequently a fragment thought to be from plank P7A was recognised as also coming from the foremost part of strake P3. This is now known as P3A* (plan 153). It is 0.78m in length and has a similar shape to P3A. The precise relationship of P3A and P3A* to P3B has to be established during the reassembly of the hull.

Conversion
P3A was fashioned tangentially close to the pith from an oak log or limb of medium growth rate (2.3mm per year).

During conversion much of the log had been worked away leaving less than a quarter of the diameter. The plank's edges are almost parallel. The after end and the upper edge (which butt against P3B) are normal to the plank faces. The lower inner edge is bevelled (18–36°) where this plank fits against the port bow bottom plank BP. The forward end is also bevelled to fit into the stem post rabbet; it is also shaped to match the angle of the stem post, here rising at about 20° to the horizontal.

P3A was positioned in the boat with its pith-facing face inboard. The grain generally flows along its length; no sapwood had been left on. The plank's dimensions are: length *c* 0.8m; breadth *c* 110mm; thickness 30mm. P3A* was similar. Together the fragments would have weighed *c* 9 kg.

Boatbuilding features

Fastenings
Plank P3A was fastened by one nail at each end to the stem post and to side frame SF2Pt (5090). That it was fastened to a side timber suggests that P3A was added late in the building sequence possibly as a 'shutter' (McKee 1972, 29). Alternatively it may have been a repair. The plank's hooked forward end ensured that it was in contact with the post over a greater length than otherwise; nevertheless there was still insufficient room at this end of the plank for more than one nail (cf Fenwick 1978, 229–36). Plank fragment P3A* may have been fastened to SF1Pt.

P3B (5110) – Fig A2.44

This plank, with P3A and P3A*, is the foremost plank in the lowest side strake P3. It was lifted in three units which were subsequently drawn individually (plans

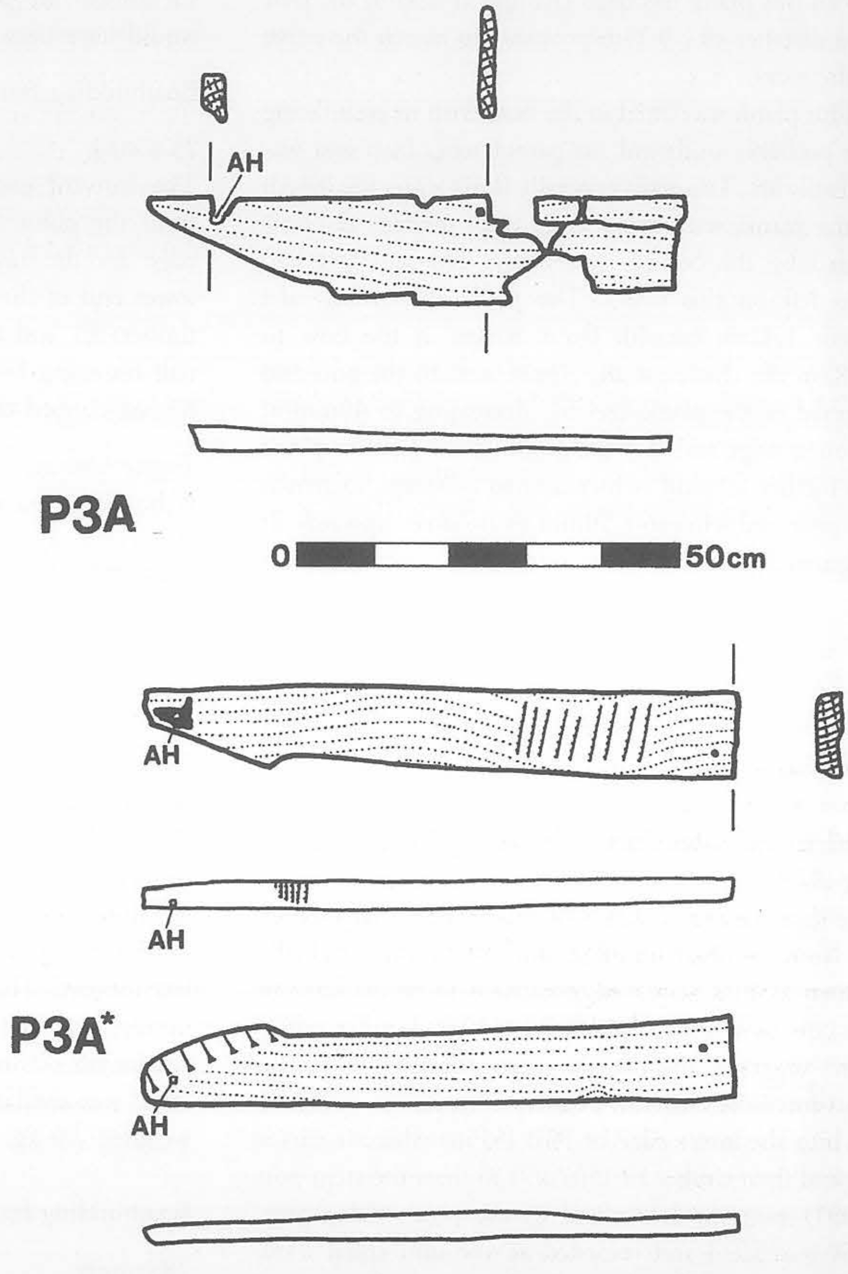


Figure A2.43
Port Side Plank P3A, P3A*.
(Scale 1:10)

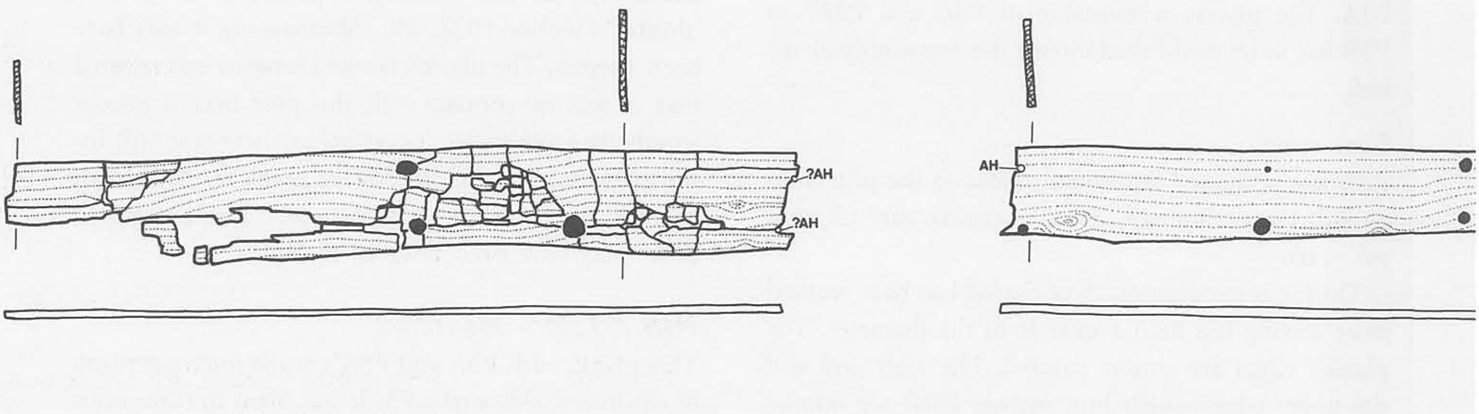


Figure A2.44 Port Side Plank P3B. (Scale as shown)

137, 138, and 135). The first 2m from the bow are broken with pieces missing and are so fragile that it has not yet proved possible to examine the inner face. The remainder of this plank, however, is generally in good condition with the frame positions visible on the central section from F6 to F9 – such 'ghosts' are only seen elsewhere on this boat's side planking on P4A from F4 to F7Pt and on P6B at SF9Pt. The plank extends from near F1 to F14 where it butts with P3C.

Conversion

This plank was fashioned tangentially not far from the pith from a straight-grained oak of medium growth rate (2.3mm per year). There were only a few small branches throughout the length. This bole was more than 7m tall and had a maximum girth of *c* 1.45m (diameter 0.46m). Such a bole would have weighed *c* 930 kg.

Much of the bole had been worked away during conversion leaving only half the diameter near amidships and somewhat more than that at the ends. This plank has a near-rectangular cross section. In plan, the plank is not parallel-sided but tapers from each end towards the middle, with the lower edge curved longitudinally. It also has a slight bevel outboard. This shape was needed so that P3B would fit the outer curve of the boats's bottom at its seam with strake P2 and also so that its upper edge would be near horizontal at its seam with strake P4. The upper edge of this plank was normal to the plank faces. With the addition of planks P3A and P3A* this plank extended forward as far as the stem post; the after end was cut at a slight angle to the normal to meet P3C in an angled butt at floor timber F14.

This plank was positioned in the boat so that its parent log's butt end was forward and its pith-facing face outboard. The grain flows along the length, except for minor disturbances near knots; no sapwood had been left on. The plank's dimensions are: length *c* 7m; breadth forward 0.26m, near amidships 0.17m, aft 0.26m; thickness *c* 18mm forward, otherwise *c* 25mm; there is an apparent 6mm difference from the thickness of P3C in the butt at F14. Such a plank would have weighed *c* 30kg.

Boatbuilding features

Fastenings

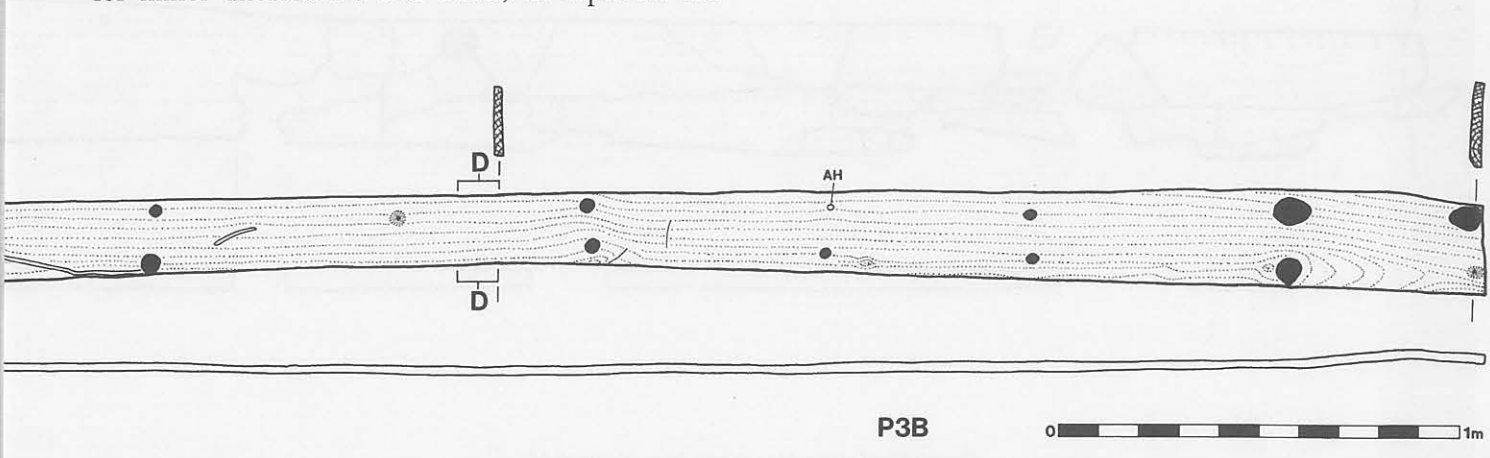
The plank was fastened by two nails each to floor timbers F2, F3, F6, F8, F11, F13, and F14 and to half-frames F5pt, F7pt, F10pt, and F12Pt. It was fastened by one nail each to floors F1, F4, and F9. There is no obvious reason for not using two nails at F4, but at F9 this plank was at its narrowest and at F1 this plank may have been repaired and P3A and P3A* inserted. No side timbers appear to have been fastened to this plank, although both SF8Pt and SF13Pt overlapped it (see the discussion under SF13Pt above). At frames F5 to F8 the nails in the upper part of the plank lay at about the same distance from the plank's edge and the plank was found to be split along this line when examined after excavation.

Builders' marks

A shallow mark has been scribed across the inner face between the positions of floor F8 and the adjacent side frame SF8Pt (see also P4C below).

P3C (5109) – Fig A2.45

This aftermost surviving plank in strake P3 was lifted and recorded in one piece (plan 132). It extended from floor timber F14 where it butted P3B to a position aft of floor F17 where it is now broken: originally it may have extended to the stern post. Plank P3C is in a reasonably good condition, but a large part of the upper edge aft is missing.



Conversion

This plank was fashioned on a diameter across the pith from a whole log of reasonably straight-grained oak of medium growth rate (2.4mm per year). This log was 2.05m long and had some minor branches; its girth was *c* 1.13m (diameter 0.36m).

The plank is almost parallel sided, with a slight increase in breadth towards the stern. Its lower edge is normal to the plank faces; the upper edge inboard

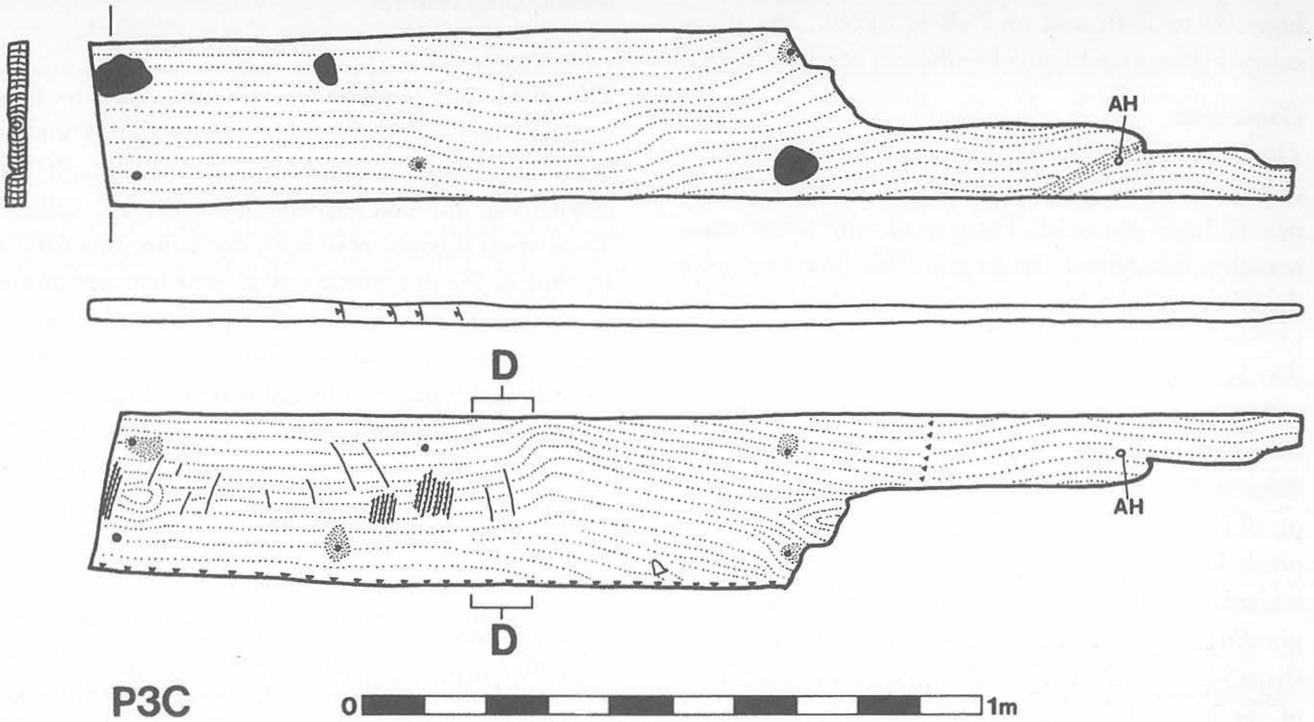


Figure A2.45 Port Side Plank P3C. (Scale as shown)

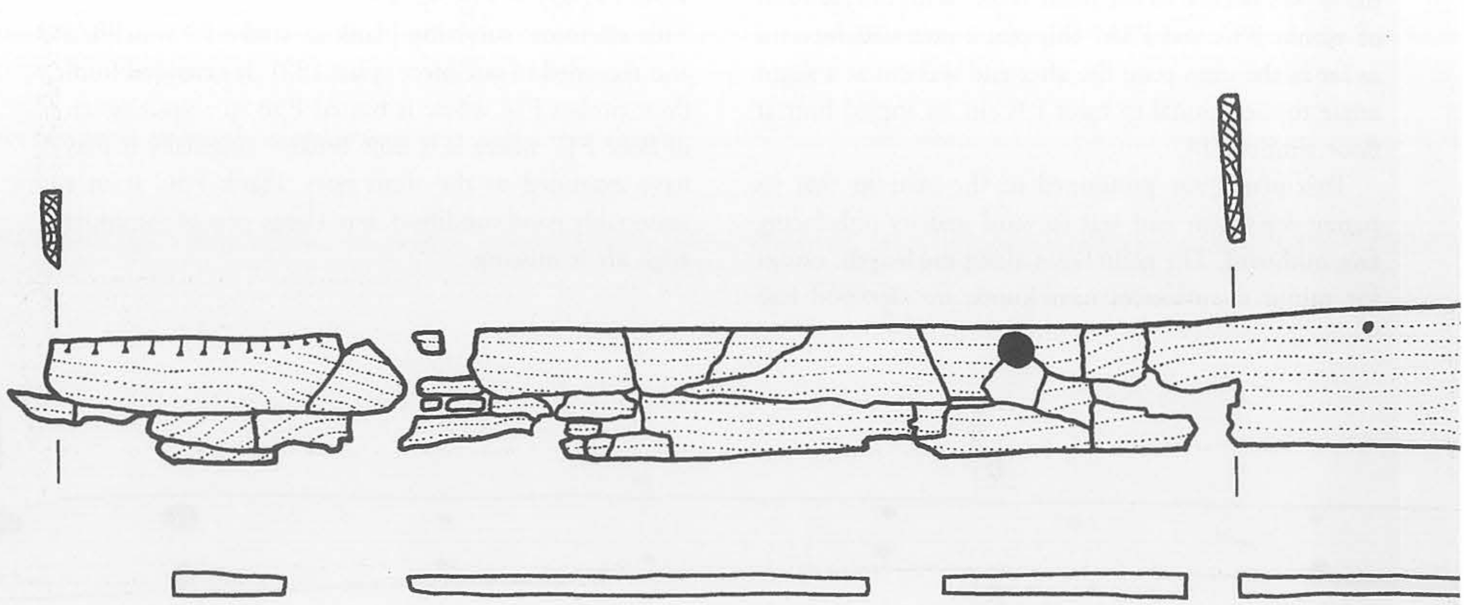


Figure A2.46 Port Side Plank P4A. (Scale 1:10) appears to be similar. The forward end of this plank is cut at a slight angle across the plank where it meets P3B in an angled butt. The angle of the butt (if such is the case) at its after end is indeterminate.

The plank was positioned in the boat so that the butt end of its parent log was forward. The grain generally flows along the plank, but is slightly wavy in places; no sapwood had been left on this plank. The plank's dimensions are: length 2.05m; breadth forward 0.26m, near F16 0.268m; thickness 31mm – an apparent difference in thickness of 6mm from plank P3B. This difference may be an anomalous reading or it may have been taken up by irregularities in the shaping of F14: this question may be resolved during the reassembly of the hull. Such a plank would have weighed *c* 13kg.

Boatbuilding features

Fastenings
This plank was fastened by two nails each to floor timbers F14, F16 (and probably F17) and by one to F15. It was fastened to half-frame F15Pt by one nail and to side timber SF17Pt by two nails.

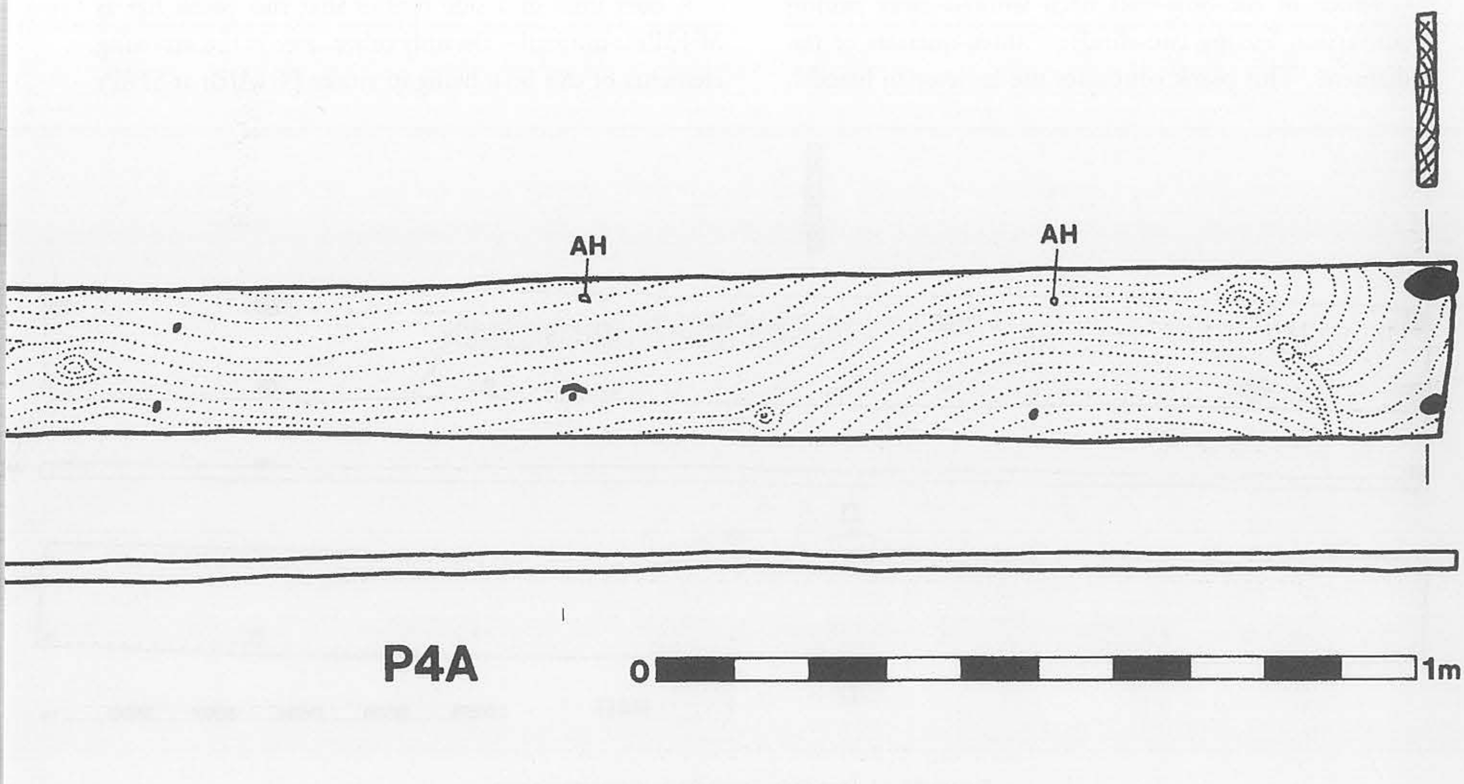
P4A (5118) – Fig A2.46

This foremost plank in strake P4 was lifted and recorded in two units. The unit nearer to the stem post (plan 152) is incomplete and fragmented and only the outer face could be recorded until after conservation. The unit further aft (plan 141) is in a much better condition and framing 'ghosts' are visible from F4 to F7Pt. This plank extends from close to (originally from) the post to half-frame F7Pt.

Conversion
This plank was fashioned tangentially close to the pith from an oak of fast growth rate (3.8mm per year). The bole chosen was 4 to 5m long, with some medium-sized branches. Its girth was *c* 1.22m (diameter 0.39m) and it would have weighed *c* 415kg.

Much of the bole had been worked away during conversion, leaving two-thirds to three-quarters of the diameter. The breadth of this plank generally diminishes towards the bow. The forward end is missing, but originally it would have been shaped and bevelled to fit the post; the after end is cut at a slight angle to the normal at its butt with plank P4B. The lower edge is normal to the plank faces generally, but with a bevel near the post; there is a slight bevel on the upper edge.

This plank was fitted to the boat so that its parent log's butt end was aft. Unusually it was fastened with its pith-facing face inboard. The grain generally flows along its length but with some spiral grain aft; no sapwood had been left on. The plank dimensions are: length 4.13m; breadth 0.24m, aft to *c* 0.165m at the post; thickness *c* 24mm – the evident difference in



thickness of *c* 8mm with P4B, if not due to an anomalous measurement, may have been noticeable in the butt at F7Pt. Such a plank would have weighed *c* 16kg.

Boatbuilding features

Fastenings

In the bows forward of floor timber F4, this plank was fastened by one nail each to floor timbers F2 and F3 (and possibly to F1) and to side-frames SF2Pt, SF3PtM, and SF4PtF. Further aft it was fastened by two nails each to floor timbers F4 and 6 and to half-frames F5Pt and F7Pt (here in a butt).

Caulking

Caulking was found on the after end of this plank by side frame F7Pt, where the plank was butted to P4B.

P4B (5117) – Fig A2.47

This second plank from forward in strake P4 was lifted and recorded in two units (plans 140 and 143): both are in good condition. It extends from half-frame F7Pt to side timber SF13Pt.

Conversion

This plank was fashioned tangentially close to the pith from a straight-grained oak of slow growth (1.7mm per year). The bole chosen was 3.5–4m long, with some small branches. Its girth was *c* 1.41m (diameter 0.45m) and it would have weighed *c* 357kg.

Much of the bole had been worked away during conversion leaving two-thirds to three-quarters of the diameter. This plank continues the increase in breadth seen in P4A as far as the midships station where it then gradually narrows. There is an angled butt at the forward end: the lower edge is normal to the plank faces; the upper edge has an inner bevel of *c* 10° where it meets strake P5.

This plank was fitted in the boat with its parent tree's butt end forward; its pith-facing face was outboard. The grain flows along the length of this plank; no sapwood had been left on. The plank dimensions are: length 3.22m; breadth 0.24m forward increasing to 0.255m near amidships and then reducing to 0.25m; thickness 30 to 35mm. This plank was some 8mm thicker than P4A at the F7Pt butt and 5 to 10mm thicker than P4C at the SF13Pt butt. Unless these differences are the result of anomalous measurements, this may have been noticeable at the two butts. Such a plank would have weighed *c* 21kg.

Boatbuilding features

Fastenings

This plank was fastened to side timber SF9Pt by one nail through its lower end. It was fastened by two nails each to floor timbers F9 and F11, to half-frames F7Pt, F10Pt, and F12Pt and to side timbers SF8Pt and SF13Pt – one of the nails in SF13Pt being very close to the end and possibly shared with plank P4C in the butt at this station. The upper end of frame F8 takes against this plank, but there is no fastening between them.

A butt joint at a side timber that this plank has at SF13Pt is unusual – the only other cases in the surviving elements of this boat being in strake P6 (A/B) at SF8Pt

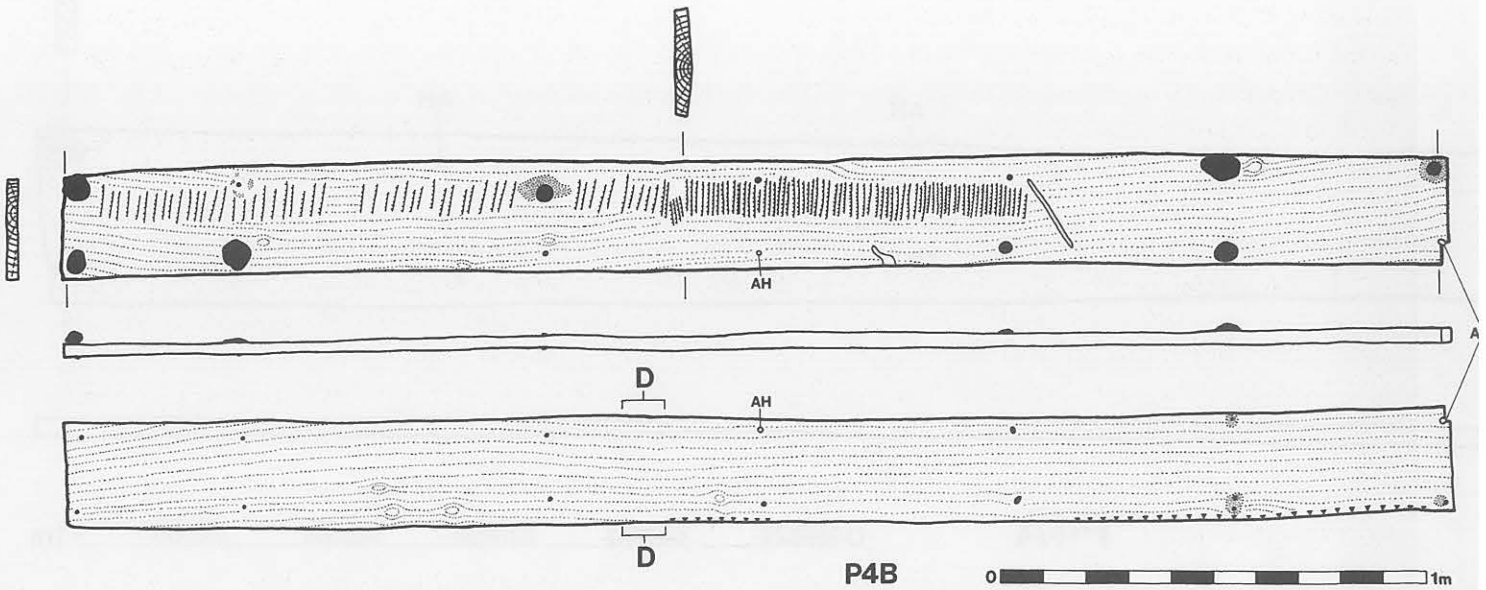


Figure A2.47 Port Side Plank P4B. (Scale as shown)

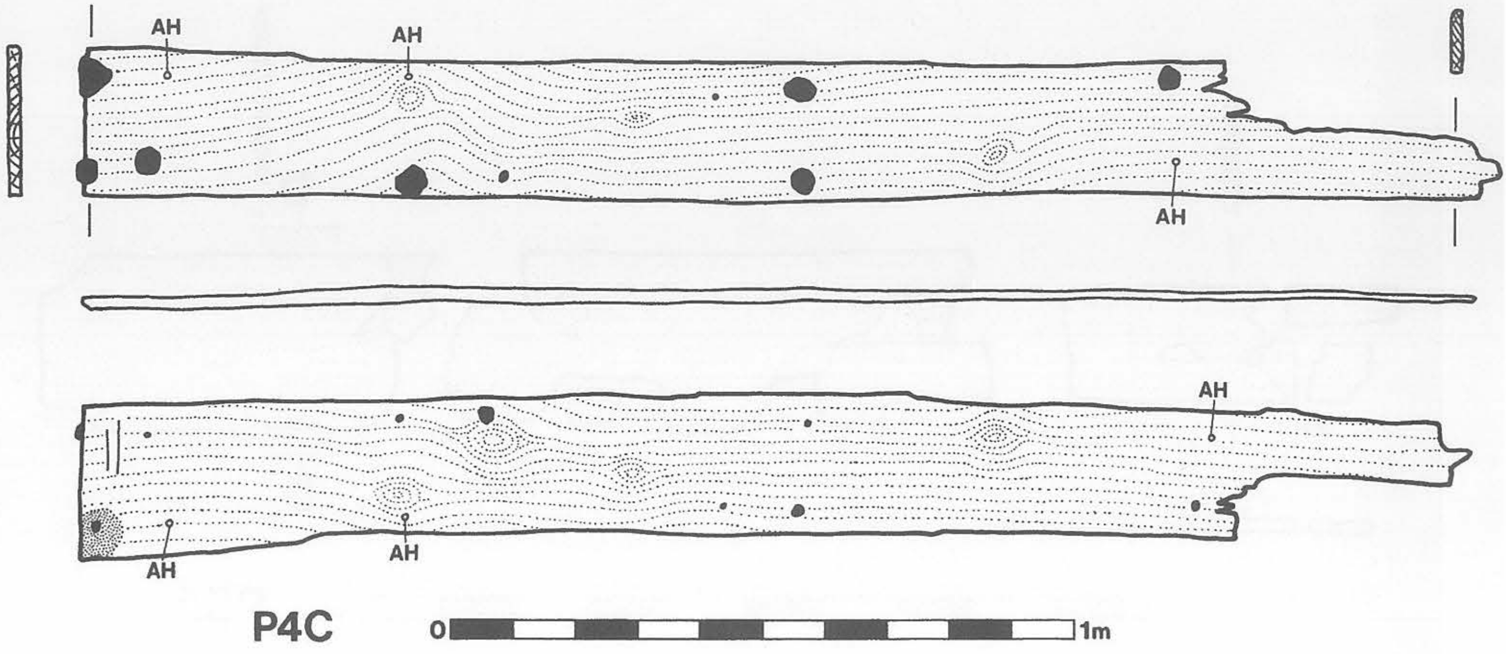


Figure A2.48 Port Side Plank P4C. (Scale as shown)

and in the inset/repair to plank P3B at SF2Pt. The butt at SF13Pt in strake P4 poses a special problem in that, before planks P4B and P4C could be fastened to this side timber, it would seem to require that the latter is already fastened to strake P3. Although SF13Pt takes against P3, however, it is not fastened to it.

Repairs

The apparent mismatch in thickness between this plank and its neighbours at both its ends suggests that this plank may have been a replacement. If so the original fastening holes through the framing must have been reused. If P4B were a replacement plank, this could be the reason why there is a butt at SF13Pt. Originally there could have been a butt at F12Pt, which is a half-frame and a more substantial timber and, therefore, more appropriate than any side timber. After damage the old P4B and the part of P4C forward of SF13Pt could have been removed and a new, slightly longer and thicker P4B inserted. At this stage SF13Pt would already have been fastened to strake P5 and probably higher strakes and thus would have been a firmer base for a butt joint. Future examination of the timbers during the reassembly of the remains may throw more light on this matter.

P4C (5108) – Fig A2.48

The aftermost surviving plank in strake P4 was lifted as one unit (plan 139). It extends from a butt joint at SF13Pt to the vicinity of F17 where it was broken in antiquity. The plank is in a good condition, but a large part is missing from the upper edge, aft.

Conversion

This plank was fashioned tangentially near the pith from a straight-grained oak with a fast growth rate (4.6mm per year). The bole chosen was 2.5 to 4m in length and had some medium-sized branches and a girth of *c* 1.35m (diameter 0.43m).

Much of the bole had been worked away during conversion. This plank continues the breadth-narrowing tendency of P4B towards the stern. The forward end has a vertical butt; the after end is broken. The lower edge is normal to the plank faces; the upper edge has an inner bevel of *c* 10°.

The plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was probably forward. The grain generally flows along its length; no sapwood had been left on this plank. The plank dimensions are: length 2.25m+; breadth reducing from 0.25m to *c* 0.2m where broken; thickness *c* 20mm: there is a mismatch at the forward butt (see P4B). If this plank had originally extended as far as the stern post, it would have weighed *c* 14kg.

Boatbuilding features

Fastenings

This plank was fastened to floor timbers F13 and F16 by two nails and to F15 and the port end of F14 by one nail. It was fastened to half-frame F15 Pt by two

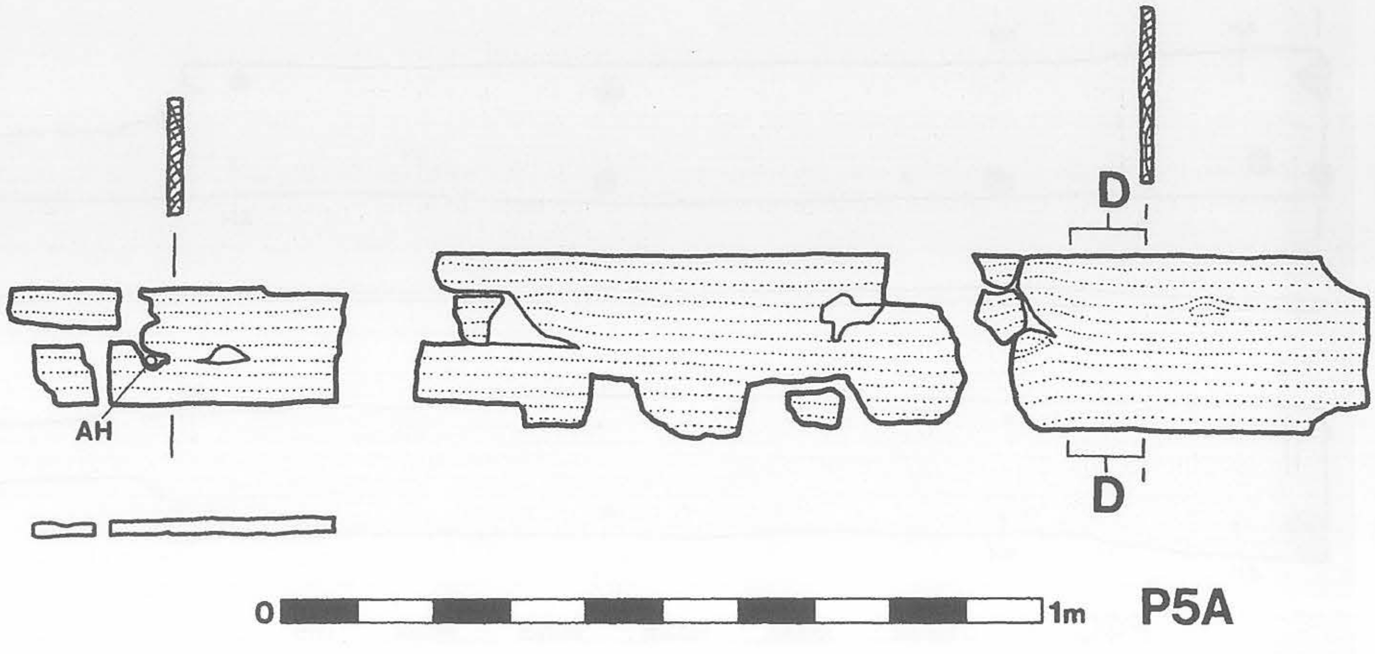


Figure A2.49 Port Side Plank P5A. (Scale 1:10)

nails, to side timber SF14Pt by two nails, and to side timber SF13Pt by one nail and another which it appears to share with P4B at this butt.

Builders' marks

There is a mark 82mm long scribed across the inner face of this plank where F13 lies alongside SF13Pt (see also P3B at F8).

P5A (5129) – Fig A2.49

The foremost plank in strake P5 was lifted and recorded as two units (plans 154 and 97). This plank extends from near the post (probably from the post originally) to a butt with P5B at half-frame F5Pt. Apart from a short section forward of F5Pt, the remains are very fragmentary; only the outer face has been recorded.

Conversion

This plank was fashioned tangentially some distance from the pith from a relatively straight-grained oak with a medium growth rate (2.1mm per year). The bole chosen was 2m long and had some small branches and a girth of *c* 1.41m (diameter 0.45m).

Much of the bole had been worked away during conversion leaving about two-thirds of the diameter. The plank breadth increases from the bow and both edges appear to be normal to the plank faces. The forward end is now broken, but would have been shaped and possibly bevelled to fit into the post rabbet; the after end is a near-vertical butt.

The plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was probably aft. The grain generally flows along its length; no sapwood had been left on. The plank dimensions are: length greater than 1.7m – probably *c* 2m; breadth increasing from 0.145m near the bow to 0.26m near F5Pt; thickness *c* 16mm near the bow increasing to *c* 21mm at F5Pt. If this plank originally extended from the post it would have weighed *c* 6kg.

Boatbuilding features

Fastenings

Although nails were found with this plank, their original position is unclear. Holes in appropriate frames show, however, that this plank was fastened by one nail each to side timbers SF2Pt, SF3Pt, and SF4Pt and by two nails to half-frame F5Pt at the butt. Its forward end would probably have been spiked to the post.

P5B (5119) – Fig A2.50

This plank, the second from the bow in strake P5, was lifted and recorded as two units (plans 147 and 148). It extends from a butt with P5A at half-frame F5Pt to a butt with P5C at floor F11. This plank is in a reasonable condition. The inner face of the forward element has not, however been recorded.

Conversion

This plank was fashioned tangentially near the pith from an oak with a fast growth rate (3.5mm per year). The bole chosen was 3.31m long, with some medium-sized branches and a girth of *c* 1.38m (diameter 0.44m)

Much of the bole had been worked away during conversion. The plank breadth decreases very slightly from the bow towards the midships station and then increases towards the stern. The forward end has a vertical butt, the after an angled butt. The lower edge is normal to the plank faces; the upper edge has a slight bevel.

This plank was fitted to the boat so that its pith-facing face was unusually inboard; its parent tree's butt end was possibly aft; no sapwood had been left on; the grain is slightly wavy and the plank is somewhat cross-grained aft. The plank dimensions are: length 3.31m; breadth at F5Pt 0.26m, near amidships 0.255m, at F11 0.275m; thickness *c* 22mm. Such a plank would have weighed *c* 15kg.

Boatbuilding features

Fastenings
This plank was fastened near the top of floor timber F6 by one nail and near the top of F11 by two; to half-frames F5Pt and 10Pt by two nails each and F7Pt by one; and to side timbers SF6.5Pt, SF8Pt, and SF9Pt by two nails each.

Caulking
A fragment of caulking remained stuck to the lower edge of this plank between SF8Pt and SF9Pt.

P5C (5106) – Fig A2.51

The aftermost surviving plank of strake P5 was lifted and recorded as one (plan 146). This plank extends from a butt with P5B at floor F11 to a butt with P5D at floor F16. It measures *c* 2.75m in length and is in a reasonable condition, although a large part of the upper edge aft is missing. The inner face was not recorded.

Conversion
The felling of the parent tree is dated by dendrchronological method to AD 281–326. This plank was fashioned some distance from the pith from an oak with a slow growth rate (1.6mm per year). The limb chosen had some small branches and a girth of 1.57m (diameter 0.5m.).

Much of the bole had been worked away during conversion. The plank breadth decreases slightly towards the stern. The ends of this plank were both angled butts; the edges were normal to the plank faces.

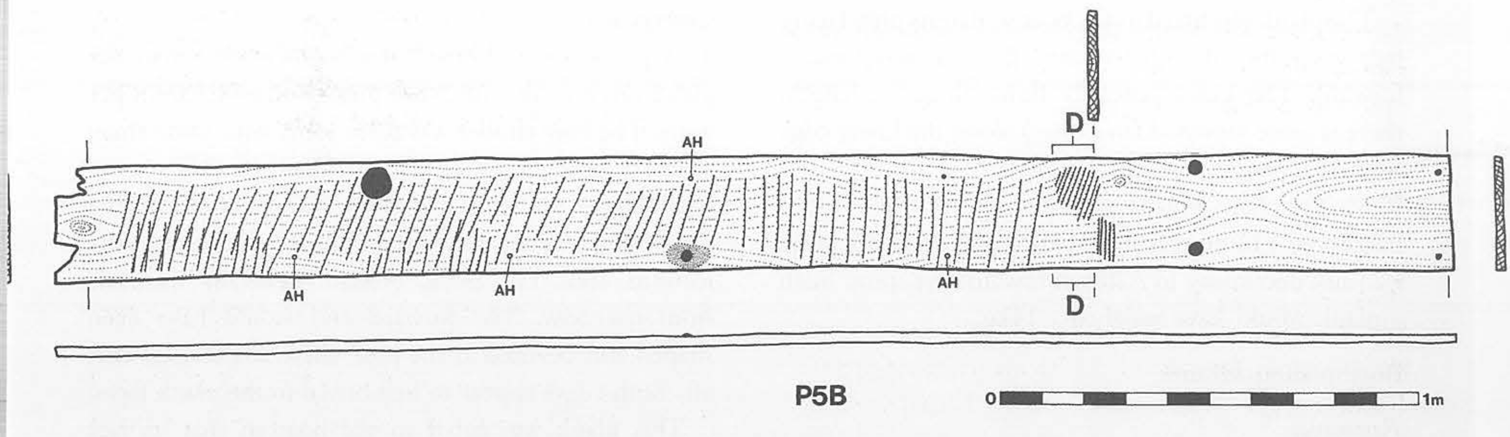


Figure A2.50 Port Side Plank P5B. (Scale as shown)

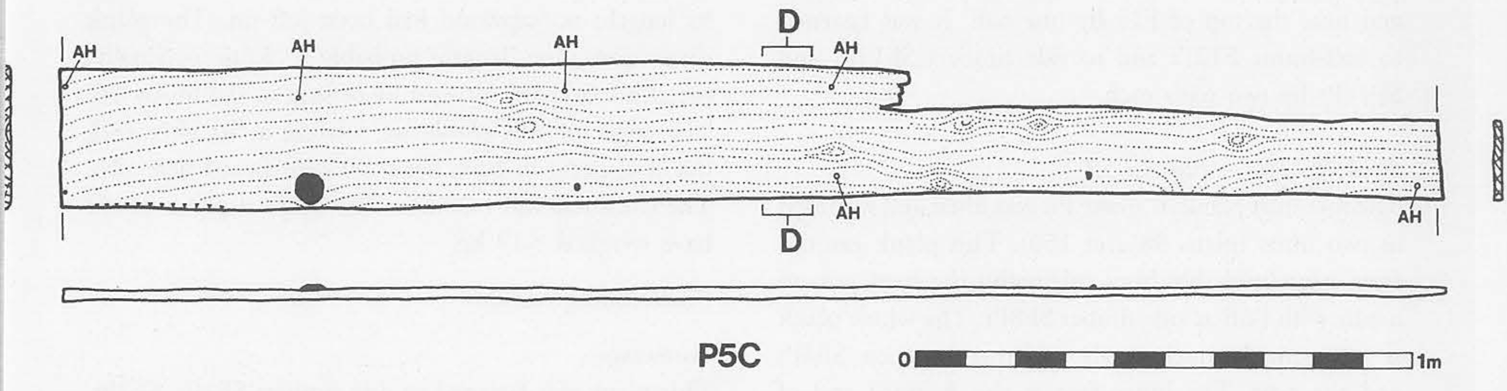


Figure A2.51 Port Side Plank P5C. (Scale as shown)

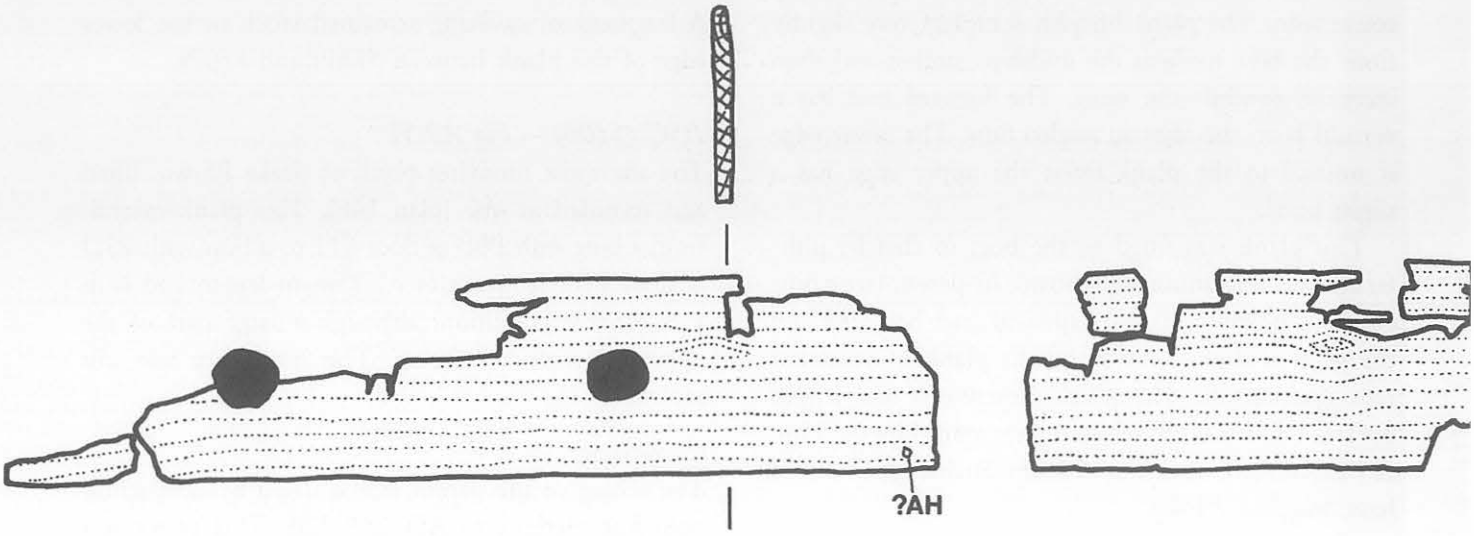


Figure A2.52 Port Side Plank P6A. (Scale 1:10)

The plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end was possibly forward. The grain generally flows along its length; there is some sapwood (five rings) along the lower edge forward where this plank is broadest (see also S5A and P7A). The plank dimensions are: length 2.75m; breadth 0.275m at F11 decreasing to *c* 0.26m by F16; thickness *c* 25mm decreasing to *c* 20mm towards the stern. Such a plank would have weighed *c* 14kg.

Boatbuilding features

Fastenings
This plank was fastened near the top of floor timber F11 (butt) and F16 (probable butt) by two nails each and near the top of F15 by one nail. It was fastened to half-frame F12Pt and to side timbers SF13Pt and SF14Pt by two nails each.

P6A (5130) – Fig A2.52

The foremost plank in strake P6 was lifted and recorded as two units (plans 98 and 150). This plank extends from near (probably from originally) the stem post to a butt with P6B at side timber SF8Pt. The whole plank is fragmented; much is also missing between SF4Pt and the post. The inner face at this forward end of the plank has not yet been recorded.

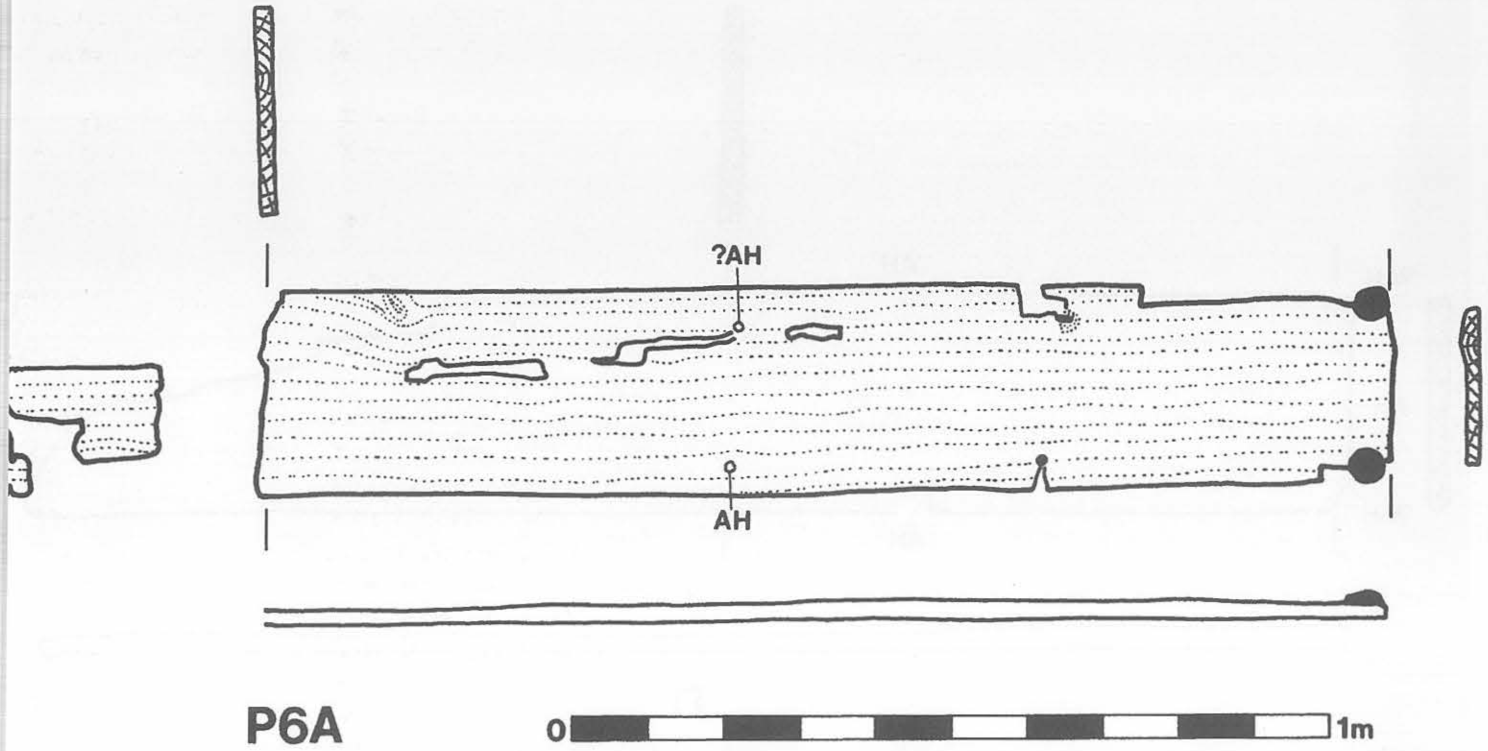
Conversion
This plank was fashioned at a slight angle across the pith from an oak with a fast growth rate (4.33mm per year). The bole chosen was 3.5m long, with some small branches and a girth of *c* 2.2m (diameter 0.70m).

Much of the bole had been worked away during conversion leaving only about half the diameter at the forward end. The plank breadth generally increases from the bow. The forward end would have been shaped and bevelled at the post; there is a vertical butt aft. Both edges appear to be normal to the plank faces.

This plank was fitted to the boat so that its face which was most pith-facing was outboard; its parent tree's butt end was aft. The grain generally flows along its length; no sapwood had been left on. The plank dimensions are: length probably *c* 3.5m originally; breadth *c* 0.255m forward increasing to 0.27m by F6. The edges of this plank are missing at its after end, but it appears to have been *c* 0.27m broad here also. The thickness was *c* 22mm. The original plank would have weighed *c* 17 kg.

Boatbuilding features

Fastenings
This plank was fastened to side timbers SF1Pt, SF2Pt, SF3PtA, and SF4PtA by one nail each and to side



timbers SF3PtM and SF4PtF by two nails each. Further aft it was fastened by two nails each to half-frames F5Pt and F7Pt and to side timbers SF6.5Pt and SF8Pt (butt).

Repairs
Near the after end of this plank caulking had been forced into a longitudinal split some 100mm in length.

P6B (5120) – Fig A2.53

The aftermost surviving plank in strake P6 was lifted and recorded as two units (plans 151 and 149). This plank extends from a butt with P6A at side timber SF8Pt to aft of half-frame F10Pt where it was broken in antiquity. The surviving elements are in a reasonable though broken condition – there is a 'ghost' of SF9Pt visible on the inner face (see also P3B and P4A). Part of the upper edge by and aft of F10Pt is missing; the inner face aft has not yet been recorded.

Conversion
This plank was fashioned tangentially some way from the pith from an oak with a fast growth rate (4.6mm per year). The chosen bole had a girth of *c* 1.7m (diameter 0.54m).

Much of the bole had been worked away during conversion, leaving only about two-thirds of the diameter near the after end. The breadth of this plank generally decreases slightly from forward. The lower edge seems to be normal to the plank faces; the upper edge was probably bevelled. The forward end of this plank has a vertical butt; the after end is broken.

This plank was fitted to the boat so that its pith-facing face was unusually *inboard* (see also P3A, P4A, and P5B); its parent tree's butt end was possibly forward. The grain generally flows along its length; no sapwood had been left on. The plank dimensions are: length indeterminate but greater than 1.74m; breadth *c* 0.28m forward, slightly decreasing to *c* 0.27m aft; thickness generally 24mm, but thinner at the upper edge – this may be the remains of a bevel. The original plank would have weighed more than 10kg.

Boatbuilding features

Fastenings
This plank was fastened by two nails each to side timbers SF8Pt (butt) and SF9Pt and to half-frame F10Pt.

P7A (5121) – Fig A2.54

The remains of strake P7, deduced to be the top strake, are generally fragmented and much appears to be missing. The inner face has not yet been recorded. The growth rates, the breadths of individual elements, and the general nature of the surviving fragments are very similar, suggesting that these all came from one plank; nevertheless there remains the possibility that there is more than one plank here. These remains were lifted and recorded as four units (plans 153, 96, 94, and

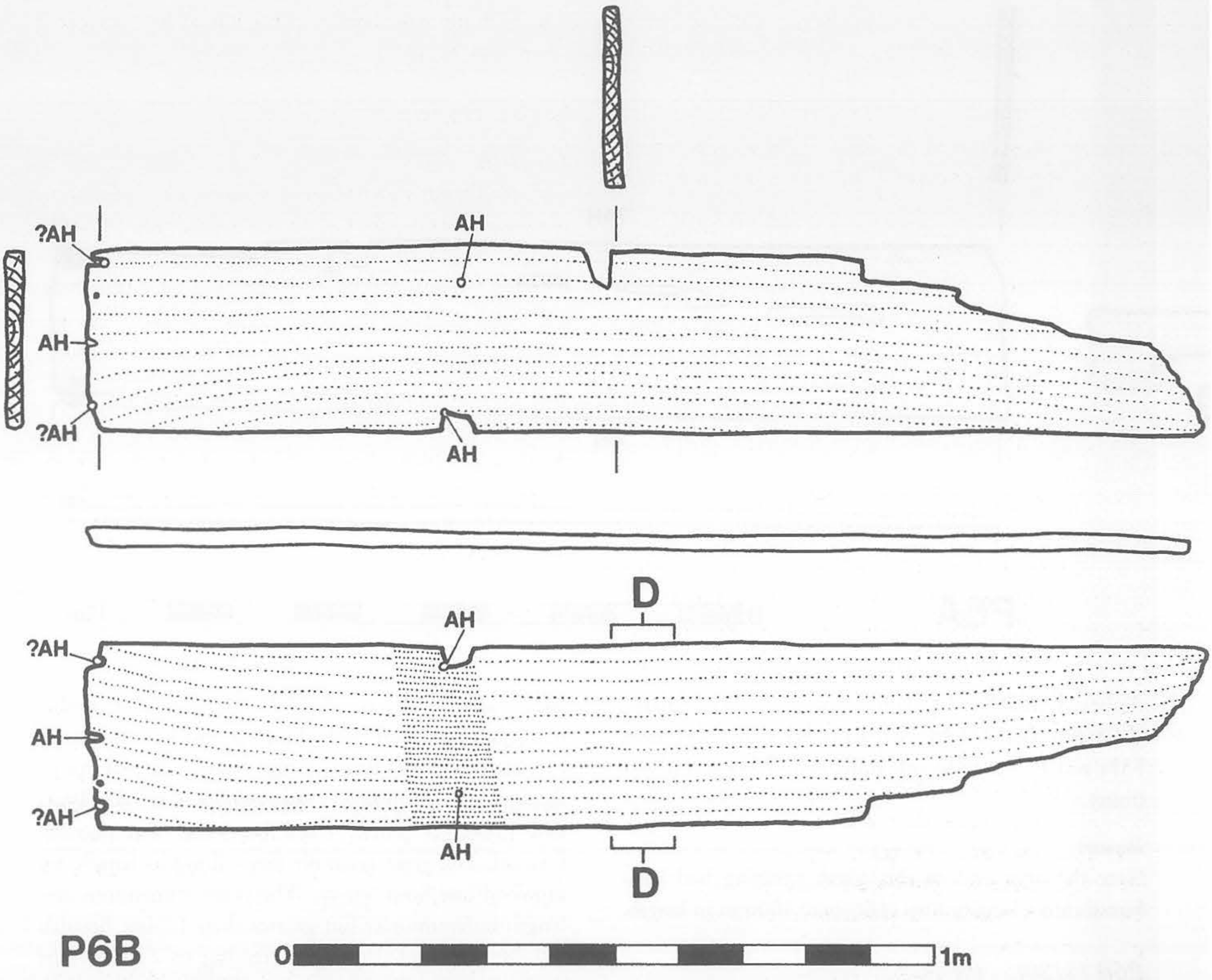
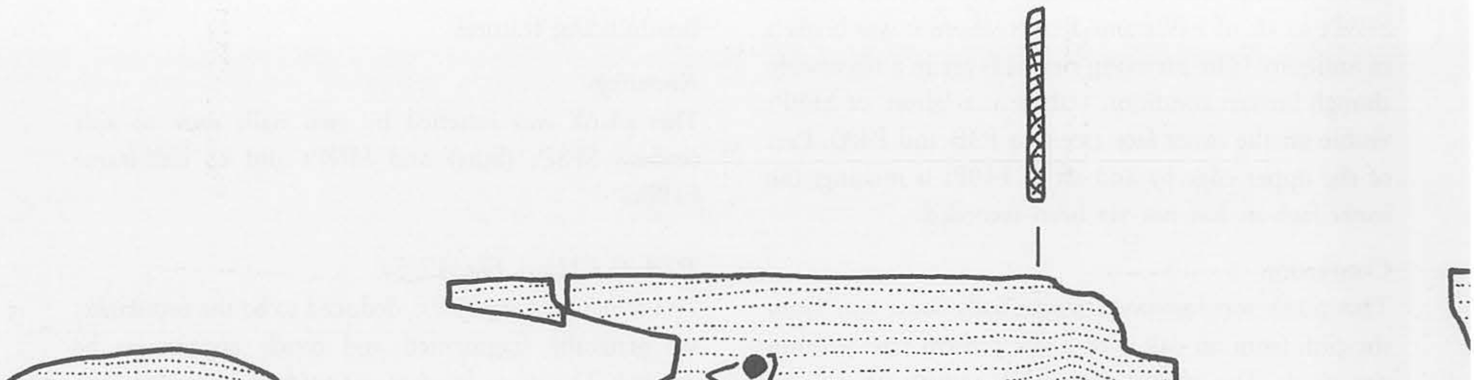


Figure A2.53 (*above*) Port Side Plank P6B. (Scale 1:10)



95). Subsequent to the recording, what had been thought to be the foremost fragment of this strake (plan 153) was identified as P3A*, a leading part of strake P3. Plank P7A appears to extend from near the stem post approximately to SF9Pt. Two fastening holes near the top of half-frame F10Pt show that originally this plank probably extended as far as that station, since there are no butt joints evident on SF9Pt or F10Pt.

Conversion

This plank was fashioned tangentially away from the pith from an oak with a medium/fast growth rate (3.07mm per year). The bole chosen was 5m and more in length, with some small branches and a girth of *c* 1.51m (diameter 0.48m).

Much of the bole had been worked away during conversion, leaving less than two-thirds of the diameter near the middle of the surviving fragments. The breadth of this plank apart from close to the post appears to decrease slightly from forward to a minimum near F7Pt, then to increase very slightly further aft. The forward and after ends are broken. The edges appear to be normal to the plank faces; there is no indication that P7 is not the top strake.

This plank was fitted to the boat so that its pith-facing face was outboard; its parent tree's butt end may have been forward. The grain appears to flow along the length; there is sapwood on the upper edge where the plank is broadest. The plank dimensions are: length greater than 4m; breadth *c* 0.25m forward, decreasing to 0.23m near F7Pt, then increasing to 0.24m; thickness *c* 25mm. The original plank would have weighed more than 19kg.

Boatbuilding features

Fastenings

This plank was fastened by one nail each to the tops of side timbers SF1Pt, SF3Pt(M), SF4Pt(F), and SF6.5Pt and by two nails to SF8Pt and SF9Pt. It was fastened by one nail each to the tops of half-frames F5Pt and F7Pt and by two nails to F10Pt.

Signs of use

Just aft of side timber SF6.5Pt *c* 40mm from the upper edge, a sub-rectangular hole 50 × 30mm had been cut through the plank; there appear to be signs of wear on its upper forward corner. This hole may have been connected with the rigging arrangements (see also SF6.5Pt above).

Starboard

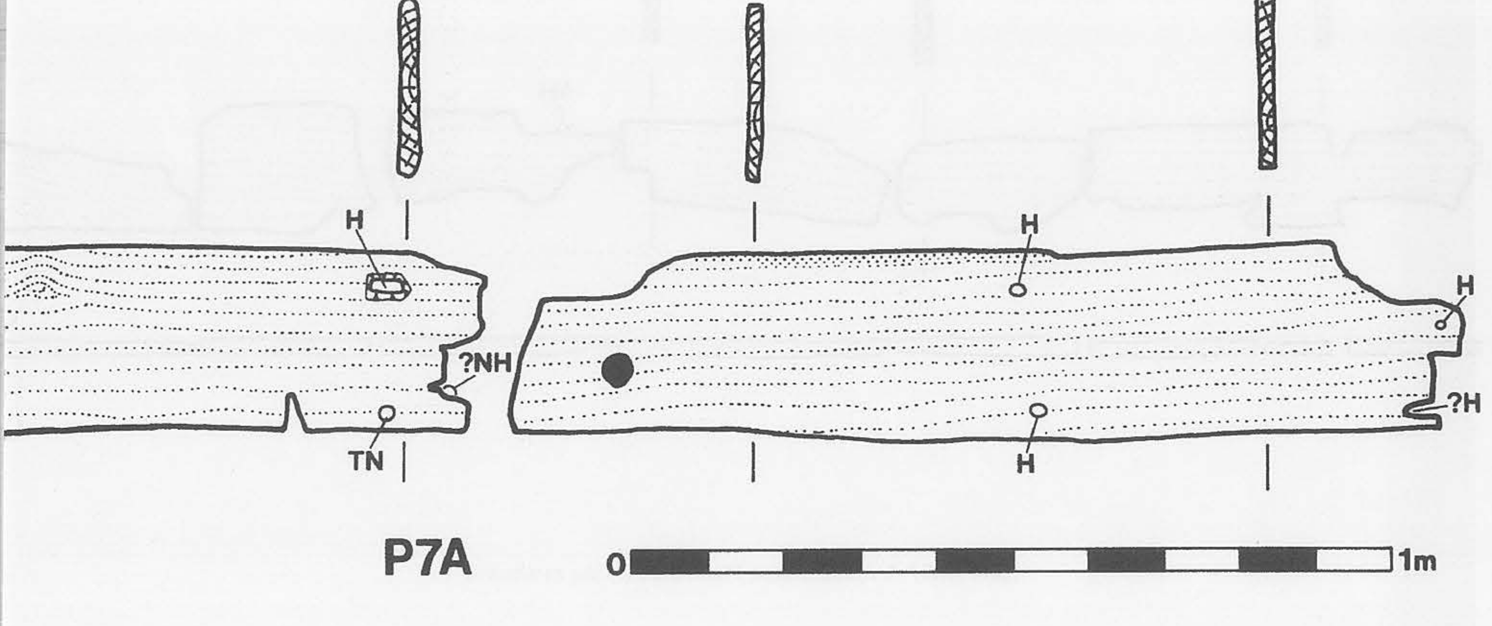
S3A (5127) – Fig A2.55

This is the foremost plank in S3, the lowest side strake to starboard. It was lifted and drawn in six units (plans 161, 171, 159, 173, 174, and 175/part) each one in fragments. The inner face has not yet been recorded. This plank extends from forward of floor timber F1 (probably from the stem post originally) to floor F13 where it butts with plank S3B.

Conversion

This plank appears to have been fashioned at a slight

Figure A2.54 (*below*) Port Side Plank P7A. (Scale as shown)



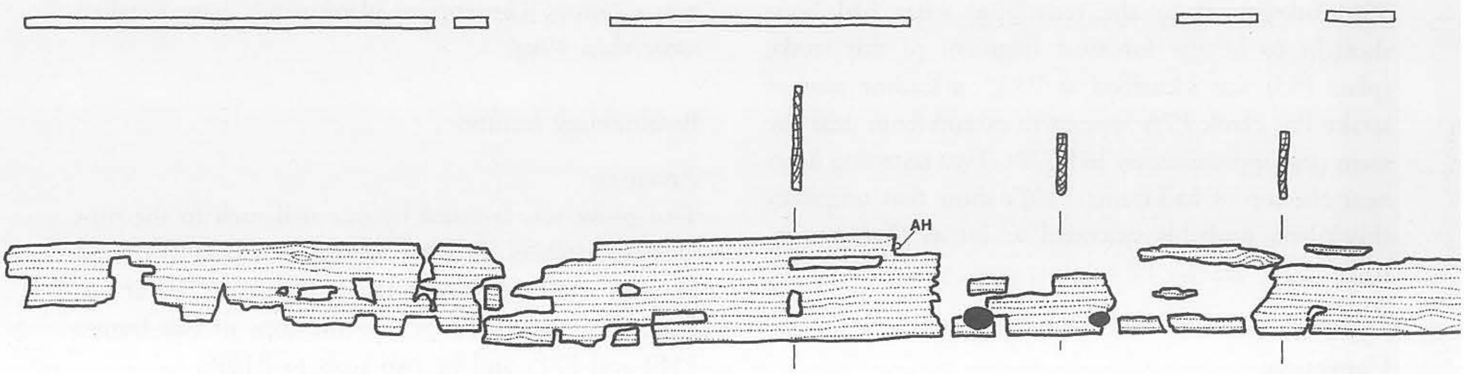


Figure A2.55 Starboard Side Plank S3A. (Scale as shown)

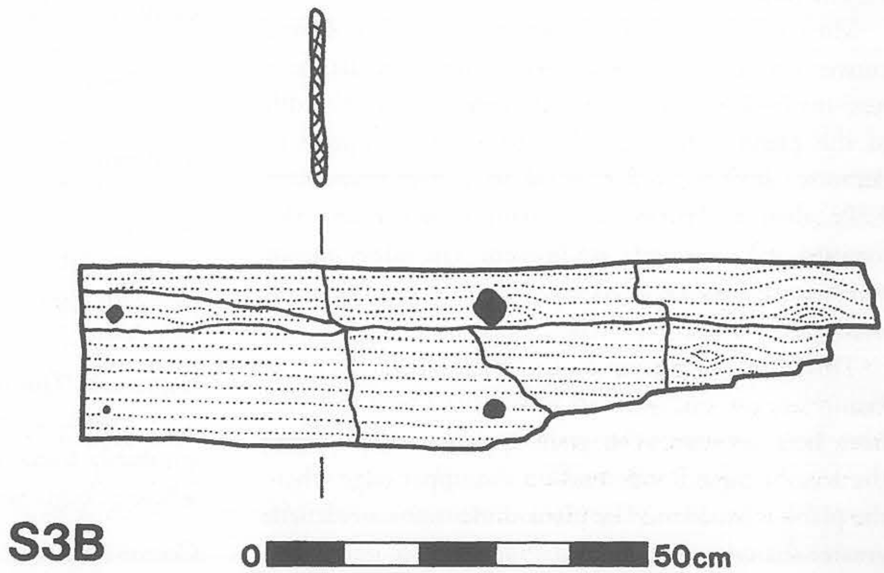


Figure A2.56
Starboard Side Plank S3B.
(Scale 1:10)

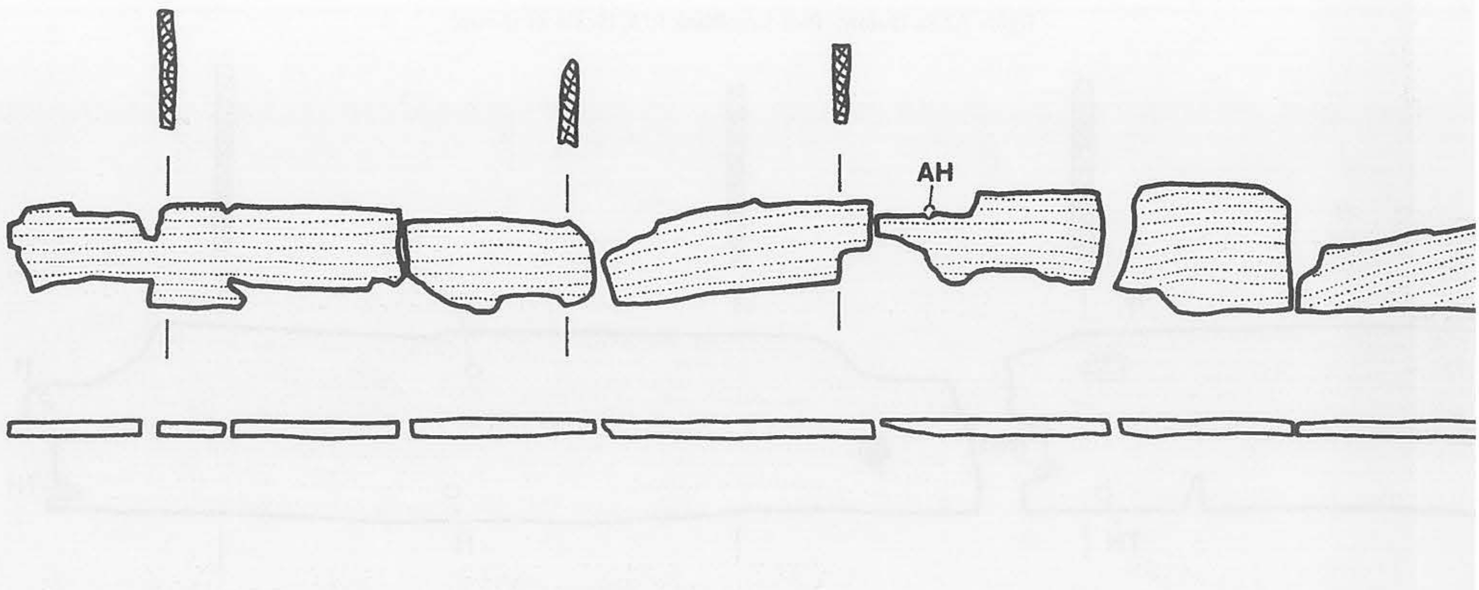
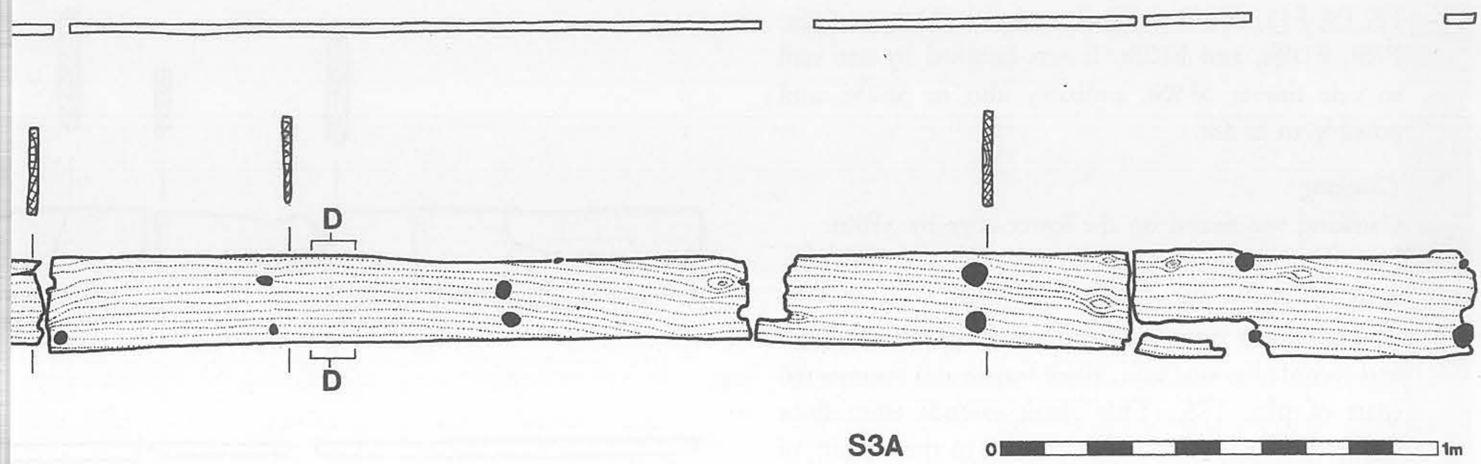


Figure A2.57 Starboard Side Plank S4A. (Scale as shown)



angle across the pith of a straight-grained oak. The growth rate measured by eye was 2 to 2.5mm per year, ie a medium rate; dendrological examination of a section which had been uppermost in the tree, however, gave a relatively slow rate of 1.6mm per year. Like the parent tree of plank P3A/B, this bole had only a few small branches throughout its length. It was more than 7m tall, had a girth of *c* 1.85m (diameter 0.59m), and would have weighed *c* 1.19 tonnes.

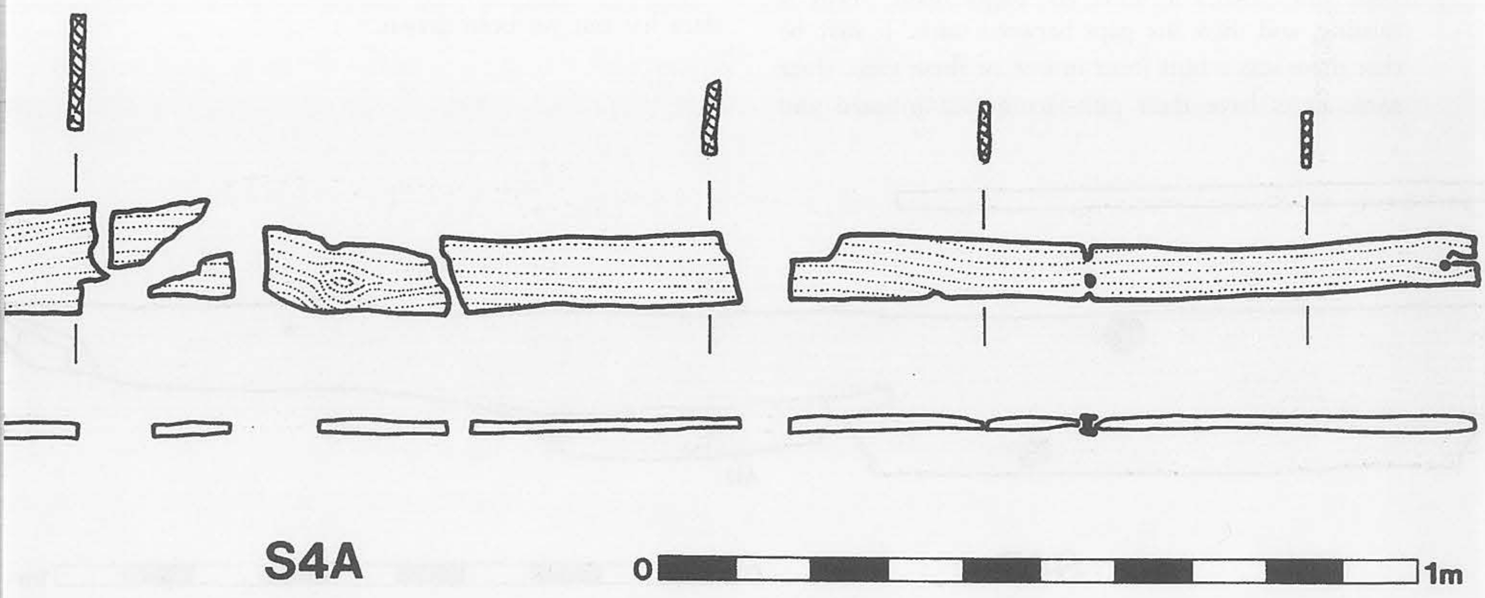
Much of the bole had been worked away during conversion, leaving only about half the diameter near amidships, for example. This plank tapers in breadth from each end towards the middle, while its lower edge is curved longitudinally to fit the outer curve of the boat's bottom. It is impossible to determine whether the plank edges were bevelled. The forward end would have been shaped and bevelled to fit the post's rabbet; the after end butts with plank S3B at floor timber F13.

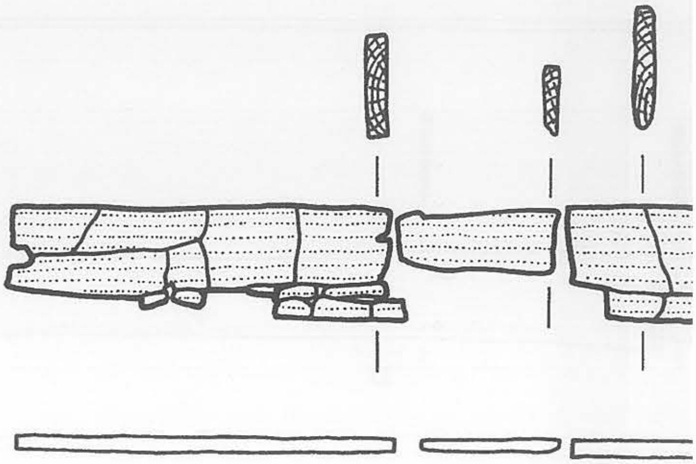
Like P3A/B, this plank was fitted to the boat so that its tree-butt end was forward. The grain generally flows along the length, but there is short grain along the lower edge where it has been shaped across the grain; no sapwood had been left on. The plank dimensions are: length greater than 6.92m; breadth forward 0.22m (possibly 0.24m), near amidships 0.2m, aft 0.23m; thickness generally 20–23mm. Such a plank would have weighed *c* 27kg.

Boatbuilding features

Fastenings

This plank was probably spiked to the stem post. It was fastened by one nail each to floor timbers F1, F3 (see also BS), and F4, by two nails to floors F2, F6,





F8, F9, F11, and F13 (butt), and to half-frames F5St, F7St, F10St, and F12St. It was fastened by one nail to side timber SF9St, probably also to SF2St, and possibly to SF3St.

Caulking
Caulking was found on the lower edge by SF9St.

S3B (5126) – Fig A2.56
The aftermost surviving plank in strake S3 was lifted and recorded as one unit, albeit fragile and fragmented (part of plan 175). This plank extends from floor timber F13 where it butts with S3A to the vicinity of floor F15 where it is broken. The inner face has not yet been recorded.

Conversion
The parent oak of this plank had some minor branches in the length that survived, and a girth of *c* 1.16m (diameter 0.37m). The plank dimensions are: length greater than 1.05m; breadth 0.23m; thickness 23mm. No sapwood was noted.

Boatbuilding features

Fastenings
This plank was fastened to floor timbers F13, F14, and F16 by two nails. It is probable that it was also fastened to floor F15 and half-frame F15St but neither plank nor framing has survived in this region.

S4A (5137) – Fig A2.57
The foremost surviving plank in strake S4 was lifted and recorded in six units (plans 162, 163, 169, 160, 166, and 172). All units are fragmented, much is missing, and there are gaps between units. It may be that there was a butt joint in one of these gaps, since some units have their pith-facing face inboard and some outboard. On the other hand the growth rates are all very similar, knots are about the same size and frequency, and the implied length of plank matches those in other strakes. The remains are best considered as those of one plank unless examination during reassembly of the boat suggests otherwise. The variation in orientation of the pith face may be explained by an anomalous recording or by assuming that the parent log was converted across the pith (see also P6A and S3A). This plank extends from near floor timber F2 (originally probably from the stem post) to an angled butt joint with S4B at half-frame F10St. The inner face has not yet been drawn.

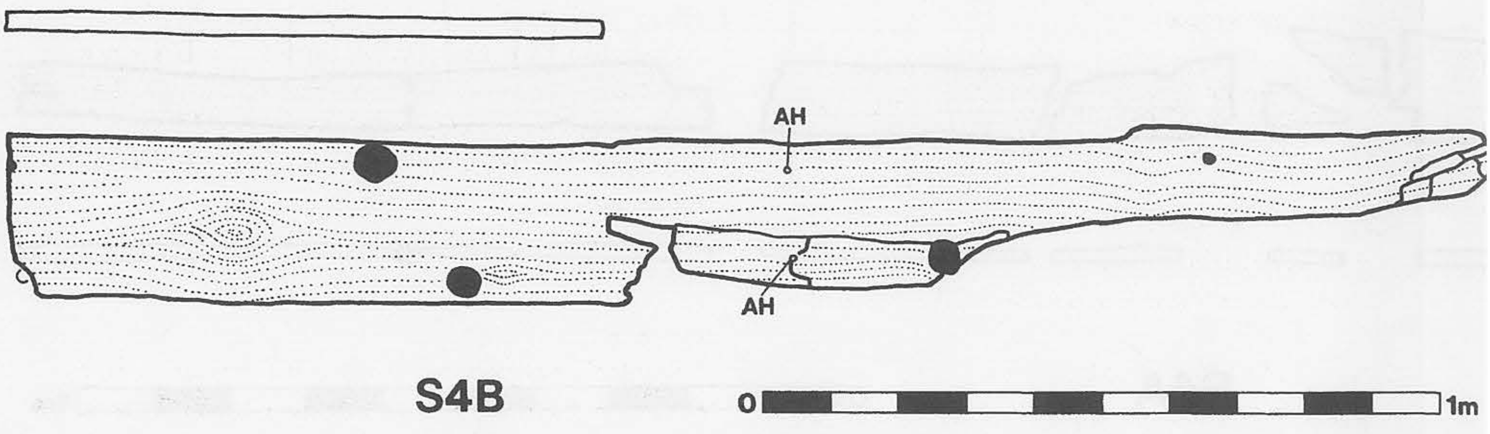


Figure A2.58 Starboard Side Plank S4B. (Scale as shown)

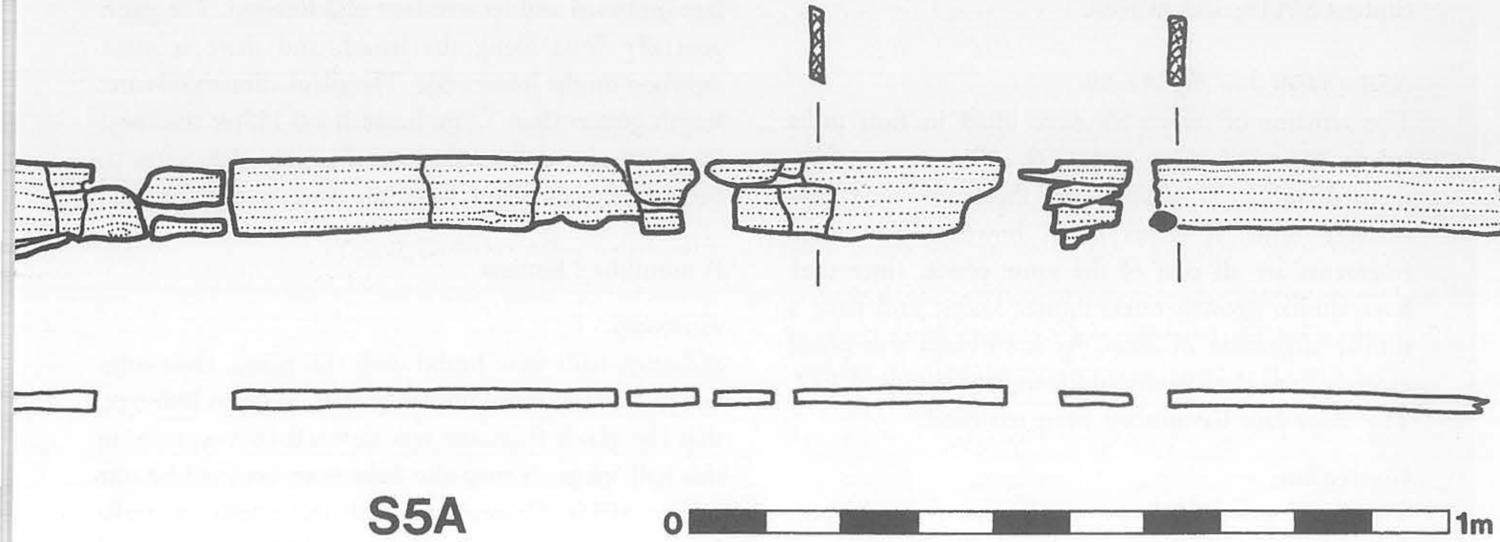


Figure A2.59 Starboard Side Plank S4B. (Scale 1:10)

Conversion
The parent tree of this plank was an oak of fast growth rate (4.5 to 5.3mm per year). The height of the bole must have been greater than 4m, with a girth of *c* 1.32m (diameter 0.42m).

The plank may have been fitted in the boat with its parent tree's butt end towards the bow. The forward end would probably have been shaped to fit into the post rabbet; the after end is an angled butt. The grain generally flows along the length of the plank and there is no sapwood. The plank dimensions are: length greater than 3.68m; breadth 0.15m or greater; thickness *c* 20mm. At the butt at half-frame F10St this plank appears to have been 5–10mm thinner than S4B; this question may be resolved during re-examination when the remains are reassembled.

Boatbuilding features

Fastenings
This plank was fastened to floor timbers F8 and F9 by two nails each, to F4 and F6 by one possibly two nails each, and possibly to F1 by one nail. It was fastened to half-frames F5St and 10St (butt) by one possibly two nails and to F7St by two nails. It was possibly fastened to side timber SF3St by one nail.

S4B (5128) – Fig A2.58
The aftermost surviving plank in strake S4 was lifted and recorded in two units (plans 176 and 175); both units are fragmented and they cannot be joined together. The inboard face was not recorded. This plank extends from half-frame F10St where it butts with S4A to the vicinity of floor timber F14 where it is broken.

Conversion
This plank was fashioned tangentially some distance from the pith from a straight-grained oak of medium growth rate (3.36mm per year by eye; 2.33mm by dendrochronology). The length of bole chosen must have been more than 2.5m in length (possibly up to 4m), with a girth of *c* 1.32m (diameter 0.42m).

The plank was fitted in the boat with its pith-facing face outboard. The grain generally flows along the length and there is no sapwood on the surviving fragment. The plank dimensions are: length greater than 2.26m; breadth 0.22 to 0.24m; thickness 28 to 30mm. This plank may have been some 5 to 10mm thicker than S4A. If this is confirmed, this difference may have been noticeable at the butt at F10St. The plank edges are damaged but seem to be generally normal to the plank faces; the forward end has an angled butt.

Boatbuilding features

Fastenings
This plank was fastened to the ends of floor timbers F11, F13, F14, and F16 by one nail. It was fastened by two nails to half-frames F10St (butt) and F12St

(and possibly also to F15St) and by one nail to side timbers SF11St and SF13St.

S5A (5139) – Fig A2.59

The remains of strake S5 were lifted in four units (plans 165, 167, 170, and 177). All units are fragmented, much is missing, and there are some gaps between units. It seems likely, however, that these fragments are all part of the same plank, since they have similar growth rates, similar knots, and have a similar alignment of faces. As it survived this plank extends from the vicinity of F6 to the vicinity of F12. The inner face has not yet been recorded.

Conversion

This plank was fashioned some distance from the pith from an oak of medium growth rate (2 to 2.4mm per year). The height of the bole must have been greater than 3.5m, with a girth of *c* 1.1m (diameter 0.35m) and there were some small branches.

This plank was fitted to the boat with its pith-facing face outboard and its tree-butt end forward. The grain generally flows along the length and there is some sapwood on the lower edge. The plank dimensions are: length greater than 3.5m; breadth *c* 0.155m; thickness 20 to 28 mm. Where they survive, the edges seem to be normal to the plank faces; the ends are both broken.

Boatbuilding features

Fastenings

Although nails were found with this plank, their original position is uncertain. Holes in F7St show, however, that the plank fragment was fastened by two nails to this half-frame; it may also have been fastened by one nail to SF3St. Comparison with the planks in strake P5 suggests that this plank was probably once fastened to half-frames F10St and F12St, to the heads of some of the floor timbers, and to side timbers between SF6.5St and SF12St.

Fitting

Mast-step timber

MST (5093) – Fig A2.60

The mast-step timber, fractured across the mast step, was lifted and recorded as one unit (plan 127). Its ends are complete and the near-rectangular cavity forming the mast step is in a reasonable condition. The timber extends from floor F6 to half-frame F7St, with a half-lap at each end.

Conversion

The timber was fashioned from an oak limb probably through the half-log stage as the pith is now at or very close to the inner face. The limb was *c* 0.73m in length, with an original girth of *c* 1.1m (diameter 0.35m); it had a fast growth rate (3.47 mm per year). The grain flows along the length of this timber and there is no sapwood.

This timber was fitted in the boat so that its face with the pith was uppermost. The forward half-lap is 0.14m so that the timber does not quite overlap floor F6 which here is 0.15m broad; the after lap is 0.23m so that the timber overlaps both F7Pt and St. The moulded dimensions (thick) of this timber are 40mm at the half laps, 95mm at the main body. Since the frames on which the laps rest are 80mm moulded, there is an air gap of *c* 25mm between the outer face

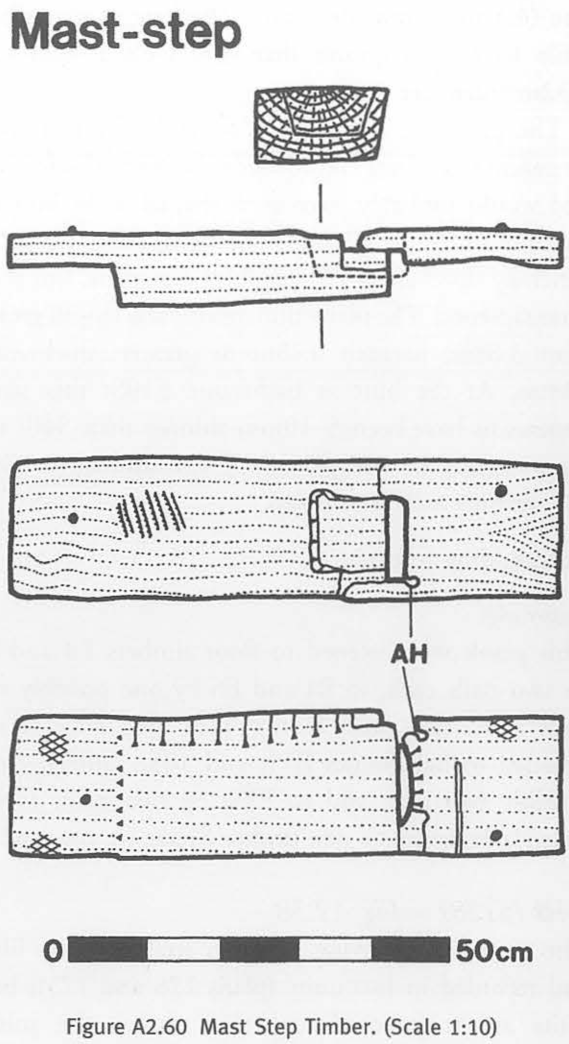


Figure A2.60 Mast Step Timber. (Scale 1:10) of the main body of the mast step timber and the inner face of the plank-keel P1 and S1. The upper edges of this timber are bevelled.

The port side of this timber is slightly angled outwards and upwards. Otherwise the main body is generally rectangular with *m/s* of 95/175 (0.54) and *m* × *s* of 16,625. With a length of 0.73m such a timber with the mast step cut would have weighed *c* 7kg. The mast step socket is *c* 60mm deep. It is not central in the timber, but has been positioned so that:

- it lies against F7Pt; a notch in that half-timber's upper forward edge completes the mast step's after face;
- it lies nearer the port side of the timber than the starboard by some 15mm; as installed, it is biased *c* 10mm to port of the boat's middle line.

The cavity that forms the step is *c* 120mm broad at the top and *c* 90mm at the bottom, each side sloping at about the same angle. Its length is *c* 115mm internally and *c* 125 mm at the top, with a slightly sloping forward end and a near-vertical after end.

Boatbuilding features

Fastenings

This timber was fastened to floor timber F6 and to half-frames F7 Pt and St by one spike each driven from above. One spike pierced floor F6 and slightly entered plank keel S1; the tip of a second spike just pierced half-frame F7Pt without marking the planking below, while the third spike entered but did not pierce half-frame F7St. A fourth spike appears to have been driven at an angle near the port after corner of the step into the forward edge of F7Pt.

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This report provides a comprehensive description and analysis of the remains of a remarkably well-preserved Romano-Celtic boat and of the environment in which it was used.

Barland's Farm is in a previously agricultural part of the Gwent Levels, the coastal plain on the northern shores of the Severn Estuary in south-east Wales. Survey and excavation in advance of construction work on that site revealed the bow section, the lower hull and much of one side of an oak-built boat. Following *in situ* recording, the remains were dismantled and recovered for detailed documentation of individual timbers prior to conservation.

The Barland's Farm boat exhibits many features characteristic of the Romano-Celtic boatbuilding tradition and has provided important insights into craft techniques and use of materials. Palaeo-ecological research has led to an environmental context for the boat and thrown light on the wider environment including agricultural activity. Analysis of associated finds and the reconstruction of the boat's original shape and structure indicate its likely uses within the Severn Estuary and the inner Bristol Channel, and on associated rivers. In the early fourth century AD the boat was abandoned in a tidal stretch of a river which flowed south into the Severn, and it was probably reused as a landing stage.

'... an exemplary account of an important boat-find, based on archaeological and historical information and on scientific analyses. This volume will be of great interest not only to maritime archaeologists, but to a much wider readership.'

Dr Ronald Bockius, Senior Curator, Museum für Antike Schiffahrt, Mainz

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