The Technology and Economics of Water-Borne Transportation Systems in Roman Britain

by

RODERICK J. O. MILLAR

B.Sc. (Eng), The University of London, 1950
Banff School of Advanced Management, 1966
B.A. The University of British Columbia, 1987
M.A., The University of British Columbia, 1991

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

Department of Classical, Near Eastern and Religious Studies

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

January 2002

copyright Roderick J. O. Millar, 2002
The Technology and Economics of Water-Borne Transportation Systems in Roman Britain

Abstract

The thesis examines a number of questions concerning the design, construction, costs and use of Romano-British seagoing and inland waters shipping. In the first part the reasons for the methods of construction for seagoing and coastal vessels, such as the Blackfriars Ship 1, the St. Peter Port Ship and the Barland’s Farm Boat, have been investigated. The constructional characteristics of the two ships are massive floors and frames, with the planking fastened only to the floors and frames with heavy clenched iron nails. There is no edge to edge fastening of the planks, with tenons inserted into mortises cut into the edges of the planks, as is normal in the Mediterranean tradition of ship construction in the Roman period. The Romano-British ships also differ from the Scandinavian tradition of clinker building with overlapping planks nailed to each other along their length. It has been concluded that a natural phenomenon, the large tidal range around the British Isles and the northern coasts of Gaul and Germany, had a dominant effect on the design of seagoing vessels. Deep water harbours, such as Portus, Caesarea Maritima and Alexandria in the Mediterranean, where ships could lie afloat at all times, were neither practicable nor economic with the technology available. At the British ports, such as Dover, London and Chichester, ships had to come in with the high tide, moor to simple wharves at the high tide level, and then settle on the ground as the tide dropped. At the numerous small havens, inlets and estuaries around the British coasts, ships would come in with the tide, settle on a natural or man-made ‘hard’ as the tide fell, and discharge cargo over the side to carts, pack animals or people. This mode of operation required sturdy ships that could take the ground without damage, and also withstand a certain amount of ‘bumping’ on the bottom in the transition period from fully afloat to fully aground.

The second part of the thesis investigates the cost of building, maintaining and operating various types of vessels. To do this, a new mode for measuring cost, the Basic Economic Unit, or BEU, has been developed. The probable volume of the various types of cargoes carried has been examined. It appears that grain was the dominant cargo in both coastal and overseas traffic. The total cost of building, maintaining and operating the seagoing and inland water shipping was less than one percent of the gross product of Britain, a small cost for an essential service.
# Table of Contents

Abstract ......................................................... ii  
Table of Contents .............................................. iii  
Appendices and Glossaries .................................... v  
List of Tables .................................................. vi  
List of Maps ................................................... vii  
List of Illustrations .......................................... viii  
Acknowledgements ............................................. xvii  
Dedication ...................................................... xviii  

## Section I: Some General Considerations

I.1. Introduction .................................................. 2  
I.2. Materials to be Transported, Sources, Destinations ..................... 7  
I.3. Containers and Packaging: Security ................................ 10  
I.4. Tools .......................................................... 16  
I.5. Procurement and Conversion of Timber .................................. 21  
I.6. Metal Work for Transportation Systems .................................. 23  
I.7. Discussion and Conclusion ........................................ 24  

## Section II: Water Transport

II.1. Introduction ................................................... 29  
II.2. The Technology: Theory and Hypotheses on Hull Form and Construction 29  
II.3. Theory and Hypotheses on Propulsion Systems and Methods .......... 32  
II.4. Bronze and Iron Age Predecessors and Frisian and Saxon Successors .... 34  
II.5. Romano-British Ships and Boats: Some Hypotheses ..................... 45  
II.6. Five Excavated Gallo-Roman and Romano-British Ships and Boats.  
   6.1. Introduction .................................................. 50  
   6.2. The Types of Vessels Needed in Roman Britain ....................... 53  
   6.3. The Logboats and Hide Boats .................................. 53  
   6.4 Some Difficulties in Building Planked Boats .......................... 54  
   6.5. The Flat-Bottomed Chine type Barges in Europe .................... 55  
   6.6 Hypothetical Flat-bottomed Barges in Britain ....................... 56
### Table of Contents

#### Section I: The Technology of Romano-British Vessels and Harbour Facilities

6.7. The New Guy's House Boat (c. AD 180) ........................................... 57  
6.8. The Blackfriars Ship 1 (c. AD 150) ..................................................... 60  
6.9. The Barland's Farm Boat (late 3rd cent. AD) .................................. 66  
6.10. The St. Peter Port Ship (c. AD 285) ............................................... 70  
6.11. The County Hall Ship (c. AD 300) ................................................... 76

II.7.1. The Literary Evidence ................................................................. 81
II.7.2. The Epigraphic Evidence .............................................................. 83
II.7.3. The Iconographic Evidence ............................................................. 85

#### Section II: The Economics of Water-Borne Transport

8.1. Introduction ............................................................ 87  
8.2. Roman Water-borne Transportation Requirements ............................ 88  
8.3. The Types and Sizes of Ports ......................................................... 90  
8.4. The Search for Roman Harbours and Harbour Installations in Britain 91  
8.5. An Alternative or Supplementary Hypothesis .................................. 94  
8.6. Canals and Artificial Waterways ....................................................... 98

Annexes to Section II.8.
Annex 1. The classis Britannica .......................................................... 100
Annex 2. List of Tidal Ranges around Britain ........................................ 102
Annex 3. The Problem of Subsidence, Silting, Coastal Erosion and Littoral Drift on the East and South Coasts of Britain .......................... 103
Annex 4. Cleere's List of harbours from the Roman Road System ......... 105
Annex 5. Possible Minor Harbours around Britain from the River Tyne to the River Exe ......................................................... 106

II.9. Discussion and Conclusions on The Technology of Romano-British Vessels and Harbour Facilities
9.1. Introduction ............................................................. 114
9.2. The Constraints ........................................................................ 114
9.3. The Technology of Hull Construction for Romano-British vessels . 118
9.4. The Technology of Harbour Installations in Roman Britain .......... 123
9.5. Summary and Conclusions on the Technology of Roman Water-Borne Transport .......................................................... 126

#### Section III: The Economics of Water-Borne Transport

III.1. Introduction .............................................................................. 129
III.2. The Cargoes and Types of Vessel Needed .................................... 131
III.3. The Cost of Building Four Representative Vessels ......................... 135
III.4. The Cost of Operating and Maintaining Four Representative Vessels and their Useful Working Life .............................................. 153
III.5. The Volume of Goods to be Transported, and the Number of Vessels Needed for Sea and Coastal Voyages, and Inland River Movements ..... 160
III.6. Discussion and Conclusions on the Cargoes Carried, and the Costs of Building and Operating the Vessels ......................................................... 174
# Section VI: Summary and Overall Conclusions

IV.1. The Technology of Romano-British Ships ........................................ 178
IV.2. The Costs and Cargoes for Romano-British Shipping .......................... 179
IV.3 Further Research ............................................................................. 179

## Appendices

Appendix A. Some Fundamental Mechanics and their Expression in the Basic
and Derived Units in the *Système International d’Unité*, or *S.I.* .............. 181

Appendix B. The Basic Energy Unit (BEU) .............................................. 184
Appendix C. The Late Pre-Roman Iron Age and Romano-British Countryside
and Environment .................................................................................. 194
Appendix D. Iron Production and Distribution in Roman Britain ................. 199
Appendix E. Non-Ferrous Metal Production and Distribution
in Roman Britain .................................................................................. 205
Appendix F. Pottery Production and Distribution ..................................... 212
Appendix G. Salt Production in Roman Britain: Sources and Distribution .... 224
Appendix H. Masonry Quarries and Gravel Pits ..................................... 231
Annex 2: Notes on Quarries along Hadrian’s Wall .................................. 246
Annex 3: Notes on Roman Masonry in Britain: Its Sources and
Points of Use ....................................................................................... 250
Appendix I. Timber and Wood: Sources, Conversion and Uses in
Roman Britain ..................................................................................... 253
Appendix J. Coal Production in Roman Britain: Sources and Distribution .... 262
Appendix K. Bricks and Tiles: Manufacturing Centres and Distribution ...... 267
Appendix L. Major and Minor Towns, and Legionary Fortresses: their
River and Road Connections .................................................................. 274
Appendix M. A Hypothetical Transport for Fifty Men in Caesar’s Expedition
to Britain in 54 BC ............................................................................ 287
Appendix N. Five Hypothetical Romano-British Flat-Bottomed Barges ....... 289
Appendix O. Possible Haven Sites from The Firth of Tay in the North along
the East and South Coasts to the River Exe in Devon ............................ 293
Appendix P. The Times and Costs for Various Activities in Building a Boat
or Ship ................................................................................................. 304

## Glossaries

Glossary of Maritime Terms ..................................................................... 317
Glossary of Tools and Technology .......................................................... 321
Glossary of Timber Conversion, Woodland, Agricultural and
Countryside Terms .............................................................................. 326
Bibliography ........................................................................................................................................... 438

List of Tables

Table III.3.1 Nail costs as percentage of total costs ................................................................. 152
Table III.3.2 Capital cost per tonne of cargo carrying capacity ........................................ 152
Table III.4.1 Annual depreciation allowance per year ......................................................... 156
Table III.4.2 Total annual and major overhaul costs in BEUs ........................................ 158
Table III.4.3 Annual operating, replacement and maintenance costs ............................. 158
Table III.4.4 Annual costs per tonne of cargo capacity .................................................... 159
Table III.5.1 Number of ships needed to move grain to the North-East .................... 164
Table III.5.2 Number of ships needed to move grain to the west coast ports .......... 164
Table III.5.3 Number of ships needed to move grain to South Wales ...................... 165
Table III.5.4 Number of Blackfriars Ship types for overseas and coastal cargoes .......... 171
Table III.5.5 Annual costs for internal and coastal shipping .......................................... 174
Table App.B.1 Seed sown per hectare in kg (averaged over 250 years) .................. 191
Table App.B.2 Yield in kg per hectare ............................................................................... 191
Table App.B.3 % of seed retained for next planting ............................................................... 191
Table App.D.1 Annual iron production in the Weald ......................................................... 201
Table App.H.1 Types of quarry ............................................................................................ 234
Table App.J.1 Sources for mining, and locations for the use of coal ............................ 265
Table App.N.1 Dimensions and quantities of materials needed .................................. 290
Table App.N.2 Draught, freeboard and weight of cargo ................................................ 291
vii. contents

Table App.P.1  Number, weight and value of blooms for iron nails .............. 306
Table App.P.2  Time required to forge nails for Barge 5, Barge3, the Barland’s Farm Boat and the Blackfriars 1 Ship .............. 309
Table App.P.3  BEUs expended to forge nails ........................................ 310
Table App.P.4  Total BEUs to make nails, from smelting to finished product 310
Table App.P.5  Time for felling trees with an axe .................................. 311

List of Maps

Map 1.  The principal rivers and natural features of Britain ...................... 329
Map 2.  The main watersheds and principal rivers of Britain ...................... 330
Map 3.  Principal Roman harbours, anchorages and inland ports ................ 331
Map 4.  Boundaries of tribal areas in Britain at the time of the Roman conquest ......................................................................................... 332
Map 5.  The main areas of silting, wetlands and coastal change ................ 333
Map 6.  Distribution of harbours proposed by Cleere, based on points where Roman roads terminated at the sea ........................................... 334
Map 7.  Road connections of the cities, major towns and small towns of Roman Britain .......................................................... 335
Map 8.  Possible Haven Sites from the Firth of Forth in the North, along the East and South Coasts to the River Exe in Devon .................. 336
List of Illustrations

Fig. I.3.1.1. River boat loaded with barrels. Upper register, amphorae and basketry work, possibly protecting amphorae. Relief from Cabrières-d’Aigues, now in Musée Calvet, Avignon (Bromwich 1993:Plate 20; Casson 1994:132, Fig.97) .......................... 338

Fig. I.3.1.2 Wooden box with cremation burial 30 at Skeleton Green (de la Bedoyère 1989:173, Fig 106a) .................................................. 339

Fig. I.3.1.3. Baskets for fruit picking (King 1990:101) ................................................. 339

Fig. I.3.1.4. Sacks of grain being loaded on to a small cargo vessel. Wall painting from Ostia, now in the Vatican Museum (Casson 1991, Plate 52) ........................................................................... 340

Fig. I.3.1.5. Trajan’s Column: legionaries and auxiliaries loading barrels and bales into river craft (Lepper and Frere 1988:Plate V, Plate XXV. From the Cichorius Plates) .......................................................... 341

Fig. I.3.2.1. Amphora with olives recovered from the Thames Estuary (Milne 1985:110, Fig. 64) ................................................................. 342

Fig. I.3.2.2. Relief with hooped barrels and tubs. From Grand, in Musée des Beaux Arts, Nancy. (King 1990:104) ........................................ 342

Fig. I.3.2.3. Relief showing a slave scooping flour from a sack (Tingay and Badcock 1972:141) ................................................................. 343

Fig. I.3.2.4. Inscribed Romano-British barrel stave (oak) from Barhill Fort, Strathclyde, Scotland. In the Hunterian Museum, Glasgow (Robertson, Scott and Keppie 1975:52 No. 8, fig. 16.8; RIB II, Fasc. 4, 2442.9) ................................................................. 343

Fig. I.3.2.5. Stevedores carrying sacks ashore. Tombstone fragment from Mainz, in Mittelrheinisches Landesmuseum, Mainz (Ellmers 1978:12, Fig. 16b) ................................................................. 344

Fig. I.3.5.1. Stevedores rolling (wine?) barrels ashore. Tombstone fragment from Mainz, in Mittelrheinisches Landesmuseum, Mainz (Ellmers 1978:12, Fig.16a) ................................................................. 344
Fig. 1.3.5.2. Tombstone depicting a deck cargo of wine barrels in a vessel on the Moselle. From Neumagen, Moselle, in the Rheinisches Landesmuseum, Trier (Ellmers 1978:8, Fig. 12; Chevallier 1988:106) 345

Fig. 1.3.5.3. Cargo of wine barrels on a river vessel, with bow and stern steering oars. The central figure has apparently tapped a barrel and is sampling the wine through a straw. Cast from a pottery mould fragment from Trier, in the Rheinisches Landesmuseum (Ellmers 1978:6, Fig. 9) 346

Fig. 1.3.5.4. A cargo of wine barrels being punted. Fragment of altar from Colijinsplaat, Netherlands (Ellmers 1978:10, Fig. 9) 347

Fig. 1.3.5.5. ‘Wine Tanker’: a large wine barrel on a wagon. From a relief in the Musée Saint-Didier, Langres. (Chevallier 1988:37) 348

Fig. 1.3.5.6. Tombstone of Eppatricia, from Portugal, in the form of a wine barrel (Toynbee 1971:Plate 81) 349

Fig. 1.3.5.7. Wooden bucket with staves and hoops from Newstead, Borders, Scotland. In the Museum of Scotland, Edinburgh. (Clarke, Breeze and Mckay 1980:58, Fig. 56; Curle:1911:284, pl. LXII) 350

Fig. 1.3.5.8. Barge with a load of bales of cloth. Relief on a tombstone from Igel, near Trier (Ellmers 1978:7, Fig. 10) 351

Fig. 1.3.5.9. Five men manhandling a large bale of cloth. Relief from the area of Saulnois, Moselle (Chevallier 1988:287) 352

Fig. 1.3.5.10. Mosaic with cargo vessel carrying amphorae. Celtic vessel with a leather sail in the Oceanus mosaic from Bad Kreuznach. In the Karl-Geib Museum, Bad Kreuznach, Rhineland-Pfalz (Ellmers 1978:3, Fig. 3) 353

Fig. 1.3.5.11. Ship with a deck cargo of amphorae resting on dunnage. Relief in the Villa Walkonsky, Rome. Photograph, German Archaeological Institute, Rome (Casson 1995:Fig. 155) 354

Fig. 1.3.5.12. Stevedores unloading amphorae: a tally clerk keeps count. Relief from Portus, in the Torlonia Museum, Rome (Casson 1994:103, Fig. 76) 355
Fig. I.3.5.13a. Part of the cargo of amphorae in the La Madrague de Giens wreck off Toulon. Note the ceiling planks running fore and aft over the frames to protect the ship's structure from damage by the cargo (Casson 1994:105, Fig. 78) ........................................ 356

Fig. I.3.5.13b. Possible stowage system for amphorae in a ship's hold. (After Chevallier 1988) .......................................................... 357

Fig. I.3.5.13c. Various sizes and shapes of shipping amphorae from wrecks off the Grand Congloué island near Marseille. (Casson 1994:104, Fig. 77) .......................................................... 357

Fig. I.4.1.1. A two man frame saw from a fresco in Pompeii. In the Museo Nazionale Archeologico, Naples (D'Ambra 1998:79, Fig. 47) ... 358

Fig. I.4.1.2. A two man saw for sawing planks; from a tomb relief in Gaul (Rule and Monaghan 1993:17, Fig. 11, after Meiggs 1982:348, Fig. 14d: from Marion Cox, from Espérandieu, Recueil 6.4802) . 359

Fig. I.4.1.3. Spoon bits for boring holes in timber (Manning 1985:25-28, Plate 11, B51 to B54, Plate 12, B55 to B78) 360

Fig. I.4.5.1a. Iconographic evidence for Roman tools: a shipwright using an adze to shape a frame. Relief on a shipwright's tombstone from Ravenna, in the Archaeological Museum. (Casson 1994:34, Fig. 28) .......................................................... 361

Fig. I.4.5.1b. Iconographic evidence for Roman tools: a relief depicting a carpenter's workshop. In the Antiquarium Comunale, Rome. (D'Ambra 1998:79, Fig. 48) .......................................................... 362

Fig. I.4.5.1c. Iconographic evidence for Roman tools: a glass bowl from the Roman catacombs with six scenes of carpenters at work. In the Bibliotheca Apostolica Vaticana (Liversidge 1976:158, Fig. 264) .......................................................... 363

Fig. II.2.1.1. Hypothetical simple inland river craft: plan and elevations, dimensions and cargo carrying capacity. (RJOM) .................. 364

Fig. II.2.1.2.a Towing a river boat (RJOM), from a relief found at Cabrières-d'Aigues, now in Musée Calvet, Avignon; 3rd century A.D.) ..... 365

Fig. II.2.1.2.b Five men towing a boat upstream on the River Thames. From Moses Glover's map of 1635. ........................................ 365
Fig. II.2.1.3. Punting a river boat (RJOM), from altar fragment from Colijnsplaat, Netherlands, Leiden Museum, c.A.D.200) ........... 366

Fig. II.2.1.4. Leather sail on a river boat from the Moselle region (Casson 1994:135, Fig. 100) ......................................................... 366

Fig. II.4.3.1. Possible Pre-Roman Iron Age sailing routes in the English Channel (McGrail 1983:309, Fig.4) ........................................... 367

Fig. II.4.3.2. An example of the extensive river and stream network in Britain. Rivers and streams in Bedfordshire, Buckinghamshire, Hertfordshire, Essex and Middlesex, showing the sites of sixty-one villas (Green1997:189, Fig. 1). ................................................. 368

Fig. II.6.1.1a. Principles of joining an ancient Mediterranean ship’s planking with mortise and tenon joints, and an example from an underwater excavation (Casson 1994:34, Fig. 24) ........... 369

Fig. II.6.1.1b. Changes in mortise and tenon planking over the centuries (Casson 1994:106, Fig. 79) .......................................................... 370

Fig. II.6.1.1c. Mortise and tenon construction for the keel and garboard fastenings (Casson 1994:34, Fig. 29) ............................................. 370

Fig. II.6.1.2a. Construction sequence of the Romano-British Blackfriars Ship1 from London. A transition phase from shell first to frame or skeleton first construction(Marsden 1994:78, Fig. 70) ............... 371

Fig. II.6.1.2b. Medieval skeleton first construction. Detail from The Building of St. Ursula’s Boat by Paolo da Venezia (1310-1358). One of the earliest representations of skeleton first construction. (Illustration from Unger 1991: Illustration 58). ......................... 372

Fig. II.6.4.1. Strake diagram for the Blackfriars Ship 1 (Marsden 1994:93, Fig. 85) ................................................................. 373

Fig. II.6.4.2. Strake diagram for the late Saxon Graveney Boat (Fenwick 1978:296, Fig. 10.1.2) .............................................................. 374

Fig. II.6.7.1a. The New Guy’s House Boat, location and parts excavated (Marsden 1994:97, Fig. 87) ............................................................. 375

Fig. II.6.7.1b. The New Guy’s House boat, as found, plan and sections (Marsden 1994:98, Fig.88) ............................................................. 376
Fig. II.6.7.1c. The New Guy's House boat, reconstruction plan, elevations and sections (Marsden 1994:103, Fig.94) ................. 377

Fig. II.6.7.2a. The New Guy's House boat; construction of the north end (Marsden 1994:102, Fig. 93) ........................................ 378

Fig. II.6.7.2b. The New Guy's House boat; nailed frames in the north end (Marsden 1994:99, Fig. 89) ........................................ 379

Fig. II.6.7.2c. The New Guy's House boat; nailed frames (Marsden 1994:100, Fig. 90) ...................................................... 380

Fig. II.6.8.1a. The Blackfriars Ship 1: Plan from the first excavation (Marsden 1994:38, Fig.25) .............................................. 381

Fig. II.6.8.1b. The Blackfriars Ship 1: Plan after second excavation (Marsden 1994:39, Fig. 23) .............................................. 382

Fig. II.6.8.2a. The Blackfriars Ship 1: The reconstruction of the complete vessel (Marsden 1994:77, Fig. 69) ..................... 383

Fig. II.6.8.2b. The Blackfriars Ship 1: Reconstruction of the hull interior (Marsden 1994:65, Fig. 58) ......................... 384

Fig. II.6.8.3a. The Blackfriars Ship 1: The nailing system (Marsden 1994:58, Fig 48) ....................................................... 384

Fig. II.6.8.3b. Nails: 1 The New Guy's House Boat (top): 2 and 3 Blackfriars Ship 1:Side and bottom planking nails. (Marsden 1994:56, Fig. 46) ........................................ 385

Fig. II.6.8.3c. The Blackfriars Ship 1: Hooked nails from the side and bottom (Marsden 1994:57, Fig. 47) ..................... 386

Fig. II.6.8.4a. The Blackfriars Ship 1: Side frame and nails (Marsden 1994:52, Fig. 40) ...................................................... 387

Fig. II.6.8.4b. The Blackfriars Ship 1: A knee timber (Marsden 1994: 64, Fig. 57) .............................................................. 387

Fig. II.6.8.4c. The Blackfriars Ship 1: The mast step (Marsden 1994:53, Figs. 42, 43) ...................................................... 388
Fig. II.6.10.6a. St. Peter Port Ship: the stern post
(Rule and Monaghan 1993: 32, Fig. 18) ................................. 401

Fig. II.6.10.6b. St. Peter Port Ship: the stern post, isometric view from
below (Rule and Monaghan 1993:34, Fig. 20) ......................... 401

Fig. II.6.10.6c. St. Peter Port Ship: the stern post and stealers, T5 and T6
(Rule and Monaghan 1993:35, Fig. 21) ................................. 402

Fig. II.6.10.6d. St. Peter Port Ship: the stern post, junction with keel
(Rule and Monaghan 1993: 32, Fig. 19) ................................. 402

Fig. II.6.10.7a. St. Peter Port Ship: Tool marks on floor timbers, keel and
frames. All marks are of axe and adze.
(Rule and Monaghan 1993: 22, Plates 9, 10, 11) ...................... 403

Fig. II.6.10.7b St. Peter Port Ship: Tool marks on frames and stern post.
All marks are of axe and adze.
(Rule and Monaghan 1993: 23, Plates 12, 13, 14) ...................... 404

Fig. II.6.10.8. St. Peter Port Ship: mast step
(Rule and Monaghan 1993:40, Fig.27;19, Plate 4) ...................... 405

Fig. II.6.10.9. St. Peter Port Ship: Nail heads and caulking, nail clenching
(Rule and Monaghan 1993:80, Fig.60) ................................. 406

Fig. II.6.11.1a. County Hall Ship: 1910 A.D. drawing
(Marsden 1994: 118, Fig. 105) ................................. 407

Fig. II.6.11.1b. County Hall Ship: Partly reassembled remains about 1912
(Marsden 1994:104, Fig.101) ................................. 408

Fig. II.6.11.2. County Hall Ship: current 1994 drawing of the remains
(Marsden 1994:119, Fig. 106) ................................. 409

Fig. II.6.11.3. County Hall Ship: cross-section showing wale
(Marsden 1994:125, Fig.113) ................................. 410

Fig. II.6.11.4. County Hall Ship: reconstruction: deck beams, stanchions
and stringers (Marsden 1994:127, Fig.115) ................................. 411

Fig. II.6.11.5. County Hall Ship: mortise and tenon joints
(Marsden 1994:121, Fig. 109) ................................. 412
Fig. II.6.11.6. County Hall Ship: mortise and tenon joints
(Marsden 1994:120, Fig. 107) .................................................. 413

Fig. II.8.2.1. Sources for ornamental building stone used in Roman London
(Jones and Mattingly 1990:220, Map 6.38) ................................. 414

Fig. II.9.3.1a. Zwammerdam barge 2: cross-section, construction details,
and development from a simple dugout (de Weerd 1978:17) ...... 415

Fig. II.9.3.1b. Zwammerdam barge 4: Part of bottom and port side. Note the
paired L shaped one piece bottom and side frames, fitted
alternately to port and starboard (de Weerd 1978:19, fig.22) ...... 416

Fig. II.9.3.1c. Zwammerdam barge 6: Part of bottom, side and end section
The frame arrangement is similar to that in Fig. II.9.3.1b
(de Weerd 1978:19, Fig. 23) .................................................. 417

Fig. App E.1. Principal Roman mining sites in Britain
(Jones and Mattingly 1990:180, Map 6.2) .................................. 418

Fig. App. E.2. Underground Roman lead mine at Draethen, Gwent
(Jones and Mattingly 1990:187, Map 6.8) ................................. 419

Fig. App. E.3. Underground Roman copper mine at Llanymynech, Shropshire
(Jones and Mattingly 1990:191, Map 6.11) ............................... 420

Fig. App.E.4. Distribution of lead pigs in relation to some of the major roads.
(Jones and Mattingly 1990:189, Map 6.10) ............................... 421

Fig. App.E.5. Distribution of lead pigs from the seven major lead mining
areas: Charterhouse/Mendips (1); Draethen (2); Linley,
Shropshire (3); Pentre, Clwyd (4); Derbyshire (5); Pennines (6);
Wharfedale N. Yorks (7). .................................................... 422

Fig. App. F.1. Main Romano-British pottery kiln groups in the late first and early
second centuries (Jones and Mattingly 1990:207, Map 6.25) ...... 423

Fig. App.F.2. Generalized distribution of Romano-British pottery kilns
(Jones and Mattingly 1990:206, Map 6.24) .............................. 424

Fig. App. G.1. Location of principal Romano-British salt production sites
(Jones and Mattingly 1990:226, Map 6.43) .............................. 425
Fig. App. G.2. Location of Romano-British salt production sites reported since 1970. 426

Fig. App. I.1. Grain orientation in tangentially split timber. 427

Fig. App. I.2. Grain orientation in radially split timber. 428

Fig. App. K.1. Location of principal tileries in Roman Britain. 429

Fig. App. M.1. Hypothetical troop and stores transport for Caesar's expedition to Britain in 54 B.C. 430

Fig. App. N.1. Hypothetical Romano-British Barges 1 and 2 431

Fig. App. N.2. Hypothetical Romano-British Barges 3, 4 and 5 432

Fig. App. P.1: The steps in forging a 5 cm x 5cm x 46.5 cm long 9 kg iron bloom into sixteen lengths of iron rod for making nails. 433

Fig. App.P.2: Roman blacksmith's tool for making hollow cone headed nails for ship building. The hollow under the head holds the caulking. 434

Fig. App.P.3: Felling a tree with an axe. 435

Fig. App.P.4: Graph of time in minutes versus hole depth in cm to drill holes from 10 mm to 25 mm diameter, using a Roman type spoon bit or equivalent 436

Fig. App.P.5: Graph of time in minutes versus nail length in cm to drive nails about 1.0 cm diameter, using a carpenter's 0.675 kg hammer and a 2.27 kg sledge hammer 437

Fig. GT.1: Romano-British woodworking tools 323-325
Acknowledgements

This thesis draws heavily on the published work of a large number of archaeologists and other scholars. Some of the published material dates back to the nineteenth century, and some only appeared in print in A.D. 2001. It would take several pages to acknowledge all by name, but the bibliography is, in effect, a list of the scholars whose work is the source of much of the factual information I have used in the thesis. I thank them all, and hope I have not taken undue liberties with their information. Without their work it would not have been possible to develop and support the various hypotheses presented.

At the University of British Columbia, several professors in the Department of Classical Studies, now the Department of Classical, Near Eastern and Religious Studies, have encouraged and supported me over the years. In particular, I would like to thank Dr. Anthony A. Barrett, Dr. Phillip Harding, Dr. James Russell and Dr. E. Hector Williams. They have been great teachers and mentors. I must also thank Dr. Shirley Darcus Sullivan, who apart from teaching me elementary Greek, prodded me on whenever I showed signs of flagging in the race to finish this thesis.

I would also like to express my gratitude to my four children for their encouragement and support. Between them they have seven degrees from B.A. to Ph.D. I have attended all their graduation ceremonies, and they can’t wait to attend mine, a case of the ‘world turned upside-down’.
Dedicated to the memory of Audrey Bingham Millar, my wife for forty-nine years, who died in 1995 of amyotrophic lateral sclerosis before she could complete her own Ph.D.
THE TECHNOLOGY AND ECONOMICS OF WATER-BORNE TRANSPORTATION SYSTEMS IN ROMAN BRITAIN

SECTION I: SOME GENERAL CONSIDERATIONS
THE TECHNOLOGY AND ECONOMICS OF WATER-BORNE TRANSPORTATION SYSTEMS IN ROMAN BRITAIN

Section I: Some General Considerations

I.1. Introduction

This thesis investigates the technology and economics of Roman water-borne transportation systems in and around Britain, including the seaborne connections to the continent. The first requisite for such a system is the construction and employment of ships and boats which can function satisfactorily in the natural conditions of tides, winds and currents in and around the British Isles. These natural conditions differ widely from those prevailing in the almost tideless Mediterranean basin. The types and technology of ships used in and around Britain would have to be compatible with the local climatic and tidal phenomena. The inhabitants of north-western Europe in Gaul, Britain, and in the lands from the Rhine mouth up to Scandinavia, had their own boat-building traditions dating back to at least the Bronze Age, and in some areas even back to the Mesolithic. With the arrival of the Romans on the Atlantic coasts of Gaul during Caesar's Gallic Wars, the Mediterranean boat-building tradition of the Romans was confronted with totally different practices in boat-building. The thesis examines the outcome of the meeting of the two differing technologies in boat-building, and the factors which caused the Romans, in collaboration with the local inhabitants, to develop a Romano-British type of hull construction which was adapted to the natural climatic and tidal conditions and to the materials available locally in their new territory in the north. As well as the technology of ship and boat-building, the economics of building, maintaining and operating a fleet of cargo carrying vessels are investigated.

Transportation systems are a 'service' industry, not a manufacturing one. The mode of transportation, whether by water or land, has to be able to move everything, from bulky raw materials and primary products to delicate finished products, economically and with minimum loss or damage.

In the remainder of this section, a concise overview of a number of factors, constraints and problems affecting the design and evolution of transportation systems in Roman Britain are laid out briefly, to set the stage for more detailed examination in

1 Following the difficulties that he experienced in landing the troops in his first expedition to Britain and the damage that the transports and warships later suffered from the unexpected tidal range and stormy weather on the exposed coast, for the second expedition in 54 B.C. Caesar specified a design more suitable for northern waters (Caes. B Gall. IV.24,29, V.1)

2 The seagoing sewn planked Bronze age boat recently excavated, conserved and put on display at Dover has been provisionally dated to about 1550 B.C. using radiocarbon dating (Owen and Frost 1999:2).
From Lystrup in Denmark parts of a logboat dated to about 5440 B.C. have been found (Andersen 1994:4).
subsequent chapters of the thesis.

The subject matter of the thesis embraces a number of areas:

1. Consideration of the materials and objects to be transported, their point of origin and their destination or point of use

Some materials would use water transport predominantly. Others would require the use of both water and land transportation systems; for example, goods from Continental Europe to an inland destination in Britain that lacked river access. Some materials and objects would use only land transportation systems, where this was the most practicable and economic method. A distinction can be made between transportation over significant distances and the handling or transhipment of material over short distances; for example, from a moored or beached ship to an adjacent warehouse or storage location. Handling problems will be noted where they occur, but in general will not be the subject of detailed study.

2. The technology and economics of water transport.

This subject would include the vessels and the ancillary structures such as harbours, hards, wharves, jetties and warehouses.

Discussion will concentrate on the movement of low to medium value bulk materials and objects, since small light-weight valuable objects such as jewellery, bronze lamps and figurines and similar articles do not require a massive transportation infrastructure. Security of the goods is more important than the cost of transportation.

In dealing with transportation in Roman Britain there is a major difference in the archaeological sources of information available to us for land and water-borne movement. Land transport other than very limited and local movements would have used principally the Roman road network. In Britain the network of the major and many of the minor roads is substantially known, and can be located on the ground, as can quite a number of secondary roads and tracks (Chevallier 1976:158-9, 1997:268-70, Johnston 1979, Margary 1973, Rivet 1970, Taylor 1979:1-83, Viatores 1964). It is reasonable to assume, for example, that, except for purely local movement within a farm or rural estate of grain from the fields to storage pits or a granary, land transportation would use the major and minor Roman roads. This assumption is strengthened by the fact that twenty-one towns, fifty-four small towns, and several hundred rural settlements and several hundred villas have been found on or very close to the road system (Burnham and Wacher 1990; Hingley 1989; Scott 1993; Wacher 1995). There is a town or settlement of some type at practically all the nodes in the road network. By contrast, with the evidence available for land transport, for the seaborne and river movements of goods, very few harbours, hards or wharves have survived in the archaeological record. Movement on a river can be compared with that on a road, in that both are relatively fixed parts of the landscape. For coastal and open sea voyages, the path of the vessel is determined by a number of uncontrolled variables, winds, tides and the state of the weather and sea. In reconstructing the routes for seaborne commerce it is more

---

3 A hard is a piece of ground at the water's edge, smoothed and covered with sand and gravel, sometimes laced with timber, on which small vessels can safely take the ground. The hards are covered at high tide and dry out at low tide. The hard surface is usually carried well above the high water mark to facilitate the movement of carts and people engaged in loading or unloading, or in servicing the vessels.
practicable to deduce the routes from known or inferred harbours or havens, and from the materials moved. For example there was certainly a regular movement of shipping between Boulogne and Dover, but no two voyages would take exactly the same path over the sea. If from the archaeological record we know the point of production or manufacture of an item, and it is found at one or more points of use or consumption, then a most likely seaborne route or number of likely routes can be deduced. For example, south-east Dorset Black Burnished Ware I (SEDBBI), manufactured in the area of Poole Harbour on the south coast, was "....present in quantity on the northern frontier...." (Allen and Fulford 1996:224), as well as having an extensive distribution in the coastal zones of Dorset and south-east Devon, in Somerset, in other areas in the south-west, in Wales and at lower densities at sites in most of mainland Britain. The southern coastal sites and the northern frontier were almost certainly supplied at least in part by sea. In London, waterfront finds of SEDBBI, together with other south-western wares point to a ship-borne trade. Transport by water eastward and southward brought the pottery as far east on the mainland coast of Europe as the mouth of the Rhine (Aardenburg), Boulogne, and to many localities in Normandy and Brittany." (Allen and Fulford 1996: 257). More local distribution to the inland areas was probably either by road, or by the use of local rivers for large consignments.

The key element in any transportation system, whether ancient or modern, is the harnessing and utilization of energy of some form to overcome friction and the other forces impeding motion. In the expenditure of energy both technological and economic factors come into play. In moving materials of comparatively low value per unit of weight a cheap form of energy is needed, while for high value items of low unit weight, a relatively expensive form of energy may be acceptable. The technology and economics of transportation systems are not independent variables, but interact with each other in various complex systems. For the movement of any sort of material the aim generally would be to find the cheapest technology appropriate for that particular commodity. To take a hypothetical example from possible distribution systems for different types of fired clay ceramics, cheap articles of high weight used in volume, such as coarse cooking pottery, tiles or bricks would require a bulk transportation system with a low unit cost per kilogram if the material is to be saleable in a competitive market. On the other hand, fine high quality lamps or table wares could tolerate a much higher cost per kilogram and still be marketed at an acceptable price. While the ancient world may not have formalized sophisticated modern type theories for economic activities, the manufacturers, merchants and their customers would have appreciated these problems from a common sense approach.

The sources of energy for producing movement known to the Romans were human and animal muscle power, and the natural forces of wind and the movement of water. Heat as a form of energy was used for the smelting of ores, the forming of metals, the forming of glass and the firing of ceramic products, but was not used directly to produce practicable or economic forms of motion. Hero's devices using hot air to open temple doors as if by magic and his steam turbine were ingenious toys, not useful applications of power in the movement of goods or people (Hodges 1992:214-16).

In considering Roman Britain's need for transportation systems, the need and the situation were not static. Before the Roman arrival a LPRIA (Late Pre-Roman Iron Age) system was functioning, both to distribute internal food supplies and products, such as salt,
metals and pottery, and to distribute the known imports entering at sites such as Hengistbury Head and Mount Batten on the south coast and Camulodunum on the east coast. These included wine in amphorae, raw glass, figs, Armorican pottery, coins from Gaul and a small amount of high status goods (Cunliffe 1987, 1988, Hawkes and Hull 1947, Millar 1991). There was certainly some level of water-borne transport, both cross-channel and inland. Sophisticated Iron Age dugouts, such as the Hasholme boat were in use on estuaries and probably for short coastal voyages. The Hasholme craft had a cargo capacity of between 4 and 8 tonnes, depending on the freeboard needed (Millett and McGrail 1987:134). There were quite frequent literary references to high status people crossing from Britain to Gaul and vice-versa. As Salway comments "...we can at least be confident that by the time Claudius came to form the Roman province, and perhaps already before Caesar, influential contacts existed between the aristocracies on both sides of the channel." (Salway 1993:14). Strabo on Britain comments, “It bears grain, cattle, gold, silver and iron. These things, accordingly, are exported from the island, as also hides and slaves, and dogs that are by nature suited to the purposes of the chase;” (Strabo IV.5.2). The Iron Age in southern Britain had at least two long distance trackways, the Icknield Way and the Ridgeway, and others possibly existed such as the Jurassic Way and the North Downs Trackway. These were almost certainly complemented by numerous local paths and tracks (Ordnance Survey 1962, 1990). Land transport by pack animals or human porters would have been quite practicable. Locally within a farmstead or village simple carts may have been used.

After the Claudian invasion and conquest in A.D.43, a start was made constructing what was to develop into the Roman road system. By the end of the first century and the early second century AD a network of Roman roads covered most of England and Wales (Chevallier 1976:158-9, 1997:268-70, Johnston 1979, Margary 1973, Rivet 1970, Taylor 1979:1-83, Viatores 1964). The infrastructure for land transportation, the roads, bridges, the forts and fortresses, and the towns and other settlements which were the centres for markets, have been the subject of extensive excavations and study over the past one hundred years. By contrast, most of the archaeological evidence for the water-borne system has been uncovered, and to some extent studied, in the past twenty years. For the water-borne system one is working with a much smaller data base.

With the changes in the size and composition of the legions and auxiliaries during the Roman occupation, the numbers in the garrison of Britain declined (Frere 1987:143-6). There was also a significant drop in inter-provincial trade over the decades, as the products of local industries replaced the importation of goods such as fine pottery. For example, by the early part of the third century AD Millett comments on “...a substantial decline in the volume of pottery traded between Britain and other provinces of the empire.” (Millett 1990:159). Fulford, for the late Roman period, believes that the amount of imported pottery fell drastically, “During the late Roman period individual categories of import can scarcely account for even 1% of the total pottery assemblage.” In the south-east the percentage of imported wares was somewhat higher, but even there the quantity was small, “Nevertheless, rough estimates at Canterbury and Richborough, for example, where assemblages no longer survive in their original state, do not indicate that late Roman imports ever amounted to more than 10% of the assemblage.” (Fulford 1978:63-4). Wine, olive oil and certain luxury
goods, such as fine marbles, would continue to be imported, local sources not being available. This drop in interprovincial trade would also imply a decrease in cross-channel shipping movements, but some increase in internal traffic, using coastwise shipping, river craft and road transport to distribute locally produced goods around Britain.

In summary, there was a continuing change in transportation routes and systems, from the LPRIA through the decades of conquest and pacification, as Roman influence, roads and administration became established. By the early second century A.D. a fairly stable Romano-British transportation system would have become established. Internally this would have been manned and operated primarily by romanized or un-romanized native Britons. Other than the military, parts of the civil administration, certain traders and specialists, native Britons in general would have continued to supply the manpower for agriculture, pastoralism, fishing, mining and quarrying, and the manufacturing and craft occupations. Practical considerations alone would have made this almost certain. Successful traditional agriculture and the operation of small vessels in coastal waters require local experience and knowledge which can only be built up over several generations. Farming and seagoing tend to be conservative occupations. The outcome of unsuccessful innovations can be catastrophic, resulting in starvation or drowning!

The 'stability' in the transportation system would be primarily in those parts of the economy dependent on a developed infrastructure involving considerable capital cost, such as the roads, bridges and fords, and to some extent the wheeled vehicles on land. For water-borne transport the 'vehicle', the ship or boat, although representing a major capital outlay, had a limited life through normal wear and tear, and marine casualties from stranding, shipwreck, foundering in bad weather and piracy. Built harbour facilities, wharves, jetties, hards and warehouses would live or die depending on whether there was stability or change in the trading patterns and routes.

For the technological aspects of water-borne transportation, and for determining possible river and coastal sea routes this study will use the following technique. For each mode of transport a hypothetical construct will be postulated for the form of the vessels and facilities used, based on what would have been possible with the known technology of the period, and on the basic laws of physics and motion, and their practical offshoots in naval architecture and engineering. These hypothetical constructions will then be compared with the often very limited material from the archaeological record, the literary material, the iconography and the epigraphic material.

As part of this general introduction to the subject matter of the thesis, the following five sections briefly review key elements in establishing a transportation system. Most are covered in more detail in subsequent chapters or the appendices, but an overview has been included at this point to provide some useful background to the later chapters. The five

---

4 The Kyrenia ship from the Mediterranean was about 80 years old when it was lost (Johnston 1997:228). Evidence for the working life of Romano-British ships is limited to the five vessels discussed in this thesis. An examination of the marine casualties in a group of thirty wooden sailing schooners from Porthmadog in Wales engaged in the coasting and continental trade in the early 1900s gave an average working life of about eighteen years. Two were lost in the first year at sea, and the longest-lived was broken up when fifty years old, see page 155.
sections are:

i. The types of materials and goods to be transported, their sources and destinations.
ii. Containers and Packaging.
iii. Tools.
iv. The procurement and conversion of timber.
v. Metal work for transportation systems.

**Section 1.2: Materials to be Transported, Sources and Destinations**

2.1. Introduction

The principal materials and objects requiring bulk transportation systems are:

Food, particularly grain, see Appendix C.
Iron, both semi-finished blooms and finished fabricated items, see Appendix D.
Non-Ferrous metals, see Appendix E.
Pottery of all types, from amphorae to drinking cups, see Appendix F.
Salt, see Appendix G.
Stone and Masonry, see Appendix H.
Wood and Timber, see Appendix I
Coal, see Appendix J.
Building ceramics, bricks and tiles, see Appendix K.

2.2 The Archaeological Evidence

The archaeological evidence varies from very good for manufactures such as pottery, to rather slight for food, a most vital material. For two of the basic foods, grain and meat, production was widespread throughout Britain, and much of the output would have been consumed locally. Grain in large quantities would have been transported to fill the army’s granaries, and for major campaigns, such as the Agricolan, Antonine and Severan advances into Scotland. The archaeological evidence for the movement of grain is principally in the form of the storage facilities.

Iron was produced in large quantities in the Weald, situated in the counties of East and West Sussex in southern Britain, into the mid-third century AD, and was distributed from there to points of use in Britain, and to the Rhineland. A significant amount of iron continued to be produced in small quantities in many localities, carrying on the LPRIA tradition, and satisfying at least part of the local needs (see Appendix D). Iron tools, fittings and domestic articles have been recovered from many Romano-British sites, often in fair quantities.

Non-ferrous metals, both the precious metals, gold and silver, and the base metals, lead, copper, tin, zinc, and their alloys, bronze, brass and pewter, were mined and smelted in Britain. For lead, the archaeological evidence for transportation distribution is largely in the form of a small number of finds of lead pigs found at key points in the internal and external trade routes (see Appendix E).
Largely because it is durable, pottery does not deteriorate in most archaeological contexts, so that it often survives in large quantities, and because its source can usually be determined with a high degree of certainty, the archaeological evidence is solid for both the source and final destination. It is also usually reported in detail in excavation reports. Similar considerations apply to brick and tile, and often to masonry and stonework (see Appendices F, H, and K).

Salt production and distribution can only be traced from the archaeological remains of production sites, either inland brine springs, or coastal salt-flats, and containers thought to have contained salt. Salt, as such, is not a material that survives in archaeological contexts (see Appendix G).

Much of the timber used for fuel and construction would have been harvested locally, fairly close to the point of use. Water-borne transportation could have been used to supply material for towns and major military installations. Transportation could be in the form of rafts of logs for movement on rivers, or as a load on a barge or ship. For the legionary fortress at Inchtuthill on the river Tay in Scotland, Shirley has suggested that some of the larger timbers may have been brought in to the site from a considerable distance away (Shirley 2000:164). Archaeological evidence for the movement of timber by water is minimal.

As a result of very recent work it has been possible to assign coal to definite sources (Smith 1997), but the reporting of coal from many sites has been poor to non-existent. Coal is now known to have been used at a number of sites, spread over much of England. Dearne and Branigan list 232 sites where evidence for the use of coal as fuel has been found, most often in the form of ash. It was frequently not included in the excavation reports (Dearne and Branigan 1995:72). See Appendix J for a detailed discussion of the sources of coal and the points of consumption.

The archaeological evidence for sources and destinations can be quite firm, for example Black Burnished Ware I pottery was made in Dorset and is found in quantity on Hadrian's Wall. For other materials there is only an uncertain inference or guess as to its origin, and equal uncertainty as to its final destination, for example, grain.

### 2.3. The Literary Evidence

Certain of the classical authors, for example Strabo and Caesar, comment directly on goods produced or traded into or from Britain. Other authors, such as Cato and Columella wrote extensively on agricultural practices in the Mediterranean, but many of their prescriptions would not apply to Britain, because of differences in soils and climate. In general there are nuggets of useful information scattered throughout the classical authors on a wide variety of subjects relevant to this thesis, but they need to be used with caution. The authors were all literate members of the senatorial and equestrian classes, generally writing from a managerial point of view, and their actual detailed knowledge of the banausic occupations may have been limited. Further, to reiterate the point made above, observations on technology or economics from the Mediterranean might not be valid for the British circumstances.
2.4. The Epigraphic Evidence

The epigraphic evidence from Britain relating to the technology of transport and trade is not large. From inscriptions or graffiti at quarries, the names of a few military units and personnel are known, principally from quarry sites along Hadrian’s Wall (RIB I:1001-1015). Presumably the units were either quarrying stone, or supervising civilian quarry workers. Inscriptions on lead pigs provide dating information from the imperial titles, and in some case the names of the partners or societas responsible for production. Lead sealings were used on bales of merchandise or official stores, and may indicate the military unit or merchant owning or shipping the materials. The Vindolanda tablets mention military supplies, and in some case their destination or point of origin. Other epigraphic evidence comes from pottery, especially fine pottery showing the manufacturer’s name, and from this the source can be established. Tiles were often stamped, especially those made by or under the supervision of the classis Britannica and the legions, and some have graffiti possibly indicating information such as the size of a kiln load (RIB II, Fasc. 4 and 5). Some other objects of fired clay such as figurines and incense burners had the maker’s name inscribed (RIB II, Fasc. 4, 2456.1-12,2457.2-3 and 2457.5-6).

2.5. The Iconographic Evidence

The iconographic evidence for the goods transported and modes of transport is sparse to non-existent from Britain. From Gaul and Germany there are a considerable number of reliefs showing river vessels and road vehicles with various loads, such as barrels and bales, see Figs. I.3.1.1, I.3.1.4, I.3.1.5, I.3.2.5, I.3.5.1, I.3.5.2, I.3.5.3, I.3.5.4, I.3.5.5, I.3.5.8. It would seem reasonable, with caution, to use this for evidence of transportation technology in Britain. Both before the Roman conquest and after, there were substantial contacts between Britain and Gaul, and useful technology tends to cross political boundaries. In another context, for example, the Roman Republic rapidly became proficient in building and manning naval ships in large numbers when faced with the problems of the First Punic War.

2.6. Discussion and Conclusions

From the points discussed in this section, and from the material contained in the appendices, it is believed that sufficient evidence is available to describe, and to some extent quantify the technology and economics of the movement of raw materials and certain manufactured goods in Roman Britain.
3.1. Introduction

Materials to be transported by land or sea can be divided into several categories. Two principal considerations are how robust the material is, and the need to keep it dry. A further consideration is its density, or weight per unit volume. For example, quarry-run stone is both robust and is generally impervious to water damage. Grain is also robust in that it can be loaded in bulk without significant damage to individual grains, but is extremely susceptible to water damage. Fine pottery is fragile, but little affected by water. Another problem is whether the material can be loaded in bulk, or must it be packaged in some manner. The packaging available to the Romans includes amphorae and other pottery containers of various sizes from the underground storage pithos to the tiny unguent flask; glass bottles; barrels of various sizes, especially in the Celtic world of North-West Europe; sacks of leather or fabric; wooden boxes; baskets; nets; and bales for materials such as cloth, sheep’s wool and furs, Figs. I.3.1.1, to I.1.3.5. As well as providing containers for many items of trade, there was also a need for dunnage, material used to secure the cargo firmly in place in rough water, and to prevent relatively fragile items such as amphorae from bumping against each other. A further use for dunnage was to protect the hull against damage from heavy or sharp material. In antiquity it could be in the form of brushwood of various sorts, sand, gratings, short planks or mats, stored under or among cargo to prevent injury by moisture and chafing, see fn 5 below. Dunnage was primarily used to protect the cargo or load, but for ships and boats in particular, as noted above, it was also used to protect the vessel’s frames and planking from damage by cargoes such as broken stone. In North-West Europe brushwood, heather, reeds, vine twigs and straw would normally be available from local sources. For cargoes such as amphorae in ships, a layer of sand or fine gravel on the wooden ceiling over the bottom timbers could be used to secure the cargo.

From Mediterranean shipwrecks Parker has noted various sorts of dunnage.

La Chrétienne A wreck: “The ceiling.... was mostly preserved, and all over it was a dunnage layer of thin branches.”
Dramont C wreck: “...about 5 long iron bars (laid on a dunnage of vine branches)...”
Marsala Punic Ship: “The ballast stones lay on a dunnage including Phillyrea, myrtle, evergreen oak, cypress, lentisc, pine and ferns;...”
Port-Vendres B wreck: “Abundant pieces of heather probably represent dunnage.”
Ulu Burun wreck: “There were stacks of Cypriote pottery, much of it originally packed in a pithos...”, “The cargo was stowed on a dunnage of Thorny Burnet (Sarcopoterium spinosa).”
Yassi Ada B wreck: “...bilge sludge included sawdust, wood chips and twigs, interpreted as remains of dunnage.”
Secca di Capistello wreck (or Schläger Wreck): “The amphoras lay on brushwood dunnage.”
Ma ‘Agan Mikha’ El wreck: “The hull was covered with 12 tons of ballast-stones, many of them schist slabs, laid on grass matting over pistachio dunnage, and fastened to the planking by iron nails.”
(Parker 1992a:141, 167, 248, 263, 330-1, 396, 440, 455)
3.2. The Archaeological Evidence

As containers for liquids, amphorae were in universal use in the Greek and Roman worlds for wine, olive oil, fish sauce, salted fish and meats, nuts, olives and figs. Amphorae with various contents have been recovered from wrecks throughout the Mediterranean (Parker 1992b:92). From the River Thames estuary in Britain an amphora was found still containing over 6,000 olives, see Fig 1.3.2.1, (Milne 1985:111, fig. 64, Sealey and Tyers 1989:53-72). In Britain amphora fragments occur on some LPRIA sites, and on most Roman sites with some pretensions to higher living standards, villas, towns, and military establishments. Coarse pottery was used in Britain as a transport container for salt (see Appendix G). From the Ulu Burun wreck in the Mediterranean, Cypriote pottery was found to have been packed in a pithos, while from La Madrague de Giens wreck, near Hyères on the coast of Narbonensis, several hundred pieces of fine and coarse pottery were “....packed in boxes, stowed on top of the amphoras.” (Parker 1992a:440, 250).

Barrels were used in Britain and North-West Europe as containers for wine, and when no longer liquid tight may, have been reused to hold other objects, Fig. 1.3.2.2, 1.3.2.3. In Britain, barrels when no longer tight were reused as well linings, and most of those found in archaeological contexts are from this secondary use. Most of the barrels found were imported, with two possible exceptions. Imported barrels were made from trees not native to Britain, and were probably used for importing wine in the first and second centuries A.D. Two barrels of oak, one from London and one from Bar Hill, are known, and may be of local manufacture. Twenty-nine inscribed wooden barrel staves or heads are listed in RIB II, Fasc.4, 2442.1 to 2442.29. Subsequently another has been found at Carlisle (Britannia 28,1997:460), and in London at No. 1 Poultry “ Two of the roadside properties had wells lined with silver fir barrels, recovered intact.” (Britannia 27, 1996:429). The barrels reported in RIB II had capacities between 400 and 930 litres. A barrel from Silchester with a capacity of 889 litres would contain as much as 32 of the largest wine amphorae (Dressel 2-4), holding 27.5 litres (RIB II. Fasc. 4, p.1). A cylindrical barrel 0.84m in diameter and 1.4m long would hold 890 litres, and would be much easier to handle than amphorae. Well made barrels can be rolled with ease, even when full, and are easily lifted with a simple rope sling.

As well as their use for liquids, barrels of various sizes can be used as containers for items such as nails and other ironwork, or with suitable padding material for relatively fragile objects such as pottery lamps. For dry materials, the barrel does not need to be liquid tight, and in later periods rough barrels or kegs were used as containers for a wide range of goods. The approximately 875,000 Roman iron nails weighing nearly ten tonnes found at Inchtuthill (Pitts and St. Joseph 1985:276), if imported from elsewhere, could well...

---

6 These do not represent 29 different barrels. In a number of cases several staves from the same barrel have been found.
have come in kegs or barrels. Wooden stave buckets have been found at a number of sites, for example at Newstead (Clarke, Breeze and MacKay 1980:58), and it is only a small step from that to a keg. To date there does not appear to be any archaeological evidence for woven sacks or similar packaging containers in Britain. A certain number of textile fragments have been recovered, notably from Vindolanda, but they all appear to be from clothing. Leather fragments and objects have been found at a number of anaerobic sites. A few fragments of leather are from Roman military tents, but the predominant leather finds are shoes and boots, both civilian and military. Leather was certainly used for ships’ sails in North-West Europe, but leather sacks or containers have not yet been found in archaeological contexts in Britain. A few wooden boxes have been found: at Baldock a nailed wooden box containing a cremation (Britannia 7, 1976:338); at Skeleton Green a wooden casket with bronze fittings for a cremation burial, and fittings from a number of other wooden caskets (Partridge 1981:304-21); from London two burials in exceptionally well preserved wooden coffins and thirty-six other burials in wooden coffins (Britannia 31:415); at Binchester Fort a wooden box containing ox, pig and bird bones (Britannia 10:284); at Vindolanda a wooden needle case containing iron needles and wrapped in a roll of textile (Britannia 19:434); and at Corbridge an iron bound wooden chest containing armour, weapons, a wooden tankard, various tools and textiles (Allason-Jones and Bishop 1988). From material recovered from Roman shipwrecks in the Mediterranean, Parker has listed scrap glass carried in a wooden barrel, wooden boxes of various sizes, chests and cases. Small wooden boxes were used to ship items such as styli and pins, and for spices (Parker 1992a: 91, 178, 197, 207, 233, 340, 343, 444). He also notes baskets of various sizes. Fragments of sacks were found at Valle Ponti, and sacks have been inferred from the lead seals found at Pampelonne (Berti 1990, Lequement 1976, Parker 1992b:94). Although the Mediterranean evidence for boxes and sacks used as containers for transporting goods by sea is geographically rather a long way from Britain, by the second century AD it is probable that the technology was used in cargoes to Britain, and internally on British river systems, particularly for items such as fine pottery.

---

7 Angus, Brown and Cleere, who made a detailed typological and metallographic examination of the nails, were unable to identify the source of the iron. It could have come from a local source, possibly ores from Fifeshire (Angus, Brown and Cleere 1962:959). Tylecote also thinks the source is uncertain (Tylecote 1986:170).

8 In a casket burial the cremated remains are placed in a wooden box about 30 cm long x 25 cm wide x 15 cm deep, with grave goods disposed around the casket. Another type of cremation burial is the box-burial, where the wooden box is large enough to contain all the grave goods as well as the ashes. In excavations the caskets or boxes have almost always disintegrated, but their presence is inferred from the metal fittings, and these have been recovered from a large number of sites. Although not directly related to packaging for transportation, it seems likely that wooden boxes as containers for moving fragile or valuable goods could have existed, but are not preserved in the archaeological record. At the destination the boxes, if not recycled, would be broken up and the wood reused or simply used as firewood.
3.3 The Literary Evidence for Containers

The literary evidence for packaging for transporting merchandise and material is rather slight, principally because it would not be a subject of interest to the educated and literate Roman elite. Hesiod, viewing life from a humbler station, in the *Works and Days* refers to Pandora’s storage jar in line 93. For his campaigns in Gaul, Caesar is concerned about supplies and arranges for the collection and supply of grain and other necessities (*B Gall. I.40, II.2, IV.7, VI.44*), as does Servius Galba, commander of the Twelfth Legion (*B Gall. III.2, III.6*). Agricola, for his campaigns in Britain and Scotland, has similar concerns, arranging for an equitable system for collecting grain and tribute, and the advanced forts in Scotland “...were protected against a protracted siege by supplies for twelve months.” (*Tac. Agr. 19.4, 22.2*). These senior commanders will have issued the general orders or instructions. A more lowly figure, a quartermaster or similar functionary, would be concerned with barrels, bales, boxes and sacks (see section 3.4 below on the epigraphic evidence from Vindolanda).

The agricultural authors, Cato, Columella and Varro, all provide lists or suggestions for the storage jars, vats, baskets and water buckets needed to work a farm, but these are not packaging for transport (*Cato, Agr. 1.*, 10.11, 135.1-2, *Columella, Rust. 2.20.1-3*, *Varro, Rust. 1.17-22*). Strabo comments on the enormous size of barrels in Gaul (*Strabo 5.1.12*).

3.4. The Epigraphic Evidence for Containers

The inscribed barrel staves listed in *RIB II, Fasc. 4* have been noted above. Two types of marking have been identified on the staves: graffiti scored with a blunt instrument or inscribed, and often on the inside of the stave, occur as both number and letter sequences. These suggest manufacturing or assembly markings by the cooper. Other markings are branded or hammered in on the exterior of the staves, and probably indicate information on contents, shipping directions, owners or shippers, or customs marks. Some examples are: *RIB II, Fasc. 4, 2442.8* branded HERM in four places; *RIB II, Fasc. 4, 2442.12* marked L.E.FL; *RIB II, Fasc. 4, 2442.19* [...]HRAN; VERCTISSAE plus staves numbered from I to XVIII with VII missing.

Lead seals are another category of epigraphic evidence for containers. Over three hundred have been found in Britain (*RIB II Fasc. 1, 2411.1 to 2411.311*), with the users divided among Imperial and Provincial officials, taxation officers, and civic, military and private users. The lead sealings are most likely from bales or sacks of merchandise, although some may have been used to seal boxes, or chests containing valuable objects. Lead sealings would normally be found at the destination point, where they would have been removed and discarded. The military seals are generally rectangular and alphabetic, for example, *RIB II Fasc. 1, 2411.58* from Caerleon inscribed LEG II AUG. Civilian seals are normally round or ovoid and more commonly iconographic than alphabetic. Large quantities of military sealings have come from both South Shields, the base for the Severan campaigns in Scotland, and Brough under Stainmore, which appears to have been a collection point for goods from a wide area (*Dore and Gillam 1979:164-165, RIB II, Fasc. 1:pp 87-8*). At a base or collecting centre, inward shipments would have been
unpacked and stored, and the seals discarded.

Another indirect source of information on containers comes from the Vindolanda Tablets (Bowman 1994:109, 119-20). Tab. Vindol II.180 gives an account of the distribution of wheat:

"Account of wheat measured out from that which I myself have put into the barrel:
to myself for bread ...
To Macrinus, modii 13
to Felicius Victor on the order of Spectatus provided as a loan, modii
in three sacks...."

It is clear from this that barrels and sacks were in use at Vindolanda. Another tablet lists baskets and boxes, Tab Vindol II.194:

"a strong box and a bronze lamp bread-baskets, 4
cups, 2 in a box
bowls, 2 in a box..."

3.5. Iconographic Evidence for Containers

The iconographic evidence for containers from Britain is very limited, but from Gaul and Germany there are a considerable number of relief sculptures showing various packaging, barrels, baskets, bales and amphorae, see page 9 above. Trajan’s Column is another source of iconographic evidence for containers and packages used by the military. These sources are useful for Roman Britain. The Roman army in the early Empire tended to have standard equipment and methods in all its units, while the civilian trade and cultural connections between Britain and Gaul make it likely that packaging and containers would be similar on both sides of the Channel. As noted in the preceding sections, most of the barrels found in Britain came from the continent. The LPRIA as well as the Roman trading connections between Britain, Gaul and Germany would tend to promote similar technology for packaging on both sides of the Channel and southern North Sea.

From the Rhineland there are reliefs showing wine barrels in various sizes of inland water craft, one of which is being punted, see Figs. I.3.5.1, I.3.5.2, I.3.5.3 (Chevallier 1988:106, Lewis and Runyon 1990:8, Ellmers 1978:Fig. 9). In Fig. I.3.5.3 one of the crew is sampling the wine through a straw! From the Netherlands there is a relief showing a boat loaded with wine barrels being punted Fig. I.3.5.4. From Gaul a relief in the Musée Saint-Didier in Langres shows a wagon with a large barrel, possibly permanently mounted on the frame (Chevallier 1988: 37), Fig. I.3.5.5. The tombstone of a young woman from Portugal, Eppatricia, is in the form of a hooped wine barrel draped with
wineskins (Toynbee 1971: fig. 81), Fig. I.3.5.6. In the Musée des Beaux Arts in Nancy is a relief plaque with a number of hooped tubs and buckets, Fig. I.3.2.2 (King 1990:104). From the Roman fort at Newstead in Scotland comes an iron hooped, oak stave wooden bucket of the first century A.D., Fig. I.3.5.7 (Clarke, Breeze and Mackay 1980:58, Fig. 56). A barge with a load of bales of cloth is shown on a tombstone from Igel near Trier, Fig. I.3.5.8 (Ellmers 1978:7). A relief from Saulnois (Moselle) shows five men manhandling a large bale of cloth (Chevallier 1988:287), Fig. I.3.5.9. A stele in the Musée Archéologique of Strasbourg depicts a Roman soldier driving a four wheeled cart loaded with bales and sacks (Schnitzler 1996:100). A sarcophagus from Arles shows pickers in an orchard filling baskets with fruit, Fig. I.3.1.3 (King 1990:101). The transportation of amphorae appears in a number of relief sculptures, mosaics and wall paintings. A mosaic from Bad Kreuznach shows a cargo vessel with a Celtic leather sail carrying amphorae, Fig. I.3.5.10 (Ellmers 1978:3, Fig. 3). A small cargo ship with a deck load of amphorae resting on dunnage is portrayed on a relief in the Villa Wolkonsky, Rome, Fig. I.3.5.11 (Casson 1995: Fig. 155). A relief from Portus shows stevedores unloading amphorae on to the quay side, where tally clerks with tokens and a ledger are keeping count, Fig. I.3.5.12 (Casson 1994:103, Fig. 76). Amphorae are the commonest cargoes found on Roman period shipwrecks in the Mediterranean, Fig. I.3.5.13 (Casson 1994:104, Fig. 77, 105, Fig. 78). In the Mediterranean a wall painting from Ostia, now in the Vatican Museum, shows sacks of grain being loaded into a small vessel, Fig. I.3.1.4 (Casson 1991:Plate 52). A relief of a kitchen scene portrays a slave scooping flour from a sack (Tingay and Badcock 1972:141). Scenes on Trajan’s Column show barrels (Lepper and Frere 1988, Plates V, XXVI and XCVI), bales being manhandled and stowed (Plates VI, XXV, XXXV, LXXIV and LXXX), and baskets being used for carrying earth (Plates XV, XL, XLII, XLVI, and XCVI).

3.6. Discussion and Conclusions

In general, between the archaeological, epigraphic, and iconographic evidence, a reliable picture of the containers and packaging used for transportation by sea and land can be built up. For amphorae the evidence is solid. Amphorae from Italy, Spain, North Africa and Gaul have all been found in Romano-British contexts. For barrels the archaeological evidence is firm, if small in quantity, for imported barrels, slight but conceivable for some locally made barrels, and solid for hooped wooden buckets. The use of wooden boxes is supported by the evidence from the Vindolanda tablets, and the existence of wooden boxes, caskets and coffins from funerary contexts shows that the technology for making boxes was available. From the evidence from Roman shipwrecks in the Mediterranean small wooden boxes were used for the packaging and protection of small but valuable manufactured items, and also for spices and similar material shipped in small quantities. The question of sacks and bales is more difficult. From the iconographic evidence sacks were certainly

9 Roman tombstones in the form of wine barrels are quite common in Portugal (Personal communication from Dr. Lynn Rae, who has photographed a number.
made and used in other parts of the Roman empire, and the finds of lead seals strongly suggests the use of sacks in Britain. The one solid piece of evidence is the reference to sacks in a Vindolanda tablet. From a practical point of view handling grain and similar commodities without using sacks would be difficult, and large quantities of grain were certainly transported long distances to supply the military granaries and supply depots. A further problem with sacks in Roman Britain is the material of manufacture. Were they made of woven fabrics, presumably flax fibres, or leather? Either is technically possibly, and the choice may have depended on the relative manufacturing costs and the expected life. Leather sacks could have been reused more times than textile sacks. On balance, based on evidence from other parts of the Empire, textile sacks were probably used, but have simply not survived in the archaeological context. Baskets were almost certainly used for local marketing, and possibly for longer distances. A basket from the Roman period was found at Much Wenlock, Shropshire, containing a hoard of 3064 antoniniani (Britannia 9 1978:436), and the Scottish National Museum has a quite well preserved basket from the Roman period (personal observation). Native basketry is known from the LPRIA (Cunliffe 1991:446-7).

In summary, all the containers and packaging discussed in this section were almost certainly available and used in Roman Britain, but not necessarily in the same proportions as in the Mediterranean area.

Section 1.4: Tools

4.1. Introduction

A basic requirement for any technology that involves the shaping and forming of materials, wood, clay, stone or metals, and converting them into useful products is a set of efficient tools. Tools for these purposes can be divided into two broad classes. The first is edge tools such as axes, adzes, saws, chisels, planes and drill bits, which function by cutting

---

10 Flax was grown in Britain. For example at the Barton Court Farm villa in Oxfordshire flax seeds have been found (Dark 2000:85-6) and possibly in the area of York, where linen shrouds have been recovered from graves (Wacher 1978:211). Reynolds has noted that in the Iron Age it was grown, either for oil from the seeds or for fibres (Reynolds 1987:33-35). From Lower Caldecote “There was environmental evidence of flax-retting: finds suggest activity in the first centuries A.D. and B.C.” (Britannia 1989, 20:292). A lead defixio from a temple site at Uley, Gloucestershire mentions linen, “...a Saturnina muliere de lintiamine quod amisit...” (Britannia 1979 10:343).

11 The basket is in Case D5 in the Roman Agriculture section. It is about 40 cm high, about 27.5 cm diameter at the bottom, and slightly barrel shaped with a girth at mid-height of about 31 cm. The capacity would have been about 28 litres. The vertical members were about 0.6 to 1.0 cm in diameter, and the horizontal strands varied from about 0.3 to 0.8 cm diameter. The top rim was reinforced by bending over the verticals and weaving them together to give four layers of tightly packed heavy osiers.
a material which is softer than the tool. The second group is percussion tools, hammers of all sorts, the quarryman’s pick, stone mason’s wedges and chisels, and blacksmith’s tools for forming hot metal. Percussion tools use two modes: for stone mason’s work the tools work by chipping pieces off a hard material, and will need periodic hot re-forging and re-sharpening of the working edge; for metal working the percussion tools, the blacksmith’s or bronze-smith’s hammers and auxiliary devices work by changing the shape or form of a malleable material, usually without removing significant amounts of material. Working of metal can be done with hot metal, as in the forging of iron compounds into swords or ploughshares. Alternatively, the material can be cold worked as in the forming of thin walled bronze metal vessels, or in the repetitive hammering of a sword blade to produce a hard cutting edge. In the LPRIA and Roman period bronze, brass and lead could be cast either for utilitarian purposes, for example into lead pipes, or for artistic work, statues, figurines and lamps. The casting of iron and steel requires temperatures that were not normally attainable in the Roman period. The manufacture of pottery, tiles and bricks requires fairly simple tools, the most sophisticated equipment being the fast potter’s wheel and the kiln. For labouring type work, digging sand and gravel, digging ditches and foundations, efficient types of iron picks and iron reinforced spades and shovels would be needed. Agriculture has its own set of specialized tools, but since the primary focus of discussion is the technology of water borne transport, the agricultural tools are not considered in detail here. Other crafts required in building ships and boats and in making certain containers are leather working and spinning and weaving. In the Romano-Celtic world leather and woven fabrics were used for sails, and for sacks and other containers. After scraping and tanning the hides, leather working uses slickers (a form of scraper), knives, awls, punches and needles. For spinning spindles and whorls are needed, and for weaving looms are necessary. Tools for leather working and weaving are not discussed in detail here.

The iron edge tools for working timber and the stone mason’s chisels require the use of a higher level of technology in metallurgy. There are three possible means of making harder and more durable iron artefacts:

a. The use of high phosphorus ores to give a harder material.
b. Raising the carbon content to 0.3% or more makes hardening possible by heating and quenching. To prevent unacceptable brittleness, a tempering process would be needed after quenching.
c. Cold working by hammering the working edges produces a harder edge on an artefact. Cold working embrittles the metal and also needs to be followed by a tempering process

---

12 In any blacksmithing work involving hot metal, scale or slag is formed on the hot surface, and is displaced or knocked off as the piece is hammered into shape.

13 Very large bronze castings were used for warship rams, such as the Athlit ram, and the rams of the ships at the Battle of Actium. The Athlit ram when recovered weighed about 600 kg with accretions (Steffy 1983:230).
The iron edge tools for working timber and stone mason's chisels both require the use of steel for their working edges, but with rather different requirements. Efficient woodworking tools need to be able to be sharpened to a keen edge, and to retain that sharpness for a reasonable length of time before re-sharpening becomes necessary by grinding or honing. This requires a minimum carbon content in the metal of 0.3% if hardening is to be done by heating and quenching. In a study of 503 iron artefacts Ehrenreich found that very few of the articles he analysed had a carbon content of 0.3% or more, and those that did were principally woodworking chisels. Of the fifteen chisels in the collection, ten had a high carbon content, six from Hunsbury, and four from Danebury. Two of the chisels from Danebury were quenched and tempered, as was a wedge from Worthy Down. Ehrenreich concludes "....that an extremely restricted knowledge of high-carbon steel, quenching and tempering may have existed during the Iron Age" (Ehrenreich 1985:63). In edged woodworking tools for cutting, such as saws, planes and chisels, there is usually a lesser requirement for impact resistance, and this use permits a somewhat more brittle structure than for axes and adzes. For mason's chisels the requirement is toughness and resistance to impact damage, while still retaining the basic face shape for each type of chisel. By the LPRIA Ehrenreich believes that “....Iron Age blacksmiths were able to alter the properties of the tools they produced by selecting iron of different trace element impurities.” and that there existed “A broad distribution of blacksmiths each with his own secrets and specialities....” (Ehrenreich 1985:82-3). For edge tools the construction was sometimes composite, with the forge welding of a hardenable steel edge on to a low carbon body (Tylecote and Gilmour 1986:22-36, Tylecote 1986:174-5). Somewhere between 500 and 1,000 edge tools from Roman Britain have been examined. For example, the bulk of a mason’s chisel from Vindolanda was found to have a body of low carbon iron, but with edge hardened by both quenching and cold working. In general Tylecote’s conclusion is that “....quench hardening was not widely practised. But occasionally, as at Wanborough, a better technique prevailed....here many tools were made by the local smith(s) who had an above average standard of workmanship.” (Tylecote 1986:172-3). In general it appears that by the LPRIA and the early Roman period reasonably effective iron tools were being produced, but that the quality might vary considerably from district to district, depending on the skill of the local smiths.

Toothed saws, which in the Roman period were used only for cutting wood and soft materials, were of two types, a short stiff saw blade with a handle, like a modern hand saw (Manning 1985: Plate 9, B21), and a frame or bow saw with a long narrow blade held in a wooden frame with arrangements for tensioning the blade, Figs. I.4.1.1. and I.4.1.2.14

Saws were also used for cutting thin slabs of marble and other decorative stones, but the type of saw used is uncertain. Small handsaws are also known from the Middle Bronze Age on both sides of the Channel. They were rectangular, with teeth on one edge only, sometimes filed, but never set. British and Irish examples are known from c.8th century. They were probably used only for fine work. Without set teeth they could not have been very efficient (O’Connor 1980:177).
Several pieces of blades of this type were found at the villa site at Gadebridge Park, but no complete blades (Manning 1974:162-3, Fig. 70). In small sizes the frame saw would be used by one man, but in a large size it was used by two men for ripping squared baulks or planks into smaller sizes and similar tasks. For this work the log or timber was placed on a platform, and the saw was worked by one man on the platform and one man underneath, Fig. I.4.1.2. The Roman carpenter’s saws had set teeth, that is with teeth bent alternately to one side and the other. This makes a cut wider than the saw blade and minimizes binding of the saw in the kerf (Liversidge 1976:156-9)

For drilling holes in timber the Romans used spoon bits and bits with triangular and diamond shaped points. The spoon bit has a hollow elongated spoon shaped point, sharpened on the edges of the bowl. Bits with points were sharpened on the flat edges. In general the examples that have survived have an elongated pyramidal top, probably fitted tightly into a corresponding hole in a hardwood cross-handle, which was used to turn the drill bit, Fig I.4.1.3. There is a substantial collection in the British Museum (Manning 1985:25-28, Plates 11 and 12). Most museums with a significant Roman ironwork collection have examples. In the museum at Chesters on Hadrian’s Wall there is what today is called a gimlet, with a short ‘corkscrew’ type point, followed by a slender spoon section (personal observation). Drill bits were important to the Romano-British shipwright: holes had to be drilled through frames and planks for placing wooden treenails and the several hundreds of iron nails, some over 0.7 m long, used to fasten the planking to the floors and frames (Marsden 1994:51).

4.2. The Archaeological Evidence

The archaeological evidence for tools in Roman Britain is excellent. A wide range of iron tools and fittings for all trades and crafts has been recovered in the last one hundred years. Nearly all excavations of any extent in towns and settlements produce a range of iron artefacts and tools, which are reported in the finds section of the excavation reports. The Catalogue of the Romano-British Iron Tools, Fittings and Weapons in the British Museum lists over 800 tools and fittings (excluding weapons) from over sixty sites (Manning 1985). The major museums with Roman collections, like the British Museum and Museum of Scotland have extensive collections. Many site and local museums have significant to modest collections.

4.3. The Literary Evidence

There are no significant literary descriptions of craftsmen’s tools and their uses. Pliny the Elder in the Natural History and Theophrastus in Enquiry into Plants describe the properties and uses of various woods, but have little useful to say on the range of tools and techniques. Pliny mentions “....cutting beams or timbers from which the axe strips the bark....” (Pliny HN. 16.184-92), and Theophrastus says “Poor iron tools can cut hard wood better, for in soft wood they lose their edge....” (Theophr. Hist. pl.5.5.1,6). Pliny makes one technical comment that Roman saws were set to avoid clogging the teeth with sawdust and jamming in the cut, “....and clogs saws when teeth are set without skill in an even line.
For this reason saw teeth are bent alternately in opposite directions to throw the sawdust." (Pliny HN 16. 227-8).

4.4. The Epigraphic Evidence

Twenty iron tools are listed in RIB II, Fasc. 3, 2428.1 to 2428.20. The maker’s name is inscribed on fourteen, the owner’s name on three, and both the makers and owners name on one. On two artefacts the inscription is incomplete. The tools include: one hammer; three carpenter’s chisels; two mattocks; one axe; eight knives; two stilli; two leather worker’s awls; and one quarry wedge. The most interesting point about this small collection is the predominance of the maker’s name. This corresponds with the common practice with fine pottery which carries the manufacturer’s stamp.

4.5. The Iconographic Evidence

There is no specific evidence from Britain for tools, but from elsewhere in the Roman Empire there are a number of tombstones, reliefs, wall paintings, and a glass bowl base with six carpentry scenes. These are useful in that they show complete tools, such as frame saws, which have not survived intact in the archaeological record, see Figs. 1.4.5.1a, b, and c (Casson 1994:34, Fig.28, D,Ambra 1998:79, Fig.48, Liversidge 1976:158, Fig.264).

4.6. Discussion and Conclusions

From the archaeological context a reasonably complete collection of tools for wood and metal working has been recovered. Because the basic design of most hand tools in the West has changed very little over the past 2,000 years, it is a reasonable assumption that the Roman craftsman could achieve much the same results as a twentieth century craftsman with the same tool. The Roman’s output would be significantly lower, because modern cutting and percussion tools with their much superior steels would need far less time expended on re-sharpening. Without some experimental archaeology it is difficult to say exactly how much lower Roman productivity might be, but from personal experience with both cheap and high quality modern cutting tools, such as saws, a poor tool can at least double the time to complete quite a modest cutting task. For a major project, such as cutting a 10 m long log into planks, the time taken would be multiplied several times. Human fatigue comes into the picture. Using inefficient cutting tools requires the expenditure of far more energy.

In summary, from the various sources of evidence there is a very clear picture of the tools available to the Roman craftsman, how they were used, and an estimate can be made of their effectiveness compared with their modern counter-parts.
Section 1.5: Procurement and Conversion of Timber

5.1. Introduction

In Roman Britain timber formed the main structural elements of the man-made components of the transportation system, boats and ships, land vehicles and bridges. Three stages are involved in providing timber of the desired lengths and cross-sections. The first is the selection and felling of suitable trees, and their transportation to the primary conversion site. The most useful trees would be found in forests with well developed underbrush up to 6 m high. This causes the timber tree to develop a bushy spread of branches and leaves at the top, leaving the lower part with a fairly even diameter and relatively free of knots. The primary conversion site might be where the tree was felled, if the end use was already known. Otherwise the trunk would be cleared of branches and moved to a storage area, a lumber yard. The trunk would be de-barked and could be split, either radially or tangentially into sizes suitable for beams, post or planks, or simply squared into a baulk either for direct use as a beam or post, or as a preliminary to tangential splitting or possibly sawing.

At the site of the final product, the shipwright’s yard, or the wharf or jetty site, further conversion would take place to produce the elements needed for the structure. For a wharf, warehouse or jetty, this secondary conversion could be minimal. Wooden structures of this type are made up predominantly of straight members. Trimming to length and fashioning joints might be the only action required. For the wagon builder more complex shapes are needed, the nave or hub, the spokes and felloes for the wheels, and probably specially selected pieces for the draught pole or shafts. The shipwright has the most complex problems in shaping timbers. Apart from very simple box-like or polygonal shaped river lighters, all boats and ships involve both simple and compound curves in their frames and skeleton, but particularly in their planking.

5.2. Technology of conversion
(See Appendix I for a more detailed discussion on conversion)

The three basic tools for the conversion and shaping of timber are the axe, the adze and the saw. There is substantial evidence for the axe and the adze from the Bronze Age onwards, both in the form of the tools themselves and in tool marks. By the LPRIA and Roman period efficient iron axes and adzes were freely available. They could be sharpened by the user with a whetstone on the job, and the craftsman using these tools would

---

15 See Appendix I, pages 3 and 4 for definitions of timber and wood.

16 Wagon building is mentioned here because in later sections the technique of letting a ship take the ground, and then unloading the cargo directly into carts or wagons is discussed. To some extent warehouses and wheeled vehicles are part of the shore-side technology of handling maritime cargoes.
undoubtedly pause periodically to touch up his cutting edge. With axe, adze, iron or wooden wedges and a wooden mallet, the craftsman could convert a felled tree trunk into anything from a single beam or post, to planks and battens. Finishing the surfaces could be done to a high standard by hewing with the axe followed by delicate finishing cuts with the adze.

The evidence for saws in Roman Britain is sparse. Frame saws were used throughout the Mediterranean for cutting logs into planks, but evidence for their use in Britain is slight. On a tombstone from Gaul, a plank or baulk of timber is shown laid across two high trestles with two men cutting it with a large frame saw, Fig. 1.4.1.2. There are technical problems in making an efficient saw. For smooth and easy cutting:

a. The teeth must all be of the same height - if one tooth is higher it does most of the cutting and quickly becomes blunt.

b. For efficient and easy cutting the teeth must be ‘set’, that is bent alternately sideways so that the cut is wider than the saw blade. A saw without set is very difficult to use and jams in the cut. The teeth must be set evenly, so that on both sides of the saw all the teeth project to the same extent. If one projects more than the others, as in a. above, it does most of the work and rapidly becomes blunt.

c. Sharpening a saw requires a file, which the Romans had (Manning 1985:11, Plate 6).

d. Short stiff handsaws and small frame or bow saws to cut across the grain existed in Roman Britain, and would be within the technical competence of a good blacksmith, although forming the teeth would be time consuming compared with forging an axe or adze. The examples recovered from archaeological sites have relatively small teeth, about 3 per cm, which is in the same range as modern carpenter’s saws. One in the British Museum is 18.9 cm long (Manning 1985:19-21, Plate 9). It cut on the pull or back stroke as do most early saws, and many modern ones in some cultures. Cutting on the push or downward stroke is considered more efficient because the gravity and the weight of the saw hold it in contact with the cutting face, but it is easy to buckle the saw blade if the blade is not sharp, or if the wood is wet or sticky with resin. With modern saws the risk is acceptable because the steel is sufficiently springy to recover, but with a hand forged wrought iron blade which lacks temper and springiness the buckling would be permanent. Other Roman saw fragments have been recovered. For example, three small handsaws and five pieces from probable bow saw blades were recovered from excavations at the Roman villa at Gadebridge Park (Neal 1974:162-3, Fig. 70). Three pieces of bow saw blades were among the iron artefacts from Longthorpe. One had 3.2 teeth/cm and a second 2.4 teeth/cm. Both

---

17 The relief carving is not very sophisticated, and the depiction of the saw could be taken as a pit saw, but there is no evidence for the use of pit saws in Europe before the eighteenth century (Walker 1996:16)

18 Roman saws were set “…and clogs saws when teeth are set without skill in an even line. For this reason saw teeth are bent alternately in opposite directions to throw the sawdust.” (Pliny HN 16. 227-8)

19 Modern hand saws in Japan cut on the pull stroke.
these pieces had set teeth. The third fragment had 2.4 unset teeth/cm (Frere and St. Joseph 1974:78, Fig.42). There is no firm evidence for the use of frame saws to cut logs into long planks, at least in the earlier part of the Roman occupation. Pit saws for use with a saw pit do not appear to have been used in antiquity. For more details on working timber, see Appendix I.

Section 1.6: Metal work for Transportation Systems

6.1. Introduction

Iron in varying quantities was used in Roman Britain for constructing most of the elements of a transportation system, land vehicles, ships and boats, and the infrastructure of bridges, wharves and jetties. Ships and boats used varying quantities of iron nails, the quantity depending on the method of construction. For example the St Peter Port ship built in the Romano-Celtic tradition used 2.28 tonnes of iron nails to fasten the 24 to 35 tonnes of oak timbers and planking together (Rule and Monaghan 1993:6).²⁰ The Blackfriars and New Guy’s House vessels from London also made extensive use of iron nails in their construction. The Blackfriars Ship 1 used about 0.622 tonnes of iron nails (Marsden 1994:98). The hull planking of the County Hall ship from London was fastened with mortise and tenon joints along the edges of the planks, and floors and frames were fastened to the planking with wooden treenails. The number of iron fastenings in the hull was much fewer than in the vessels noted above (Marsden 1994:117-18). The Barland’s Farm boat from the Severn estuary was fastened in a similar manner to the Blackfriars ship (Nayling et al 1994:602-603). The few early quay installations that have survived, such as one in London, used lap joints in the roughly squared timber, varying in cross-section from 0.28 x 0.45 m to 0.46 x 0.63 m (Milne 1985:62). Later quays from the Custom House and St Magnus House sites in London used dovetail joints (Milne 1985:62-5). None required iron fastenings. Roman timber jetties built out into the river at right-angles to the bank would have used techniques similar to those for bridges. Structurally a jetty of this sort is a bridge that only goes part way across the river. Five possible jetties have been reported in Britannia (see Section 7.4.1 for details). The iron components would be nails in some quantity, and probably iron shoes for piles or vertical supports driven into the river bed.

Bronze does not seem to have been used very extensively in the transportation system. Certain elements of the animal harnessing arrangements, and some decorative elements for high status light vehicles for carrying people were made of bronze (Tarr 1969:143-45). Piggott, commenting on nave-bands and linchpins in Britain notes that both iron and bronze types from the Late Iron Age , “....continue into and beyond the period of the Roman occupation,” (Piggott 1983:223). From the St. Peter Port wreck two bronze bearings which may have been part of a bilge pump were recovered (Rule and Monaghan

²⁰Rule and Monaghan comment: “The above estimates are by necessity speculative and are based purely on pencil-and-paper extrapolations of the surviving structure.” Their estimates are certainly of the right order of magnitude. They used the surviving nails and the number of nails used in the surviving planks as the basis for calculating the number of nails and their weight for the entire ship.
By the second century AD, with the development of a major iron industry in the Weald, iron would be relatively cheap, and would be favoured for utilitarian purposes. Wrought iron only rusts at a very slow rate, far more slowly than steel, and the iron fastenings and fittings used on both land and water transportation could outlast the structures in which they were used.

### 6.2 Discussion and Conclusions

In general, it seems that iron was needed in the water-borne transportation system for boats and ships, and for some parts of the maritime infrastructure. Depending on the type of artefact, the quantity could vary from quite small for a small boat, to two tonnes or more for a large ship. There were probably more small boats than large ships, based on the premise that many goods would have been moved exclusively on rivers in simple lighters or barges, and that for every ship load of goods more than one small vessel would be used to distribute the cargo throughout the inland river system. Based on the evidence from London, it seems that substantial quays and wharves used very little iron in their structure, but some ancillary structures such as warehouses would need a considerable quantity of nails. Jetties might need iron for pile shoes, and probably used nails to fix the decking and subsidiary members. Jetty superstructures may have used carpenter joints rather than nails to secure the main structural members together, possibly supplemented with wooden pegs or treenails.

### Section 1.7: Discussion and Conclusions

In this introductory section, a number of factors affecting successful water-borne transportation systems, or in fact any transportation system, have been introduced. The materials to be transported, their properties in terms of density and relative fragility or robustness, the amount to be moved, and the required frequency and regularity for movements, all impose constraints on the system. The sources and destinations of the cargoes or part-cargoes, together with the navigational and meteorological hazards in the area, largely determine the likely routes that shipping will take. To ensure that the cargo arrives safely and in an undamaged condition, the proper and economical use of sturdy shipping containers is essential for the more fragile goods. In addition, the cargo, whether cased or loose, needs to be properly secured with dunnage to prevent it from moving in a seaway. A shifting cargo can both damage the more fragile materials, and impair the stability of the ship, possibly leading to its loss.

A successful transportation system in Roman Britain depended on the ability to build the structures needed, boats and ships for movement by water, wagons and carts for movement by land, using the materials and technology available. As well as the mobile parts of the system, static ancillary structures were needed, wharves and warehouses for ships, roads and bridges for land transport. The materials available and used were principally timber and iron, with some limited use of bronze and other non-ferrous metals. To form, shape and assemble both timber and metals, efficient tools were required.
tools that were available placed limitations on the ways in which material could be worked, and on the productivity of the craftsman. The concise overview presented in this introductory section on tools, timber and ironwork serves as a background to the hypotheses and arguments in the following sections of the thesis. More detail is provided in Appendices D and I.

In reconstructing the past there are two possible approaches, which vary according to the archaeological data available. If there is a huge amount of data, as is often the case with pottery, that most durable of artefacts, it is possible to sort and classify the material. By using this classified data, and combining it with stratigraphical evidence, and evidence for location, one may recognize a pattern that establishes which artefacts were the earlier and which the later. Shifting patterns of trade and exchange over time can be deduced, stylistic changes in shape and function can be followed. Where the data are scanty and incomplete, an alternative approach is to develop one or more hypotheses on what the sequence of events or developments might have been. The data can then be examined to see how fragments of data may fit the hypotheses. The hypotheses can then be adjusted until a best fit is obtained with the available evidence. The end result is a possible scenario for a reconstruction of the past, not necessarily the one that ultimately proves to be the correct or optimum one, but one that fits the data available at a particular point in time. As more information comes to light with further archaeological, epigraphic, iconographic or literary evidence, the hypothesis can be re-worked for a best fit with both the old and the new material. This is the situation that arises when one examines the technology and economics of the transportation system in Roman Britain. We have probably considerably less than one percent of the whole picture, and from this the possible reconstruction has to be assembled.

Unfortunately the ancient literary evidence which tends to describe operations largely from a managerial point of view, rarely pays much attention to specific details of ship construction. Caesar’s remarks about the ships to be built in preparation for his second invasion of Britain illustrates the difficulty well (Caes. B Gall. V.1.2). There he merely summarizes the character of their design in the most general terms, specifying rather the function that they had to serve and the marine circumstances that dictated the shape he required for the vessels. This failure to supply more detailed information excludes any possibility of reconstructing the physical appearance of his troop transports with any certainty. Nor does any other form of evidence, archaeological, epigraphic or iconographic survive to clarify their design. We must therefore resort to conjecture based on the known appearance of ships in use in the Roman world at the time. These suggest two alternative reconstructions. One rests on the assumption that legionary carpenters were in charge of the construction of the vessels. Given that their experience of ship construction would have been acquired in the Mediterranean, they would probably have adopted the well documented shell first technique, with edge-joined planks held together with mortises and wood-pegged tenons. The second alternative is suggested by Caesar’s interest in the sturdy vessels of the Veneti that seem to have been well suited to the conditions of tide and coastline that Caesar himself confronted in his invasion of Britain (Caes. B Gall. III.13). This assumes that because the ships were built on the Channel coast of Gaul with locally available timber, local Gaulish shipwrights were enrolled to do much of the work, and that
the transports were constructed in the Gallic style with iron-nailed heavy oak timbers.

Because the archaeological and iconographic evidence for maritime transport is so sparse, and the literary and epigraphic evidence is even more limited, my approach has been to construct hypotheses, and then test them against the limited data available. For the most important component of maritime transport, viz. water-borne vessels, there is limited evidence, the wrecks of five Romano-British ships or boats. Three are from the Thames at London, the New Guy's House Boat, the Blackfriars Ship I and the County Hall Ship. One is from the West Country, the Barland's Farm Boat from the Severn estuary. The fifth is on the fringes of Roman Britain, a Gallo-Roman wreck from Guernsey in the Channel Islands, the St. Peter Port Ship. Although wrecked in the Channel Islands, the St. Peter Port vessel could be of either Gaulish or British origin. From the evidence of artefacts found with it, it certainly traded on both sides of the Channel. Another component of maritime transport is the harbour. The only substantial remains to date are of the wharves and warehouses on the banks of the Thames in central London. A third component of a transportation system is the containers for the goods transported, but they are rare in the archaeological record, largely because of their perishable nature, except for the amphorae. There is concrete evidence for barrels and transport amphorae. For other containers, sacks, boxes, baskets and bales, the evidence is mostly indirect. Lead seals, which can reasonably be assumed to have sealed sacks and perhaps boxes, have been found in some quantity.

Iconographic evidence on both land and water-borne transport, in the form of relief sculpture from Gaul and Germania Inferior, has been utilized to fill out gaps in this type of evidence from Britain. Mosaics and wall paintings from Britain provide no useful evidence for maritime transport. With a few exceptions noted in later sections, coins and minor artefacts such as lamps supply little useful iconographic evidence for ships. The size of the depictions is so small compared with the quite numerous ones from relief sculpture and mosaics that the latter are more informative.

The indigenous iron tools of the LPRIA, supplemented by a few Roman innovations, such as the plane, possibly the large frame saw, and stone mason's tools, were adequate for the range of tasks required in building the infrastructure and vehicles needed for both land and water-borne transport. In fact there was little change in the tools used in Britain for most crafts for the next one thousand years, except for some improvement in the quality of the iron. In many instances, evidence from banausic occupations in the medieval period may reasonably be utilized to supplement gaps in the evidence from the Romano-British period. The technology in the fabrication of timber structures of all sorts was little changed over the same time period, except possibly for a greater use of carpentered joints and treenails in wooden buildings. The production of iron blooms and the manufacture of iron artefacts also changed very little until well into the second millennium AD.

In summary, the procedure adopted here is to construct a hypothesis, test and adjust it to fit the scant evidence from the Romano-British period, and, where justified and useful

---

21 In Bailey's *Catalogue of Lamps in the British Museum* there is one with a depiction of a Mediterranean type ship on a lamp from Italy (Bailey 1980:46, Fig.49). There is a lamp in the form of a Nile river boat, said to have been dredged up from Dover Harbour in Britain in the Royal Ontario Museum (Hayes 1980:103, plate 63 no. 410).
to draw on sources from Roman Gaul and Germany. In addition, some use has been made of early medieval sources and records where there is information on technological or economic matters which would apply equally to Roman Britain. This introductory section has been aimed at identifying and exploring various factors, materials to be transported, containers and packaging, tools, timber and ironwork, which affect the technology and the costs of building and operating a water-borne transportation for Roman Britain.
SECTION II: THE TECHNOLOGY OF WATER TRANSPORT
SECTION II: WATER TRANSPORT

Section II.1: Introduction

In this section a number of basic constraints and factors affecting the technology of ship construction and the design of wooden sailing and oar propelled ships and boats for use on the Atlantic and North Sea coasts of North-West Europe will be discussed. The natural constraints, the tides, the winds and the geographical formation of the coast lines and inland river systems were unalterable. The design and technology of ships in North-West Europe had to provide vessels able to cope with and survive these natural conditions. The influence of pre-Roman Iron Age experience with water-borne transportation systems, both in Britain and on the continental shores that faced the south and east coasts, are reviewed for their influence on the Romano-British shipbuilding tradition. Even before the conquest of Britain in A.D. 43 by Claudius, the Romans had been engaged in a number of maritime conflicts with peoples of the North Sea coast, the Chauci, the Frisians and others. After the conquest there were continued intermittent outbreaks of piracy from these coastal peoples. By the late third and fourth centuries the Franks and Saxons had become the principal raiders, and by the fifth century were beginning the permanent occupation of Britain and Gaul (Haywood 1999). Caesar in Gaul had encountered the ships of the Veneti, and commented on their superiority over Roman vessels for operation in Atlantic waters (Caes. B Gall. III.13). It will be argued that the Romano-British ship building tradition utilized many of the concepts already developed by the Iron Age peoples of North-Western Europe, and to some extent those of their predecessors in the Bronze Age.

After a general discussion of the hull forms and their construction, and the modes of propulsion available in the early first millenium AD, a detailed analysis is made of the five significant Romano-British vessels from the archaeological record.

Section II.2: The Technology

1. Introduction, Theory and Hypotheses on Hull Form and Construction

The basic piece of technological equipment for transport by water is some material or structure, the net specific gravity of which is considerably less than that of water. This result can be achieved by various means, with timber rafts made from the lighter woods, reeds, bamboos or similar materials, by inflated animal skins, by pots lashed to a framework, or by the planked hull (De Graeve 1981, Greenhill 1995, Hornell 1970). By the Iron Age and Roman period in Britain the normal technological devices for water transport were a planked boat of some sort, or in some cases for relatively light loads, a dugout or a skin covering over a light framework, the Welsh coracle or Irish curragh. Different types of ships or boats would be needed for different situations and different types of cargo. Hypothetically three broad classes of boat would be needed, but with overlaps between the types.
a. Inland Waters

For slow flowing inland rivers or sheltered tidal inlets with minimum wave formation structurally simple undecked open craft with a rectangular cross-section and rudimentary bow and stern forms would be adequate, Fig. II.2.1.1. The structure would need to be strong enough to support the loads carried and to take the ground without damage. With no, or minimal wave motion, in these sheltered areas it would not be subjected to significant hogging or sagging stresses.\(^1\) A full deck would not be needed as the possibility of swamping from waves would also be slight, and the freeboard would also not normally be of great concern. The rectangular cross-section is an inherently stable one. On the numerous slow flowing and relatively shallow rivers in the lowland parts of Britain, an accidental swamping for cargoes such as quarried stone, coarse pottery, bricks or tiles would be a nuisance but not a major loss, as salvage and refloating could generally be accomplished by the crew. Propulsion could be achieved by towing from the bank with human or animal muscle power, by poling or puntng, by paddling or rowing, by using the current if favourable, or in some cases with a simple sail, Figs. II.2.1.2a and b, II.2.1.3, II.2.1.4.\(^2\) In inland voyages a combination of propulsive methods could be adopted to suit local conditions as the voyage progressed.

b. Coastal Voyages

For short voyages in estuaries, or along the coast between sheltered havens or anchorages, boats could be open, partly decked or fully decked, but would have to be of sturdier hull construction to withstand the hogging and sagging stresses imposed by wave motion. They would also need a higher working freeboard to prevent swamping in rough seas or broken water. The question of the extent of the decking required in Iron Age/Roman load carrying coastal craft is an interesting one. For many centuries small undecked or partly decked fishing vessels have operated around the coasts of Britain in wind and sea conditions up to about Force 5 (20 knot wind speed) without incurring unacceptable losses. When losses have occurred it was frequently due to boats returning with a heavy catch, which reduced the freeboard, and in deteriorating weather conditions with large waves building up. In early historical times open boats have also successfully made long ocean voyages, some notable ones include the legendary voyage of St. Brendan to Greenland, and possibly beyond, in the sixth century AD, described in *Navigatio Sancti Brendani Abbatis* (Severin 1978), and more certainly those of Scandinavians to the Faroe

---

\(^1\) Hogging occurs when the centre of a boat is supported by the water, but the ends are not. Sagging occurs when the ends are supported but the centre section is only partly immersed or even clear of the water. The degree of hogging or sagging is related to wave spacing and height, the length of the vessel in relation to the crest to crest spacing of the waves, and the longitudinal strength of the vessel's structure.

\(^2\) From a tomb plaque of Hadrianic date from the Isola Sacra, Casson notes that barges were towed up the Tiber from Portus to Rome. The journey could take three days (Casson 1965:31-39, 1994:131-33).
Islands, Iceland, Greenland and North America.\textsuperscript{3} In more recent times Captain Bligh of the \textit{Bounty}, and Captain Foster of the steamship \textit{Trevessa} (Foster 1924), made voyages of thousands of miles across open ocean in open ships' boats. The open boat voyages have been made in inherently buoyant vessels, not generally heavily loaded, and with crews large enough to bail as needed in bad weather. Surviving at sea in undocked boats requires an ability to prevent water from spray and breaking wave tops filling the boat, and on the crew's ability to bail as needed. The crew has to have the ability to withstand hypothermia and exhaustion.\textsuperscript{4} If the voyage is prolonged, they also need to have sufficient food and water. The situation of an open boat off the British coast loaded with quarried stone, and with a minimum crew would be less favourable. A reasonable conclusion would seem to be that for Roman period craft engaged in coastal voyages with heavy cargoes, a decked or partly decked vessel would be desirable, but not necessarily essential, depending partly on the area in which it operated, the season of the year, and the availability of safe havens at frequent intervals along its route. Propulsion would be primarily by sail, augmented by favourable tidal currents and limited rowing for manoeuvring in and out of anchorages. Sustained rowing in open water would not generally be practicable with the likely small crew size.

c. Extended Coastal Voyages and Open Sea Voyages to Gaul and Germania Inferior

For regular voyages, which could be of some days' duration on these routes, a strongly built and thoroughly seaworthy vessel of sophisticated design and construction would be most desirable. On voyages lasting for a number of days, weather conditions could change dramatically from calm to gale. The crew would have to be large enough to provide at least two watches and have at least basic competence in nautical skills such as steering a sailing vessel, handling repairs to sails and rigging, and the safe storage of cargo. For the sustenance of the crew, food and water would be essential, and cooking facilities would be needed, or at least highly desirable. This suggests a minimum crew of three for a small vessel. More would be needed if sail areas were large. With modern rigs one man cannot handle more than about 45 m\textsuperscript{2} of canvas (Hiscock 1950:70-1), without the aid of special rigs, such as the Thames barge spritsail, batten sails or sophisticated furling systems. The sail area of the Blackfriars Ship I, described in Section II.6.8 below, has been estimated to be about 64 m\textsuperscript{2}. With a three man crew, the skipper would steer, and the other two crew members could handle the sail.

\textsuperscript{3} Using ancient writings about the boat of St. Brendan, Severin built a replica, a light wooden framework covered with oxhides, and with four companions sailed it to Newfoundland via the Faroes, Iceland and Greenland in the 1970s.

\textsuperscript{4} Among experienced small boat sailors, the accepted wisdom is that the crew fails long before the boat!
Section II.3: Theory and Hypotheses on Propulsion Systems and Methods

Possible propulsion methods fall into two broad categories, those involving muscle power, human or animal, and those using the natural forces of wind, and of tidal and hydraulic currents.

3.1. Use of Muscle Power

Of the two sources of muscle power the human is the more versatile, but the unit, one man, produces less force than the animal unit, one horse, mule or ox. Men can use paddles, row, pole or punt and tow; animal power can only be used for towing. On inland and sheltered waters man can employ the most convenient and energy efficient of the four possibilities. In coastal and offshore navigation only paddles or oars are possible. For larger vessels with a high freeboard, rowing is the only practicable form of muscle powered propulsion. Effective paddling requires the paddler to be close to the water, and this limits the vessel's freeboard. A further point is that where the vessel's form allows it, rowing is a more efficient use of human muscle power than paddling. More of the body's muscles are involved (Giesecke 1983:136-141).

For towing, the form of muscle power that can use either men or animals, the availability and relative cost of the power source may be the deciding factor. For towing with one or more animals, two humans are also required, one to drive the animals and one to steer the vessel. This was the usual configuration on canals and rivers in Europe in the nineteenth century. In other circumstances large numbers of men were used rather than animals. An example is the towing of junks up the Yangtze Gorges, using teams of over one hundred men (Worcester 1959:141-45).

3.2. Use of Natural Forces

Two natural forces are available, both on inland waters and at sea, wind and tidal or hydraulic currents. Using sails the wind can supply energy to move vessels, and if strong enough the power provided by the wind greatly exceeded any other source of power available for ship propulsion until the introduction of efficient steam engines in the later nineteenth century. Good winds made for fast voyages, a significant economic consideration. To maximize the profit of the ship owner, two factors are important. Quick voyages increase the number of voyages possible in the sailing season, and turnaround time in port needs to be minimized. The wind is a less useful form of energy in constricted inland waters. Sailing in narrow channels requires a simple and easily handled rig, and is

---

5 For definitions of the technical terms, force, energy, work and power see Appendix A.

6 Hydraulic currents occur when water flows from a higher to a lower level, as in a river. In tidal estuaries the hydraulic current will resist the flood tide current and augment the ebb tide current.
really only practicable with the sailing technology of the period in long straight stretches with a wind from aft to about abeam. A simple square or lug sail could be useful in limited and favourable conditions. The advantages of sailing over rowing, paddling or punting for a loaded cargo carrying boat are so significant that in areas where water and wind conditions made it possible, it seems probable that a sail would have been carried even if just for occasional use.

Tidal currents around Britain tend to run roughly parallel to the coast and vary from 1 to 2 knots in the more open areas, to 3 to 5 knots or more in confined areas such as the Bristol Channel, behind the Isle of Wight and around the Channel Islands. At the entrance to confined estuaries such as those of the Tyne and Humber, the river currents and coastal currents meet at about a right angle and cause turbulent and dangerous conditions for small craft except at slack water. The rivers with tidal flows such as the Thames, the smaller east and south coast rivers, and the Humber and the Tyne have strong tidal flows and stronger ebbs\(^7\). All the tidal flows reverse direction about every six hours, but by using the favourable currents and anchoring when the current is foul, significant progress can be made even when there is a dearth of favourable winds. Effective use of the tidal currents before the days of tide tables depended on local knowledge and experience. For the coastal peoples of north-west Europe this knowledge would be common and traditional, but for people coming from the almost tideless Mediterranean, it would be a new experience, requiring new learning and practical background, or the use of local native pilots.

On inland rivers with no tidal effects, the current is a unidirectional hydraulic current downstream, and can be used for travel in one direction only, but for that direction may provide a significant part of the energy to move the vessel. Sometimes nature or human ingenuity solves the problem of upstream travel. In Egypt the navigation of the Nile is facilitated by nature in both directions. The river current takes vessels downstream to the north, while a prevailing wind from the north enables them to sail back up against the current (Vinson 1994:7). On the Danube above Vienna, farmers from the Wachau, about 80 km upstream from the city, in the early twentieth century built crude boats, filled them with vegetables, floated them down the river overnight, sold the vegetables in the market, sold the boat for firewood and walked back to the Wachau.\(^8\) Herodotus describes a similar practice on the Euphrates. Vessels were built in Armenia with a light framework of withies covered with skins, loaded with wine in casks and a live ass, and then floated down to Babylon. The cargo was sold, the framework broken up and sold, the skin covering was loaded on the ass, and the boatmen returned to Armenia with the skins (Herodotus 1.194).

---

\(^7\) On the Humber the outgoing stream is stronger, 2 3/4 knots, and of longer duration than the ingoing stream at 1 3/4 knots. On the Tyne the outgoing stream runs at 2½ knots and the incoming one at 2¼ (Watts 1965:486-7, 494-5).

\(^8\) Personal communication, from Herr Josef Brunner, an elderly Wachau farmer and river boatman, who had done this in his youth. I met him on a number of evening in the local Heurigen (wine cellar), while staying at Krems an der Donau in the Wachau for a few weeks in 1972.
Section II.4: Bronze and Iron Age Predecessors and Frisian and Saxon Successors

4.1. The Early Vessels and Voyagers: Mesolithic to the Late Bronze Age

In considering water transport in Roman Britain notice should be taken of both pre-Roman and post-Roman practice in boat construction and operation. From the Mesolithic, Neolithic, and Bronze Ages through to the LPRIA there existed a long tradition of the building and operation of simple dugouts and skin boats with a light framework covered with sewn animal hides. Several dugouts from the Mesolithic have been found in Denmark. They are relatively long and slender, with lengths in the range 6.2 to 9.5 m and with a beam of 0.5 to 0.65 m. It is estimated that the larger could carry six to eight persons plus their equipment. They have been dated to the period c. 5200 to 4100 BC, in the Ertebolle culture (Andersen 1994:1-10). Dugout canoes were probably in use in Britain and northern Europe from the Mesolithic period onwards (Clark 1952:282-7), and were employed throughout the Bronze and Iron Ages. They could be up to several metres long, but were suitable only for inland or sheltered areas of water. Skin boats are depicted on numerous rock carvings in Scandinavia. A replica was built at Frederikstadt in Norway under the direction of Professor Sverre Marstrand. It is 7.6 m long, can be easily carried by six people, and can carry a load of about 0.75 tonnes plus the six paddlers. Speed is about 2.5 knots. The replica was built by one man in a month using eighteen freshly felled saplings and eight cow hides. Tools were an axe, a knife and a needle. The frame was lashed with rawhide strips, supplemented by some wooden pegs (Johnstone 1974:81-6). Bowen has suggested that the early Neolithic settlement of the British Isles from the Continent was made by using skin boats of the curragh type (Bowen 1972:36-40). This movement took place in the fourth to third millenium BC. Bowen has argued for extensive sea travel from the coast of France, from the Loire estuary round to the Cherbourg peninsula, to Ireland, western England and Scotland from early Neolithic times. The travellers would have used skin boats similar to the seagoing curraghs of western Ireland still in use recently (Greenhill 1995:91). With a following wind Bowen has estimated that the twentieth century Irish curragh could make good ninety miles in a day (Bowen 1972:36-7). This would give a crossing time from the Brittany peninsula to Cornwall of a little less than twenty-four hours. In good weather in summer this journey in an open boat would hardly expose the occupants to hypothermia or starvation; all the other parts of the voyage could be done along the coastline. A first century BC gold boat model from Broighter, Co. Derry, Ireland, depicts a curragh with oars and a mast and yard (Johnstone 1988:128, Fig.10.9). Admittedly this is close to two millenia after the Neolithic voyagers at the latest, but curraghs have changed only minimally in the last 2,000 years. Muckelroy, basing his analysis on two Bronze Age wrecks, one from Langdon Bay near Dover, and one from Moor Sand near Salcombe, Devon, has proposed a regular trade between southern England and the Continent in the

1 Logboats continued in use in Britain until at least the fourteenth century AD. The Giggleswick Tarn logboat has been dated to c. AD 1335 (McGrail 1998:58).
Middle Bronze Age, c.1200 BC (Muckelroy 1981:275). To judge from the Langdon Bay cargo, the types of bronze artefacts found, probably originated in the area of the lower Seine and were heading for the Dover area, or possibly the Thames. For the Moor Sand cargo with material from farther west, two routes are possible, a coasting voyage from the Seine to Brittany, then sailing across to Start Point in Devon, or a coasting voyage from Brittany to the Seine area, thence across the Channel and finally a coasting voyage along the south coast of England. Muckelroy is of the opinion that the ships involved could have been British, on the basis that the Britons needed the bronze and sought it out, rather than bronze being an export by traders from France (Muckelroy 1981:288-97). A recent find of a well preserved, probably seagoing Bronze Age boat from Dover, dated to about 1550 BC, of sewn oak plank construction, and capable of crossing the Channel on a fine day, lends weight to Muckelroy’s theory (Owen and Frost 1999:17). Muckelroy interprets the material as indicating a relatively long distance trade in scrap bronze objects from France, “....operated by specialist carriers of some kind.” (Muckelroy 1981:288-91). He proposes five possible zones for seaborne contact between Britain and Europe in the Middle Bronze Age: the open North Sea; the southern North Sea (from East Anglia to the Dutch coast); the Strait of Dover; the English Channel from Start Point to Guernsey; and the western approaches to the Channel. The first and last he rejects on the basis of the long distances and the possibilities of bad weather. The remaining three zones have different problems, but appear to be about equal in navigational hazards and risks (Muckelroy 1981:279-81).

Following the early dugouts and skin boats, sewn planked boats of increasing sophistication for both inland waterways, estuaries and possibly coastal seagoing trade were developed. The dugout was developed by the addition of a side plank or planks to increase the freeboard. The beam was increased by splitting the original log and inserting planks in the bottom. Examples from the Bronze Age in Britain include the Ferriby boats, dated to c. 1300 BC (Wright 1990), the Brigg Raft, dated to c. 800 BC (McGrail (ed.) 1981), a wreck from the Severn at Caldicot, Gwent, dated to c. 850 BC and associated with a hard (Parry and McGrail 1994), and the Dover boat dated to about 1500 BC (Parfitt and Fenwick 1993). All these vessels had sewn planking.

4.2. The Iron Age Vessels and Voyagers

For the later first millennium BC McGrail has examined three problem areas:
(i) What sort of boats were used?
(ii) How were the boats handled (seamanship)?
(iii) How did seamen find their way (navigation)? (McGrail 1983:291)

For the type of boat he suggests a planked open boat “....some 7 to 12 m in length propelled

2 Only the bronze items in the ships’ cargoes survived. They were predominantly broken and scrap bronze objects from France. It is likely that other materials were included in the cargoes. There is no evidence whatsoever for the type of vessel used.

3 For definition of a hard, see page 3, Fn 3.
by a single square sail, with a few oars or sweeps for use inshore, in calms, and in foul
winds and streams.” (McGrail:300). The hull shape would be full-bodied with a flattish
bottom, beamy and with a high freeboard. He estimates that a vessel with this specification
could safely make voyages across the Channel in winds up to Force 5 (20 knots). A skin
boat with its better seakeeping qualities could probably handle winds up to Force 6. The
average speed made good towards the destination would be about 2½ knots, or about sixty
miles in twenty-four hours (McGrail:300). There is no direct archaeological evidence to
date for a vessel of this type in north-west Europe in the first millennium BC, but there is the
literary evidence from Caesar on the similar ships of the Veneti (Caes. B Gall. III.13).
Navigation would be largely by ‘pilotage’, the conducting of the vessel within sight of land,
using the natural features of the landscape and coastline for guidance, possibly
supplemented by soundings with a leadline. By ‘arming’ a hollow in the bottom of the lead
with tallow, samples of the composition of the bottom can be obtained, and can aid in
establishing the vessel’s position.4 Navigation, the art of directing a ship when out of sight
of land, would depend principally on the use of celestial bodies. Sailing successfully
around the Channel in the LPRIA would depend on extensive local knowledge, long
experience, a knowledge of the tidal system and streams, and careful observation of natural
phenomena such as clouds, wind directions, and sea state. As late as the early twentieth
century many small coasting sailing vessels operated round the coast of Britain with
nothing more than a simple compass, and the local knowledge of the skipper/owner.5
McGrail has compiled a list of nine routes that were probably in use, and the relative
difficulties and dangers of each route, see Fig. II.4.3.1 (McGrail 1983:308-334). The time
for which a vessel would be out of sight of land in cross-channel voyages in the western and
middle Channel could vary from 32 hours for the longer western passages to 18 hours for
the more central and eastern crossings (McGrail 1983:316,326).

By the LPRIA the Iron Age tribes in Britain had established fairly definite
territories. All had access to river systems and networks of varying magnitude and
usefulness (Fig. II.4.3.2a). Almost all had ready access to extensive coastlines (Map 4, Fig.
II.4.3.2). One would expect that the inhabitants would make use of the rivers, estuaries and
coastal zones for both their resources in fish and shellfish, and as a means of transport.
There is archaeological evidence for some modified logboats. From Hasholme in
Lincolnshire a logboat dated by dendrochronology to 322/277 BC has been excavated,
which is a transition from the simple log dugout vessel to a planked boat. The main hull is
a hollowed out log, with strakes fitted along the topsides forward to increase the freeboard
and an inserted separate transom and complex built up bow. Fastenings were wooden

---

4 Sounding leads are known from the Mediterranean (Oleson 2000:299-310), and similar devices could
have been used in Northern Europe, although none have been recovered to date from archaeological
contexts.

5 Personal communication from Alf Smy of Brightlingsea, Essex in 1949. Alf, then in his sixties had sailed
in barges around the south and east coasts of England since he was 14 years old.
treenails. The dimensions were 12.78 m long, 1.4 m wide and 1.25 m deep. With a five man crew it could carry between 3.5 to 8.5 tonnes of cargo, depending on the free board needed (Millett and McGrail 1987). A similar although somewhat smaller logboat has been recovered from Poole Harbour, and dated by dendrochronology to c.295 B.C., with dimensions 10.35 m long, 1.6 m wide and 0.6m deep. It could carry eighteen men, or four men and 1.448 tonnes of cargo (McGrail 1998:20-2). In the summer of 2001 an excavation at Fiskerton in the River Witham valley near Lincoln exposed two logboats, one of which with a vertical transom slotted into the hollowed trunk, is very similar to the Hasholme boat (Pitts 2001:327). A slightly smaller logboat with from Loch Lotus, dated to 200 BC to 200 AD, is on display in the Iron Age and Roman gallery in the Museum of Scotland (personal observation, 2001). From mainland Europe there is the Iron Age Hjortspring boat from Denmark dated to c. 350 BC, with predominantly sewn planking, but some use of treenails in fastening the stem and stern pieces to the bottom. The boat was about 19 m long, 1.9 m wide and the depth about 0.7 m. It is the earliest known vessel with overlapping or clinker laid planking (Rieck 1994:43-49). The carrying capacity is estimated to have been about 2.11 tonnes (McGrail 1998:200). In general there is rather a dearth of finds of LPRIA ships and boats from both Britain and north-west Europe. Some vessels with seagoing capabilities must have existed to carry on the known trade between Britain and the Continent.

4.3. The Artefact Evidence for Cross-Channel Trade

Tin was probably one of the earliest materials traded from Britain to the Continent. In the later Bronze Age there was a widespread distribution of similar bronze artefacts on both sides of the Channel, but as bronze was replaced by iron the cross-Channel contact diminished until about 118 BC when wine started moving into Britain (Cunliffe 1982:40-42). A trading axis developed from Alet in Brittany to Hengistbury Head in Dorset, and this axis continued in use until the Roman conquest of Armorica in 56 BC. Based on coin evidence from Britain, the Coriosolites seem to have been the principal traders. After 56 BC and Caesar’s two expeditions to Britain, the trading axis moved east involving the pro-Roman tribes of south-east Britain (Cunliffe 1982:45-52).

By the LPRIA there is substantial archaeological evidence in the form of pottery, coins, amphorae of wine and metalwork for trade between the European mainland and Britain. By the LPRIA in Britain at a number of sites in southern and eastern Britain, for example, Camulodunum, Skeleton Green, Wheathampstead, and Verulamium, which were

6 Veryan Heal writing on the tool marks on the Hasholme log boat makes several interesting comments: “Of the felling of the tree, no trace remains to indicate whether this was done by axe or by fire, the use of a saw is unlikely as no adequate saw is known from north western Europe at this period.”. Heal notes tool marks in the hollowing process from a blade about 60 mm wide, presumably an adze, from a gouge about 30 mm from tip to tip, and the use of a chisel and boring tools (Millett and McGrail 1987:135). McGrail has also commented that to date saw marks have not been found on Iron Age boats and their immediate successors (McGrail 1998:154).
all close to or on navigable waterways, imported pottery and wine amphorae, and some imported metal goods have been found. Such goods could only have come by sea, either in ships from the continent, or in British bottoms. Other earlier pre-Roman trading sites are known at Hengistbury Head, Dorset, as noted above, and at Mount Batten at Plymouth (Cunliffe 1987, 1988). With the extensive evidence for cultural contacts between Britain and the Continent in the LPRIA, demonstrated both in artefacts, burial practices (Aylesford-Swarling), and oppida type settlements, it would seem possible that a common tradition for seagoing vessels should exist on both sides of the Channel and in the southern North Sea.

4.4. The Literary Evidence

The earliest literary evidence for seaborne contacts between Britain and mainland Europe is Pytheas of Massalia’s *On the Ocean*, which has survived only in fragments, with adverse comments, in later authors such as Strabo and Pliny. The work is dated to about 310-306 BC (Hornblower and Spawforth 1996:1285). Pytheas’ descriptions seem to have been based on observed phenomena, rather than theory (Roseman 1994:1). His work, based on an extensive sea voyage, possibly lasting more than one sailing season, describes a voyage from Cadiz to the Loire, past Ushant to Cornwall, around western Britain, and as far north as the Faroes, Iceland and possibly Norway (Hawkes 1984). This voyage would have been made in a Mediterranean type of sailing merchant vessel, a sturdy sea-going ship of the period like the Kyrenia ship, dated to the later fourth century (Steffy 1985:75-101).

The literary evidence from Caesar and other ancient authors mentions refugee princes from Britain appealing to the Romans for help: Mandubracius came to Gaul to seek Caesar’s protection (Caes. B. Gall. V.20), and Adiminus joined Gaius Caligula in Gaul (Suet. Calig.44). From Caesar we have a detailed description of the ships of the Veneti in 55 BC:-

“Not so the ships of the Gauls, for they were built and equipped in the following fashion. Their keels were considerably more flat than those of our own ships, that they might more easily weather shoals and ebb-tide. Their prows were very lofty, and their sterns were similarly adapted to meet the force of wave and storms. The ships were made entirely of oak, to endure any violence and buffeting. The cross-pieces were beams a foot thick, fastened with iron nails as thick as a thumb. Their anchors were attached by iron chains instead of cables. Skins and pieces of leather finely finished were used instead of sails, either because the natives had no supply for them or because their houses and villages were by the seaside. The king’s own ship was particularly large, and seemed to require a hundred men to handle it. A chronicle of the sea voyage of Pytheas of Massalia through the northern seas (Hawkes 1984) also contains a description of the ships of the Veneti, which are typically Mediterranean merchant vessels built for persistent use on the open sea, with the keel flat to weather shoals and ebb-tide, with a high prow and stern, and with hulls made of oak, storehouses for food and provisions, cross-pieces for protection and ballast, and anchors for moorings at anchor (Steffy 1985:75). The chronicle also describes the navigational aids of buoys and the stars of the northern seas. Pytheas was an excellent observer, and the chronicle confirms that his descriptions were based on observed phenomena, rather than theory (Roseman 1994:1). One of the ships of the Veneti that Pytheas described was a Mediterranean merchant vessel, a sturdy sea-going ship of the period like the Kyrenia ship, dated to the late second century AD (Steffy 1985:75). The king’s own ship was particularly large, and it required a hundred men to handle it. The king’s ship was a Mediterranean merchant vessel, a sturdy sea-going ship of the period like the Kyrenia ship, dated to the late second century AD (Steffy 1985:75).
of flax and no knowledge of its use, or, more probably, because they thought that the mighty ocean storms and hurricanes could not be ridden out, nor the mighty burden of their ships conveniently controlled by means of sails. When our own fleet encountered these ships it proved its superiority only in speed and oarsmanship; in all other respects, having regard to the locality and force of the tempests, the others were more suitable and adaptable.” (Caes. B. Gall. III.13)

These vessels were obviously greatly superior to those of the Romans for the winds and tidal conditions of the English Channel. Their massive construction and ability to withstand storms would enable them to make safe passages across to Britain even in the prevailing strong westerly winds and gales. One hundred years later at the time of the Claudian invasion and conquest, AD 43, one might expect there to be a common, or at least a similar shipbuilding tradition, on both sides of the Channel in Gaul, Britain and possibly the Low Countries.

**4.5. Were There Significant Numbers of British Sea-Going Planked Ships?**

The evidence for British built and manned vessels trading with the Continent before the Roman conquest is indirect, and it is possible that the British tribes felt no need to develop a significant fleet of seagoing vessels. In the later second and first century the elite seem to have been busy internally establishing their petty kingdoms. The southern part of Iron Age Britain was self-sufficient in agricultural resources, and apparently produced a surplus which could be traded to the continent or the more northern parts of the country. The island also produced all the metal, timber and pottery it needed. Being an island, there was no need at that period for a frontier defence system, and no obvious ambitions to invade and conquer territory on the European mainland. The goods that were supplied from Gaul were luxury goods for the elite, amphorae of wine, some fine pottery, coinage and élite gifts and trinkets. Metalwork, although some was imported, "...must have been a rarity: it could have arrived by merchants trading, gifts from abroad, or by visitors or immigrants bringing their personal possessions.” (Stead 1984:43). Strabo, writing at the end of the first century B.C. describes very clearly the trade routes to Britain:

"There are only four passages which are habitually used in crossing from the mainland to the island, those which begin at the mouths of the rivers— the Rhenus, the Sequana, the Liger, and the Garumna. However, the people who put to sea from the regions that are near the Rhenus make the voyage, not from the mouths themselves, but from the coast of those Marini who have a common boundary with the Menapii.” (Strabo IV.5.2).⁹

"The passage to Britain from the rivers of Celtica is three hundred and twenty stadia; for if you put to sea on the ebb tide at nightfall, you land upon the island about the eighth hour on the following day."

(Strabo IV.3.4).

And in another passage:

---

⁹ Rhenus = Rhine, Sequana = Seine, Liger = Loire, Garumna = Garonne.
"...then goes by land as far as the Sequana River; and thence it begins its voyage down to the ocean, and to the Lexobii and Caleti; from these peoples it is less than a day’s run to Britain." (Strabo IV.1.14).

Strabo’s phrasing suggests that the movement of trade goods was initiated from the continental side of the Channel rather than the British coast. The return goods traded from Britain included grain, cattle, gold, silver, iron, hides, slaves and hunting dogs (Strabo IV.5.2), and in return the natives were provided with ivory chains and necklaces, amber gems, glass vessels and "other petty wares of that sort." (Strabo IV.5.3).

In summary, the pre-conquest trade between Britain and continental Europe was primarily luxury imports into Britain, paid for by the export of agricultural products, metal, slaves and dogs. The carrying trade could easily have been exclusively in the ships of the maritime tribes of Europe, from the mouth of the Garonne on the west coast of France, round the Brittany and Cherbourg peninsulas to the mouths of the Rhine. From Caesar’s comments the Veneti certainly had a very large fleet of seagoing merchant vessels. The Coriosolites of the St. Malo region were trading with Hengistbury Head in the first century BC. Langouët postulates that: "...a Coriosolitan navy survived after the events of 56 B.C., which involved the destruction of the Venetic navy.” (Langouët 1984:76).

4.6. Piracy in the Roman Period and Beyond

A century into the Roman period in Britain, seaborne raids by the Chauci and Frisians, and in the third and fourth centuries by the Franks and the Saxons had exposed the Romano-British to the boat and ship technology of areas outside the empire. Piracy around the coasts of Roman Britain and Gaul could have had two effects on Roman transportation systems and their technology. Firstly, the depredations of pirates, if on any significant scale, could divert traffic to safer land routes, or promote the convoying of military supply or merchant vessels by warships of the classis Britannica. Caesar’s invasion fleets for his British expeditions (Caes B Gall. IV.22.3, V.2,8) were accompanied by warships, but there is no evidence for convoys for routine cross-channel movements in times of peace. Convoying of merchant vessels was not usual. Secondly, if the pirate vessels were noticeably speedier or had better sea-keeping qualities than the Roman or Romano-British ships, there would be a strong inducement to copy their design. In the various maritime encounters between Roman and northern European fleets in the campaigns of Drusus the Elder and later Germanicus the Roman naval performance was not very successful (Starr: 1941:141-7).

In the first and second centuries AD piracy in the North Sea and Channel was the work of the Chauci, a Germanic tribe from the area of the rivers Elbe and Weser, who had expanded their territory to the river Ems by about AD 100. The Frisians from north Holland appear to have participated in the piratical activities of the Chauci. The objective of the pirate raids would be easily portable and valuable loot. Their main target would be wealthy and ill defended sites on land, or ships with high value cargoes. Except for the value of the vessel, capturing a vessel loaded with quarry-run building stone or coarse pottery would be frustrating and unprofitable. The Chaucian society in the second century AD became more hierarchical, and this coincides with the most intense period of their
marauding. The new elite wanted Roman luxuries, but with no land frontier with Roman territory, raiding by sea was the obvious option (Haywood 1999:19-23). The Chauci attacked the coastal area of Belgica in AD 41 and again in AD 47 (Cass. Dio. LX. 8.7, Tac. Ann. XI. 18-19). Later in the second century Chaucian piracy continued, leading to a state of insecurity in the coastal areas of Belgica, Brittany and south-eastern Britain. Coastal fortifications in Belgica built in this period included Aardenburg (c.170-3), Oudenburg (first phase), and other probable sites at Bruges, Walcheren, de Oude, Werelde and Brittenburg (Haywood 1999:26-30). In Britain, coastal defences span the period from early in the second century to the late fourth century. These defences appear to fall into three groups. An early group, dating from the Hadrianic period to the late second century includes South Shields; Brough on Humber; Brancaster; Caister-on-Sea; Bradwell; (Walton?); Reculver; Dover; Lympne; and Pevensey. These sites may have been part of a maritime supply chain. There is no evidence for the type of craft the Chauci used for their raids, but they must have been large enough to make coastal and short cross-Channel voyages, able to carry an adequate fighting group, and with sufficient cargo capacity to carry back the loot. The Bjorke type of boat of about AD 100 from Stockholm, 7.16 m long and consisting of a plank fastened to each side of an expanded dugout with iron rivets, is one possibility (Muckelroy 1978:85), but it seems on the small side.

McGrail has advanced the hypothesis that a Celtic tradition of planked boat building was active from before the first century BC until after the third century AD. The evidence is literary and iconographic. Caesar describes the ships of the Veneti and in the civil war campaigns in Spain mention is made of a *ponto*, a flat bottomed Gallic type vessel, “....pontones quod est genus navium Gallicarum” which was a “navis oneraria” (Caes. B Civ.III.29, a reliable sailing cargo vessel (McGrail 1990a:41). There is a named depiction of a *ponto* on a mosaic from the Maison des Muses at Althiburus in Tunisia (Dunbabin 1978:127, plate 122). Two bronze coins of Cunobelin, respectively from Sheepen near Camulodunum and Canterbury, dated to AD 20-43, depict planked boats with masts and

10 In Britain coastal defences or depots, often referred to collectively as “The Forts of the Saxon Shore”, are situated along the east and south coasts of Britain from South Shields (Arbeia?) on the River Tyne in the north to Portchester (Portus Adurni?) in the upper reaches of Portsmouth Harbour in the south. In addition five “signal stations” are known, sited on high headlands along the Yorkshire coast. There may have been more, but some were probably lost to coastal erosion (Ottaway 1995). The role and date of these structures have been a subject of intense debate for some decades (Allen and Fulford 1999, Cotterill 1993, Cunliffe 1980, Hutchinson, Poole, Lambert and Bromhead 1985, Johnson 1979, Maxfield 1989, Ottaway 1995). The most recent work by Allen and Fulford made an intensive study of the materials used in building the forts. Their conclusion was that the forts fall into two groups. The early group of ten forts or depots, dated from the early to late second century, were built using a mix of local materials and stone imported from elsewhere in Britain. In one case, Walton, lava blocks from the Rhine were utilized. They speculate that these forts or bases were part of a military-civilian supply and trading system around the south and east coasts. They suggest that the imported stone may have come as cargoes, part-cargoes or ballast, in ships engaged in transporting pottery, grain and other perishables from agricultural and production sites in the hinterland of each fort or base. The later group of forts, all built exclusively of local materials, and with external towers, are attributed to hasty building at the end of the third century, probably in the Carausian-Allectus period (Allen and Fulford 1999:163-184).
sails and a steering oar on the obverse (McGrail 1990a:43; Van Arsdell 1989:408). It seems probable that in the period from the early first century BC to the first century AD, a number of the coastal tribes of northern Gaul, Holland, Germany and south-eastern Britain had developed at least a small number of plank-built sailing vessels capable of seagoing voyages. If so, they had the technology for successful piracy. The number of their vessels was probably in the tens, in contrast to the hundreds at the disposal of the Romans. They were probably constrained by limited supplies of iron for fastenings, and by a limited pool of skilled boatbuilders.

In the third and fourth centuries the Frankish confederation in the lands between the Rhine and the Weser began to form by about AD 230, and they were engaging in piracy by about AD 260. The Saxons, another confederation of peoples from the area between the Elbe and the Ems, started to appear as pirates about AD 280. By the middle of the third century the classis Britannica and classis Germanica had both become ineffective. In AD 285 Carausius, a Menapian, was appointed by Maximian, Augustus of the western provinces, to command the western fleet at Gesoriacum (Boulogne) and put down piracy. Carausius established himself as an independent ruler in Britain, but was murdered by his successor Allectus, who was in turn defeated and killed by Constantius Chlorus. For the first half of the fourth century there was no major piracy, but many small local raids. By the mid-century there were major incursions, which were ultimately brought under control by Count Theodosius. A number of signal stations were built along the Yorkshire coast, and a chain of coastal fortifications, the Litus Saxonicum was established. Ultimately, with the withdrawal of the Romans the whole system decayed and collapsed in the fifth century.

4.7. Discussion

From the very limited evidence we have it would appear that sometime in the period between the fourth century BC and 56 BC the coastal peoples of northern Europe had developed substantial iron fastened planked sailing vessels. The principal literary evidence is Caesar’s quite detailed description of the ships of the Veneti. To date, the archaeological evidence is limited. The Blackfriars Ship I from London, dated to the period

---

11 By the fifth century they had become settlers and rulers in Britain.

12 Caesar only mentions iron nails in connection with the transverse beams: “The cross-pieces were beams a foot thick, fastened with iron nails as thick as a thumb.” (Caes. B Gall. III.13). But if the planks had been sewn he would surely have mentioned such an oddity. Other possibilities are the use of treenails to attach the planking, or even the Mediterranean mortise and tenon edge-joined planks. Mortise and tenon seems unlikely. The mid-second century Blackfriars I ship was fastened entirely with clenched iron nails. Treenails were used, but were only driven into the frames, not into the planking. It appears that the builders did not have the tools or technology to drill deep small diameter holes, about 13 mm diameter, across the grain. By using the oak treenails they were able to drill a larger hole through the frame, plug it with a treenail, and then drill a hole to match the nail size from inside the hull along the grain of the oak treenail, with only a short distance across the grain in the planking. The nail was then driven from outside the hull and clenched into the frame (Marsden 1994:50-54, Fig. 48).
AD 130-175, is entirely fastened with large iron nails (Marsden 1994:80), as are the three barges from Zwammerdam on the lower Rhine, dated to the same period (de Weerd 1978:16-170). How did the sea-going people of Northern Europe fasten their ships between about 300 BC and AD 150? By the end of the first century AD the Romano-British iron industry of the Weald was able to produce large quantities of iron, in the range of 700-750 tonnes per annum (see Appendix D:3). Marsden has estimated that the Blackfriars Ship I needed about 0.62 tonnes of nails (Marsden 1994:51). The larger and later St. Peter Port vessel used about 2 tonnes of nails (Rule and Monaghan 1993:79). Iron was produced in small amounts in the Weald and in many other areas of Britain before the conquests. It was made in small local furnaces, and was “....a widespread homecraft and not solely a skill in the hands of specialists.”, but by the second century BC more centralized production in the south-east seems probable (Cunliffe 1991:452-4). In the Roman period sufficient iron was being produced to provide the iron requirements for ship building. Although there is no firm information on the amount of iron produced in pre-Roman Britain it seems likely that it was small compared with Roman production. Iron Age artefacts from archaeological sources are principally weapons, tools and iron ‘currency bars’. There is minimal evidence for iron nails in any quantity from Iron Age Britain, compared with the quantities found at Roman sites in Britain. The typical Iron Age round hut dwellings and structures could be assembled without nails, as demonstrated at the Butser Farm experiment (Reynolds 1979:29-45).

From the eighth to the middle of the fourth century BC there were vigorous trading contacts with the Continent. Cunliffe has commented on the LPRIA in Britain:—
“The material culture and settlement pattern of the third and second centuries suggest that Continental contact decreased during this period, allowing the British communities to assume an intensely regional aspect reflecting little of contemporary European developments. Contact was reintensified about 100 BC when the activities of the Roman entrepreneurs in southern Gaul impinged upon the Solent harbours and the south-west and bound these areas closely once more in an Atlantic trading network. But after Caesar’s conquest of Gaul this trade rapidly declined, to be replaced by even more intensive contacts between the Roman world and the pro-Roman tribes of eastern Britain. This system was subsumed when Rome invaded Britain in AD 43.” (Cunliffe 1991:443).

As suggested in Section II.4.5 above, there may have been political reasons for the proto-states of the LPRIA in Britain to be inward looking. This, combined with a limited output of iron, may have impeded the development of substantial sea-going trading vessels until the advent of the Romans in AD 43 suddenly produced a huge increase in cross-channel traffic. Up until this time the shipping needs were largely met by continental vessels from

---

13 Iron tools, weapons and miscellaneous iron objects when broken or worn can be recycled almost indefinitely by the blacksmith forging them into replacement or new items.

14 Caesar, describing the products of Britain says, “In the midland districts of Britain tin is produced, in the maritime iron, but of that there is only a small supply: the bronze they use is imported (Caes. B Gall.V.12).
groups such as the Veneti and Coriosolites and later by vessels from northern France and Holland, and possibly by a small number of British vessels operating between the Rhine and south-east Britain. The only possible evidence for British built and operated trading vessels prior to the Roman conquest are the two bronze coins of Cunebolinus depicting planked sailing vessels, see page 41. The Romans initially brought shipping with them from the continental sources. After iron production on a large scale was established in the Weald, the Romans took advantage of the large quantities of oak available in Britain, and using either shipwrights from Gaul, or later locally trained Britons, built sturdy sea-going ships in Britain. These could be either government vessels or belong to entrepreneurs and merchants.

With the arrival of the Romans and the conquest, the normal sequence of events in a technological realm would be a continuation of the native tradition by the natives, the importation of a different technology by the invaders, and then one either supersedes the other over time because it is better or cheaper, or the two traditions assimilate good points from each other until a new composite tradition is established. In the case of large sea-going cargo ships it seems that the Romans may have already adopted the northern nailed construction of northern Gaul, keeping the flat plank type keel probably used by the Veneti, but giving a rounder form to the rest of the hull, not unlike that of the Kyrenia ship. The so-called Romano-Celtic type of hull construction has some of this amalgamation of techniques.

---

15 Although these coins show ships, there are two possible explanations other than that Cunebolinus ‘owned’ ships. One is that they simply imply that he had access to ships. The second is that he was copying the coinage of others. “For much of the first century B.C. the currency of Britain consisted of a mixture of the imported coins with locally made versions,...” (Allen 1980:26). Much of the Celtic coinage of Britain copied motifs from continental and Mediterranean coins.

16 Blackfriars Ship 1 is built of English oak from south-east England (Marsden 1994:80).
Section II.5: Romano-British Boats and Ships: Some Hypotheses

5.1. Introduction

As noted in the previous section, in pre-Roman Britain several simple types of water-craft have been recovered from archaeological contexts. The indigenous inhabitants used logboats from Neolithic times, and possibly even earlier in the Mesolithic (Clark 1952:282-7). The Late Iron Age Hasholme logboat, dated to the period 322-277 BC was a sophisticated example of the genre, with a maximum carrying capacity of 8.9 tonnes in calm water (Millett and McGrail 1987:133-5). There seems to be no reason why logboats would not continue in use for local waterborne loads of small to moderate weight in Roman Britain. They would not require sophisticated shipwrighting skills, and were probably fashioned by the owner/users. Similar considerations apply to the skin covered boats of the coracle and curragh type. Curraghs and coracles continued in use in Ireland and Wales into the twentieth century. As with logboats it seems probable that skin covered boats would continue in use throughout the Roman period, and like logboats they were most likely built by the users, using simple technology passed on from father to son. The only tools needed were an axe, a knife and a needle or awl for stitching the hide, as demonstrated in the construction of a replica of a Bronze Age skin boat in Norway (Johnstone 1974:82, 1988:109). In summary, the logboat and skin covered boat probably continued in use throughout the Roman period. They would have been constructed by the indigenous inhabitants to meet their own local needs. Planked boats in the archaeological record of the pre-Roman period are the Bronze Age Brigg Raft, dated to c.860-820 BC (McGrail 1981:121), and the Ferriby boats of c.1300 BC (Wright 1990:175). Both the Brigg Raft and Ferriby boats have sewn planking. There are no metal fastenings.

For planked boats with metal fastenings, the earliest Romano-British examples are the Blackfriars Ship I, dated to 130-175 AD, and the New Guy’s House barge dated to the second half of the second century AD (Marsden 1994:80, 103). It seems reasonable to suppose that by the mid-first century BC some of the inhabitants of Britain from the south and east coasts would be aware of iron-fastened planked ships from the trading contacts across the Channel and the southern North Sea. The Veneti of the south side of the Brittany peninsula and the Coriosolites of the area around the river Rance and settlement at Alet on the north side had iron-fastened planked seagoing ships (Caes. B Gall. 3.13, Strabo 4.4.1). The Coriosolites as traders show up much more strongly in the archaeological record of finds of coins and pottery than the Veneti (Cunliffe 1982:39-68). Most of the cross-channel trade was almost certainly carried in ships from Gaul. There might have been a small number of iron-fastened planked ships owned and operated by one or more dominant rulers in eastern and southern Britain, but the evidence for this is minimal.

After the Roman conquest in AD 43 there was a substantial increase in maritime activity between Gaul and Britain. Quite apart from a steady stream of soldiers, administrators, and military and government supplies crossing the Channel in both directions, there was a major increase in imports which lasted well into the second century. This would have required a significant increase in the tonnage of shipping needed.
5.2. Hypotheses on Caesar's Transports: Forerunners of Plank Type Boats in Early Roman Britain? (See also Appendix M, A Hypothetical Invasion Transport)

As noted previously, an early reference to plank-type boats in northern Europe is Caesar's description of the vessels of the Veneti. Prior to his second expedition to Britain in AD 54 BC Caesar had left orders with his generals for the construction of transports and warships (Caes. B Gall. V.1). The specifications were that they were to be able to carry a heavy cargo, be suitable for both sailing and rowing, have a broader beam than normal, and to have slightly less freeboard than Mediterranean vessels. Six hundred of the transports were built, together with twenty-eight warships. The warships almost certainly would be of the normal Roman type in construction, but the transports, particularly as they were intended for beaching, could have been of the flat bottomed Venetian type. There are two arguments in favour of this hypothesis. Firstly, although the legions contained many skilled craftsmen, and all legionaries carried tools for building camps and forts with earth, turf and timber, they were not skilled shipwrights in the Mediterranean tradition of shell first mortise and tenon planking. Secondly, if sources of local coastal labour, gathered from along the coast were used, they would be familiar with building in the local tradition of flat bottomed boats with frames and iron-nailed planking.

In the second expedition to Britain Caesar had a total of about 700 transports, 100 carried over from the first Channel crossing in the previous year plus the new vessels built in the winter of 55-54 BC. In addition there were about fifty plus warships. The five legions, each with around 4,800 men, plus the 2,000 cavalry with their horses gave a total force of about 26,000 men plus the sailors and marines needed for managing the ships. The cavalry with at least 2,000 horses, averaging about 1.5m high and weighing about 400 kg each (Hyland 1990:153), would require special facilities. Horses had been moved by sea since antiquity, but the Greeks, and later the Romans utilized special vessels for this purpose. Herodotus in listing the Persian naval forces involved in the Salamis campaign includes horse transports, “Galleys of thirty and fifty oars, horse transports and boats made the total number of the fleet up to 3,000.” (Herodotus 7.97). Later, older triremes were converted to carry thirty horse, using 60 oarsmen for rowing the ship (Morrison, Coates and Rankov 2000:227-8, Fig.70). Thucydides lists horse transports on several occasions (Thuc. 2.56.2, 4.42.1, 6.43.1). Arrian mentions Alexander building horse transports for the journey down the Hydaspes to the Indian Ocean (Arr. 6.1). At the naval battle of Ecnomus in the First Punic War the Roman horse transports were placed at the rear of the triangular formation of the fleet (Polyb. 1.26.11-15). In the Roman war against Perseus and Macedonia, thirty-five horse transports were driven ashore on Chios (Morrison and Coates 1996:111). Water transport was much easier on horses than long marches which, “wore out the hooves of the often unshod horses (Speidel 1994:117-118).
would be between about 1 m x 2.4 m to 1.8 m x 3 m, depending on how closely they were packed (Dixon and Southern 1997:182-3, Hyland 1993:117). The cavalry man with his weapons and horse gear weighed about 104 kg (Hyland 1993:154). The infantry with their armour, weapons, tools, cooking and camp equipment probably averaged about the same weight as the cavalry man. The weight of a horse and the space necessary to accommodate it would be equivalent to what was required for four men. The total number to be transported would be 28,000 men plus the equivalent 8,000 men for the 2,000 horses, or a grand total of 36,000 ‘equivalent man units’. Spread over 700 transports, the number per vessel is about fifty, for a total load per vessel of 5.2 tonnes. Adding in sailors, rations and miscellaneous items the load would be 6 to 7 tonnes per transport.

Of the ships recovered through archaeological excavation, the ones that offer the closest parallels to the specifications outlined for Caesar’s transport vessels are the Blackfriars Ship 1 of the early second century A.D., and the Barland’s Farm Boat of the late third century. The first could carry a maximum load of fifty tonnes of high density cargo such as stone, although the actual cargo was estimated to be about 26 tonnes (Marsden 1994:81, 89). Its dimensions were 18.5 m long by 6.12 m breadth by 2.86 m deep, giving a length/breadth ratio of 3.02, quite typical for wooden cargo vessels for centuries. The Blackfriars ship was a decked sailing vessel, and was probably not moved with oars except for manoeuvring in harbour. The Barland’s Farm boat of the late third century was an open boat, suitable for rowing or sailing, with a cargo capacity of about 4.5 tonnes of stone with a crew of three. Its dimensions were 11.4 m long by 3.16 m breadth by 0.9 m deep, with a length/breadth ratio of 3:6 (McGrail and Roberts 1999:139). Both these vessels used iron nails to fasten the planks to the floors and frames. Caesar’s transports would probably have been somewhat like the Barland’s Farm boat, open rowing and sailing vessels, but somewhat larger and probably with a smaller L/B ratio. To carry fifty soldiers in four files of twelve the transport would need a breadth between 4 and 4.5 m, and for rowing a fore and aft space between men of two archaic cubits or 0.98 m, based on the spacing proposed for a modified design for the replica trireme *Olympias* (Morrison, Coates and Rankov 2000:137, 245-6). In the transports about 11 m of the length would be taken up by the twelve oarsmen per side, and with the narrowing of the hull towards the stem and stern at least another 2 m at each end should be added. With a length of 15 m and breadth of 4.5 m the L/B ratio is 3:33, quite appropriate for a large rowing boat. The depth of the hull amidships would be about 1.5 m. For comparison, a Class I ship’s lifeboat of the first half of the twentieth century AD had a length of 7.92 m by 2.51 m breadth and 1.02 m depth, giving an L/B ratio of 3:15. It could accommodate 44 persons, about 3.6 tonnes weight, if

---

4 In the excavations of the Roman fort at Wallsend (Segundum) on the north bank of the River Tyne, four barrack blocks have been identified as combined accommodation for cavalry troops (*turmae*) and their horses. Each stabling unit, about 3.4 m square, held three horses, giving a space per horse of 3.4 m x 1.1 m (Bidwell and Griffiths 1999:86-7, 92). The space allowance for horses on the transport seems reasonable for a short sea voyage lasting only a few hours. For a long voyage more space would be needed for feeding, watering and grooming.
tightly packed, but this left no room for working the boat. With 20 to 25 people the boat could be sailed and rowed, although it was still very crowded (Foster 1952:53). In general it would appear that the proposed dimensions for the transports is well within the range for a practical troop transport in calm to moderate weather, and certainly Caesar’s crossing was made in calm weather, “...proceeded under a gentle south-west wind.” and later after the wind fails the troops “...who, in the heavily built transports, by uninterrupted effort of rowing kept level with the men-of-war.” (Caes. B Gall. V.8). The mention of heavily built transports suggests the substantial type of boat used by the Veneti, rather than the lighter shell-first type construction almost certainly used for the warships. On the subject of oars, the oars for the replica trireme Olympias were 3.99 or 4.2 m long (Morrison, Coates and Rankov 2000.:215), and modern oars supplied to ships’ lifeboats in the twentieth century were about 4.26 m long (Foster 1952:58). The length and weight of oar that can be handled effectively by one man has not changed significantly over the centuries and the oars of Caesar’s transports would have fitted into this range.

The number of horses that could be carried in one of the hypothetical transports described above could not be more than about eight to ten, after allowing for sufficient room for sailors and a minimum number of oarsmen. With 2,000 horses this would require 200 to 250 of the transports. The 24,000 legionary infantry would need 480 ships. It would be possible to fit the men and horses into the vessels available, with a little crowding. Two other possibilities for the horses would be to distribute them equally among all the transports, which could have made them easier to manage, or possibly to have special horse transports, which Caesar has omitted from his description of the fleet.

For the Claudian conquest the information on the Channel crossing is scanty. We know it was made in three divisions, that the army of Aulus Plautius was made up of four legions, Legio II Augusta, Legio IX Hispana, Legio XIV Gemina and Legio XX Valeria Victrix, which together with auxiliaries gave a force of some 40,000 men (Frere 1987:48). There is no specific information on the fleet of warships and transports used for the invasion, or on the size and types of particular vessels. It would seem likely that the invading fleet was made up of a mixture of regular merchant ships requisitioned from the coastal areas of northern Gaul and Germania Inferior, of vessels from the classis Germanica, which under Augustus and Tiberius had been engaged in a number of conflicts as far as the Elbe (Starr 1941:141-4), and possibly by some vessels built especially for the invasion. Locally requisitioned vessels would be in the lineage of the planked ships fastened by iron nails, known from the ships of the Veneti to the Blackfriars Ship 1.

5.3. The Technology of Romano-British Ships and Boats

The hard evidence for the construction of Romano-British vessels is scanty, but from the evidence available from Britain and adding that from Gaul and the Rhine area, one

5 Based on more recent shore to shore invasions it is unlikely that the whole 40,000 would have been carried in one lift. A force of 24,000 men, either all legionaries, or a mix of legionaries and auxiliaries would be enough to establish the beachheads at Richborough and possibly Chichester, and could be reinforced with the balance of the army within a few days.
might reasonably exclude the possibility that large numbers of vessels were built in the Mediterranean tradition using mortise and tenon technique with shell-first planking. In the early part of the first century AD a number of warships and government owned vessels may have been built in this manner. The only vessel found in Britain built using this technique is the very late third century County Hall Ship from the Thames, and as is argued in section II.6.11 below, this ship is an anomaly. Building using mortise and tenon technique would require the bringing of shipwrights skilled in this technique from the Mediterranean, as it was entirely foreign to the indigenous boatbuilders.
Section II.6: Five Excavated Romano-British Ships and Boats

6.1. Introduction

In this section the five planked Romano-British ships and boats recovered from archaeological sites are examined in detail, in order to look for similarities and differences in the technology of their construction. Is there one general type of hull construction, or more than one? Traditionally two types of planked ship construction from antiquity have been recognized. The earlier Greek and Roman Mediterranean tradition used shell-first construction, with planks edge-joined with mortises and tenons working up from the keel, and with the floors and frames inserted afterwards, Figs. II.6.1.1.a, b and c. Subsequently, in the Byzantine and Islamic periods, the later tradition of skeleton-first construction developed, with the framework or skeleton built first and the planks were then fastened to the floors and frames, Fig. II.6.1.2.b. Between the late sixth century and the tenth to eleventh centuries, there was a transition period combining both methods. Two examples of the developing frame first technique are the Yassi Ada 2 wreck of the seventh century A.D. and the Serçe Limani wreck of the eleventh century. In the Yassi Ada 2 wreck the mortises and tenons are small and widely spaced, and were used only in the lower part of the hull up to the waterline amidships. Bass comments:

"These joints were designed primarily to facilitate as much as possible the task of fitting the strakes together and shaping the hull, and their contribution to outer shell strength was both slight and incidental to their primary function.” and “The frames, normally 14 cm square, were fastened to the shell planking by nails driven from the outside;” (Bass et al 1982:56, 59).

By the time of the eleventh century Serçe Limani wreck the planks are no longer joined edge to edge, “No evidence of mortise-and-tenon joints was detected.” and “Skeletal building may have been employed in all stages of the hull construction.”. Fastenings were a mix of treenails and iron nails (Bass and van Doorninck 1978:122). A separate Scandinavian tradition of clinker or lapstrake building, with overlapping planks fastened to each other along their length existed, starting in the Iron Age and persisting to this day for small craft in northern Europe.

More recently, a separate tradition has been identified in parts of northern Europe, variously called Gallo-Roman or Romano-Celtic, the latter being the term preferred by McGrail. Four of the five Roman period vessels excavated in Britain belong to this group, the Blackfriars 1 vessel, Fig.II.6.8.1.a, and the New Guy's House boat Fig.II.6.7.1b from

---

McGrail has proposed that an “intermediate” method best describes the Roman-Celtic, Romano-British nailed plank boat construction, with building in the following sequence:-

1. Framing which defined the shape of the lower hull was fastened to the plank-keel and to the posts.
2. Lower hull planking was fastened to this framework.
3. Side framing was fastened to the lower planking (but not to adjacent timbers), and extended above it, thereby defining the form of the upper hull.
4. Upper hull planking was fastened to the framing. (McGrail 1997a:78).
London, the Gallo-Roman ship from Guernsey, Fig.II.6.10.1 and the Barland's Farm boat, Fig.II.6.9.4 from South Wales. In this Romano-Celtic tradition the planks are not fastened to each other, but are nailed to the floor timbers and frames. These vessels date from c. A.D.130 to 300. Thus it appears that frame first construction was employed in northern Europe for several centuries before it was first used in the Mediterranean. McGrail believes that the origins of frame first construction lie in north-west Europe (McGrail 1997a:79).

Marsden first recognized this tradition of frame first carvel building with caulked seams in the 1967 publication of the Blackfriars ship (Marsden 1967:14, 1994:33-95). In more recent work McGrail has examined the characteristic features of the Romano-Celtic tradition (see Fn.1 above), and has defined it as an "intermediate" method, in which, although the planks are fastened to the frames and not to each other, the framework or skeleton was built up in stages, somewhat ahead of fitting the planks. A brief description of the construction sequence is as follows: the floors or lower framing, which defined the shape of the cross-section of the lower part of the hull were first fastened to the keel or keel planks. This was followed by fastening the garboard strake and some of the lower hull planks to the lower framing with clenched iron nails. The side frames were then fastened to the lower hull planks, but not to the floors or lower framing. Planking was then continued up the side frames to the gunwale, with the planking fastened to the side frames with clenched iron nails (McGrail 1997a:76-80, 1995:139-145). McGrail sees these Celtic shipwrights as "the first boatwrights or shipwrights known to us who seem to have visualized their vessels in terms of the framing rather than the planking." (McGrail 1997a:78-9).

The fifth Romano-British ship, the County Hall ship from London, was built in the traditional early Mediterranean method, shell-first with the planks joined edge to edge with closely spaced tenons and mortises, and the frames fitted in afterwards Fig.II.6.11.2. This was demonstrated by one of the surviving plank fragments having a frame treenailed to it through one of the mortise and tenon joints. Hence the mortise and tenon, joining and securing the planks in place, was installed before the frames were fastened into place with treenails. It might be supposed that the ship had been built in the Mediterranean, or more likely in Gaul, and sailed to Britain, but it was built entirely of oak, rare in the Mediterranean, and the oak was identified from tree ring patterns as coming from south-east Britain (Marsden 1994:124-125). Marsden's conclusion is that although built in Britain, the shipwright had been trained in the Mediterranean technique. The purpose and role of this ship remains an enigma. It seems unlikely that it was a warship, as there is no definite evidence for it being fitted with oars. If a merchant vessel, the dimensions are unusual, particularly the depth at c.2 m, about two thirds of that of the two seagoing ships, Blackfriars Ship 1 and the St.Peter Port ship. It fits more closely with the hypothetical Caesarian troop transport discussed in Section II.5.2.101. Marsden suggests that the County Hall ship, "...had an official use of some form, possibly associated with the restored imperial government after AD 296." (Marsden 1994:127). It was decked, at least in part, but no mast step was found, although a possible location for a mast was located at about the

---

2 Planking fitted edge to edge to give a smooth exterior to the hull.
mid-length (Marsden 1994:122-3). The vessel may have been intended for civilian or military administrative use, such as that suggested for the Type B Mainz boat by Höckmann (Höckmann 1993:133), or as a navis iudiciaria, a type known from the Danube fleet (Höckmann 1988:31).

The dates of the building of the five vessels are:

- Blackfriars wreck 1: c.A.D.130-175 (or possibly 79-150)
- Barland’s Farm boat: c.A.D.250-300
- New Guy’s House boat: c.A.D.250-300
- Guernsey Gallo-Roman wreck: before c.A.D.280 (wrecked in 280, and not new)
- County Hall ship: c.290-300

The relative dates of the five vessels are of considerable interest, in that the four built in the Romano-Celtic tradition appear to pre-date the County Hall ship, built in the Mediterranean tradition. The anomaly is the County Hall ship, belonging to the period of Carausius and Allectus, A.D.286-296, and the re-conquest of Britain by Constantius in A.D.296.

With the concept of a Romano-Celtic shipbuilding tradition in mind, it is possible to advance the following hypothesis for the sequence of ship and boat construction in Britain:

1. Prior to the conquest in A.D.43, British shipbuilding techniques would be derived from indigenous late Bronze Age and Iron Age traditions, possibly modified by Continental and particularly Gallic influences. There is substantial evidence for trading activity between Britain and northern Europe from the Bronze Age to the Roman conquest. According to Cunliffe, in the late Iron Age there was extensive cross-channel trade between Britain and northern France (Cunliffe 1987:339-343), obviously carried out by vessels of the region.
2. The naval and transport fleets of Caesar’s expeditions, probably built by a combination of the legions and local labour, would have had some vessels, particularly the naval ones, built in the Mediterranean tradition, while most, or all of the transports could be in the Romano-Celtic tradition, and similar to the vessels of the Veneti described by Caesar.
3. In the Claudian conquest, as noted in Section 11.4:90, the invasion fleet was probably a mix of Roman warships, some government military transports from the classis Germanica, together with some locally requisitioned merchant ships and specially built vessels, both built in the local tradition.
4. After the conquest, the Celtic logboats and skin boats would continue in use for local movement of modest loads. For planked vessels, the “intermediate” tradition defined by McGrail for coastal and seagoing voyages, would continue and would supply the merchant vessels trading to Spain, Gaul and the Rhineland. Cross channel trade was vigorous in the Roman period, particularly in the first two centuries.
5. In the re-conquest of Britain in AD 296, after the Carausius and Allectus usurpation, Constantius certainly came with a combined fleet of naval vessels and transports. He, like

---

3 The County Hall ship appears even more anomalous when set beside the five fourth century Roman boats from Mainz. These were found at a military establishment, and four at least were clearly meant for naval or military patrolling. They were constructed of planks nailed to floors and frames, with no mortise and tenon joints (Höckmann 1988:25)
Caesar, Gaius and Claudius, may have had to build additional vessels over and above those available to him in Gaul. Although the majority would have been constructed in the Romano-British fashion, some warships built by military or naval personnel may well have been fabricated in the Mediterranean tradition. Once he had arrived in London, one or more vessels of the Mediterranean shell-first system may have been built by his naval forces for local use on the Thames, probably for some administrative or ceremonial use rather than as a cargo vessel. This could account for the apparent oddity of a Mediterranean type hull at a late date in a Romano-Celtic shipbuilding area. If he just needed lighters or river craft for mundane use, he could have simply requisitioned the existing local vessels in the port.

6. The 'normal' ship and boat building tradition in Britain in the late first century AD and after would have been Romano-Celtic. Further finds of ships or boats of the Roman period from datable contexts would be needed to provide more evidence for this hypothesis.

6.2. The Types of Vessel Needed in Roman Britain

Apart from the indigenous logboats and hide boats, four types of vessel would be needed in the water-borne transportation system of Roman Britain.

1. Barges or lighters for moving goods along quiet rivers and in sheltered harbours or estuaries with minimum wave motion. They could also be used to transfer cargoes from seagoing or coastal ships anchored in mid-stream, where no suitable wharves or hards were available. These barges could be of two possible configurations. Both configurations would aim for a very stable hull form, and would have a relatively small depth. One type would be flat bottomed and with flat sloping bow and stern, primarily for use as harbour lighters or movement in calm rivers. The second type, for use on longer inland river voyages and in situations where modest wave motion could be experienced, would have stem and stern posts, with pointed bows and transom or pointed sterns. The Zwammerdam barges are an example of the first type, Figs. II.9.3.1a,b, and c, and the New Guy’s House boat, Fig. II.6.7.1b and c, an example of the second type.

2. Open or partly decked boats of greater depth with good sea keeping qualities for use in larger estuaries, and for short coastal voyages in good weather along coasts with numerous easily accessible harbours and havens. The Barland’s Farm boat is an example of this type.

3. Modest sized sailing cargo ships, fully decked, and able to make long coastal voyages or seagoing voyages to the Rhine or across to Gaul in most weather conditions short of Beaufort Force 7 winds (wind speed 21 to 26 knots), a moderate gale. The Blackfriars Ship 1 meets these criteria.

4. Larger seagoing sailing cargo ships, fully decked, and able to sail anywhere in northern seas between Spain and the North Sea. The St. Peter Port Ship is an example of a seagoing cargo vessel.

The technology of these types of vessels are discussed in detail in the following sections.

6.3. The Logboats and Hide Boats

There are to date only three finds of logboats of the Roman period from Britain, the
Hardham boats 1 and 2 from the River Arun in Sussex dating to c.AD 300. Both are small, 3.99 x 0.84 x 0.45 m with a carrying capacity of one man plus 549 kg of grain or 299 kg of turf, and 3.88 x 0.84 x 0.47 m with a carrying capacity of one man plus 613 kg of grain or 363 kg of turf respectively (McGrail 1998:203). A third was found in 2001 at Fiskerton in the River Witham valley near Lincoln, and is almost certainly from the Roman period, but to date has not been fully published (Pitts 2001:327). From the Iron Age, the Hasholme logboat (322-277 BC) with dimensions of 12.78 x 1.4 x 1.25 m could carry a five man crew and between 3.5 and 8.5 tonnes of cargo, depending on the specific gravity of the cargo and the freeboard desired (Millett and McGrail 1987). The somewhat smaller logboat from Poole, 10.01 x 1.52 x 0.5 m (c. 300 BC) could carry four men and 1.5 tonnes of cargo (McGrail 1998:20-22). For the post-Roman period a logboat from Amberley, Sussex has been dated to AD 640 (McGrail 1975:196). Nine logboats from the Mersey area have been dated to between the eighth and thirteenth centuries AD (McGrail and Switsur 1979:103, Fig.6.15).

Despite the rather fragmentary nature of the evidence, the archaeological record appears to support the hypothesis that logboats continued in use in Britain from the Bronze Age or earlier, through Roman and Saxon times and on into the medieval period and later. The location of the finds suggests that at least from the Iron Age and on through the Roman period they were used on rivers for moving people and modest loads. For hide boats in the Roman period there is no archaeological evidence to date, but the literary evidence (Caes. B Civ. 1.54), and the fact that hide boat types, with heavy tarred canvas replacing the hides, continued in use in Ireland and Wales into the twentieth century, implies a continuity in this tradition in some areas. The technology for fabricating logboats remained fundamentally the same over the centuries, as evidenced by similar tool marks from axe and adze through time. An interesting point is that the late Iron Age boats, such as the Hasholme boat, were more sophisticated in forming the bow and stern than most later boats. The Hasholme boat and others like it had transom sterns fitted into slots cut into the hollowed out log. In the case of the Hasholme boat, the bow was formed from two complex wooden shapes fitted into a one metre long slot cut longitudinally into the bow with the whole structure held together with long wooden pegs (Millett and McGrail 1987:Fig. 25). Most later logboats were simply hollowed out of a log.⁴

6.4. Some Difficulties in Building Planked Boats

In building planked boats there are three areas of the planking which present particular difficulty. Attaching the garboard strakes, the planks which are adjacent to the keel, requires careful fitting, particularly in the area where they run into the keel and join the stem and stern posts. The point at which the planking makes the transition from the bottom to the side can cause problems, especially in ‘hard chine’ hull forms, where the

---

⁴ The reason for the greater sophistication of the Hasholme boat may be that in its time it was the equivalent of a capital ship or liner. In later centuries, when planked boats of all sizes had become common in Northern Europe, logboats were probably made and used only in remote and more primitive areas, where people lacked the skills and financial resources to build planked boats.
transition can form quite a sharp corner. The third area is in the shaping of the planks to follow the curves of the hull. The perimeter of the hull at the midship section is much greater than the perimeter at the bow and stern, and in fitting a number of planks around a hull with a curved cross-section the planks are not straight, but twisted along their length. Planks are of varying width along their length and generally wider at the centre of the vessel than at the ends. To avoid impractically narrow strakes with no room for fastenings, it is sometimes necessary to introduce ‘stealers’, where two planks are terminated before the stem and scarfed or joined to a wider short piece to make the stem connection. In all hulls, except those that are strictly box shaped, all planks have curvature along the edges, are sinuous along their length and require twisting along their length to fit them into position, Fig.II.6.4.1 (Marsden 1994: 93, Fig.85) and Fig.II.6.4.2 (Fenwick 1978:296, Fig.10.1.2).

6.5. The Flat-Bottomed Chine Type Barges in Europe

There are no examples to date from the archaeological record in Britain, but a number from the Rhine area and the lakes of Switzerland. With the close political and trading connections between Britain and the German provinces after the conquest of Britain, it seems likely that there would be similarities in useful technology between the two areas, particularly on occasions when the movement of troops was required to meet various emergencies. From Zwammerdam in Holland three barge wrecks have been excavated. Their dimensions are:
Barge 2: 22.75 x 2.8 x 0.95 m
Barge 4: 34.0 x 4.4 x 1.2 m
Barge 6: 20.25 x 3.40 x 0.9 m
The carrying capacity varies between 30 and 105 tonnes and all three date to the late first century (de Weerd: 1988a, 1988b, 1990:75-6, 1994: 43-4). From Druten and Kapel Avazaath near Zwammerdam similar vessels have been found (Lehmann 1990:77-81). From Pommeroeul in Belgium two similar craft have been excavated, one c.18-20 x 3 x 0.67 m and the second of similar size, both dated to about AD 200 (De Boe 1978:22-30, P.Johnstone 1988:164). From farther inland two barges have been recovered from Lake Neuchâtel, one from Bevaix and one from the other end of the lake at Yverdon. The Bevaix barge is 19.5 m long and dates to about AD 182, while the Yverdon barge is earlier, dating to c. AD 115, and is 16 m long (Arnold 1975:123-6, 1978:31-35, 1990:57-65, 1991:19-23, 1999:34-43, Fenwick 1995:167-170). The common technological feature of all these large but shallow river barges is that the problem of the corner between the bottom and the sides, the chine, is resolved by an L shaped ‘chine girder’ or ‘ile’ made out of a quarter of a log. In some case the chine girder has been made by splitting one log, in others each chine is

5 The 1988b publication is de Weerd’s thesis in Dutch from the University of Amsterdam, and is not readily accessible. In his other publications he makes some reference to it, and it seems probable that his more recent work incorporates and updates the information contained in it.

6 Chine girder is the term used in Britain and the United States. Arnold uses the term bordage de bouchain, but in French vernacular craft the short word ile is used. Fenwick suggests we should all use ile.
made from a separate log, see Fig. II.9.3.1a. The bottom is made of a number of planks, which are joined to each other and to the chines by L shaped frames, placed alternately. The sides are built up from one or more planks secured by the frames, see Figs. II.9.3.1.a,b and c.

6.6. Hypothetical Flat-Bottomed Barges in Britain

As noted in Section 5.5 above no flat-bottomed barges have been found in Britain. In fact only one river barge of any sort has been found to date in Britain, the New Guy’s House Boat from the Thames at London. It has sides which curve up, a keel or a keel plank and was pointed at both bow and stern, and is of a completely different shape from European examples (Marsden 1994:101-3, Fig.94). However, with the British Iron Age experience in building logboats, such as the Hasholme boat (see Section II.5, p.44), there seems to be no technical reason why barges of the Zwammerdam type should not have been built and used in early Roman Britain. Their most likely areas of use would be in areas with extensive river systems and sheltered estuaries, where there were industries which would need their relatively low cost and high carrying capacity. Areas for which they would be suitable would be the river systems converging on the Wash, the extensive river systems flowing into the Humber estuary, and possibly the rivers Stour and Orwell and Blackwater and Colne serving eastern Essex and Colchester. On the Thames and Medway they could have had a limited use, but in the Thames only on the upper reaches at London and farther inland. The Thames estuary below Gravesend is too exposed to the sea for this type of craft. On the South Coast they could have had a use on the upper Reaches of Southampton Water and the rivers Test and Itchen, in Christchurch Harbour and on the Hampshire Avon and Dorsetshire Stour, two rivers running into the harbour, and in Poole Harbour and the river Frome. The Severn estuary is too exposed for this type of vessel, as is most of the West Coast of England and Wales. They might have had a rather local use at Chester and the river Dee estuary, and in the Mersey. The most likely location in which to find the transfer of technology for this type of barge would be on the East Coast, with its trading connections with the Rhine. Another very likely area for its use would be on the Wantsum Channel between Richborough and Reculver. In Roman times this was a completely sheltered waterway, rather shallow but navigable, which eliminated the exposed sea passage around the South Foreland into the Thames estuary. It would be an ideal area for the shallow draft but distinctly unseaworthy Zwammerdam barge type.

What sort of cargo and in what quantities would barges of this type carry in Roman Britain? The obvious candidates are heavy materials needed in large amounts such as building stone, bricks, tiles, utilitarian pottery, lumber, coal and possibly grain. The

---

7 The New Guy’s House barge dates to the later second century AD, some 50 to 100 years later than the Zwammerdam barges. It is estimated to have been about 16 m long by 4.25 m wide and with a depth of a little over 1 m amidships, with a cargo capacity of 6 to 7 tonnes.

8 Even today the Wantsum Channel can be navigated in parts in a kayak (personal experience).
presumed cargoes of the Zwammerdam barges with their capacities of 30 to 105 tonnes were building stone (de Weerd 1995:477). Barges could also be used as ferries to move people, livestock and carts across rivers and estuaries. The level of trade and movement up and down the Rhine was almost certainly more intensive than on British river systems. Barges for use in Britain would probably be in the smaller range of sizes, with capacities from about six tonnes, the estimated loads of the New Guy’s House barge (Marsden 1994:104), and the Barland’s Farm boat (McGrail and Roberts 1999:144) up to about thirty tonnes. With a load capacity of thirty tonnes, the total cargo of the Blackfriars Ship I could have been transhipped for movement up the Thames.

In Appendix N the lines and construction methods for five hypothetical Romano-British flat-bottomed barges have been sketched, based on using L shaped chine members, essentially a logboat split in half longitudinally, a planked bottom, L shaped natural crooks as frames and planks to raise the sides. The Late Iron Age British would have been able to construct vessels of this type with their existing tools and technology. The possible availability of large Roman frame saws could be used to produce the planks, or they could equally well be shaped with axe and adze, as was done with the Dover Bronze Age boat (Owen and Frost 1999:10-15). The fastenings would all be clenched iron nails, caulked with moss under their heads, and with caulkling between planks.

6.7 The New Guy’s House Boat

1. Site Location (Fig. II.6.7.1a)
This boat was discovered in 1958 in a foundation trench being dug for the New Guy’s House, close to the south end of London Bridge, in a silted creek dated to the late second century AD by the associated pottery finds (Marsden 1994:97). Small excavations were made in 1960, and the boat was finally scheduled as a protected monument on June 22 1983 (Marsden 1994:97). The boat is a broad barge-like planked vessel, fastened with iron nails, pointed with a sternpost at the north end. Only one end and part of one side has been recovered in the excavations, so that only a tentative reconstruction has been possible.

2. General Construction
The planks, frames and sternpost are of oak (Quercus sp), with a caulking of crushed hazelwood sp. (Corylus avellana) shavings between some of the planks. The planks were fastened with iron nails to the frames. There was a pine tar coating on the exterior of some of the planks. A ceiling or floor of oak planks about 0.02 m thick was nailed to the frames with iron nails, about 4 mm square and 0.102 m long.

3. Planks, Endposts and Caulking
The planks were about 0.025 m thick, laid edge to edge, and cut tangentially from

---

9 de Weerd notes that the Zwammerdam barge no. 6 is “ferry-like” (de Weerd 1978:15).
the log. The excavators presumed that the planks were cut by sawing, although no saw marks could be seen on the timbers.\(^{10}\) No scarf joints were found on the excavated planks, and there were no edge to edge or Mediterranean type fastenings. Some, but not all seams were caulked with hazel shavings and warm pine resin. Caulking was used only where the planks were not a tight fit edge to edge. The ends of the planks were fitted into a rabbet on the endpost. No specific thicker keel plank was noted. The end post was 0.152 m wide at the top, narrowing to 0.114 below frame 2 (Marsden 1994:98).

4. Frames and Floors (Figs. II.6.7.1b and c)

Frames were flat on the bottom and curved 0.52 m up to the surviving top of the side. Frames were spaced at either c.0.432 m or c.0.533 m apart. They had a rectangular cross-section, 0.146 m wide by 0.076 m deep, with some narrowing towards the top. Limber holes\(^{11}\) c. 30 to 38 mm wide and about 5 mm deep were cut diagonally with an inverted V section, which retained the marks of the blade making the cut, most probably an axe or adze. At the end of the boat that was excavated there were separate side frames where the hull narrowed in, with splayed U shaped natural crooks about 0.114 m wide by 0.076 m deep, Fig. II.6.7.2a and b. Two scarfs were noted in the frames, but appeared to be from repairs. Each frame was cut from a quarter of a naturally curved tree branch (Marsden 1994:99-100).

5. Fastenings

The planking was fastened to the frames with flat headed iron nails, about 8 mm square and 0.20 m long. Holes had been drilled before driving the nails and the ends were hammered over diagonally to the frame, alternately towards the bow and stern, and the ends were further clenched, bent over and driven into the frames. The ceiling planks laid over the frames to carry the cargo were nailed with 4 mm square nails 0.102 m long to the frames (Marsden 1994:100).

6. A Reconstruction of the Boat

It seems probable that both ends were pointed. Although only 6.7 m of the north end of the boat was recovered, it was estimated that the overall length was a minimum of 16 m. The beam is estimated at 4.25 m, and by adjusting for the missing upper strake, the depth amidships would be a little over 1.0 m. The configuration of the planks at the surviving end shows that the boat had a modest sheer. The building sequence seems to have been as follows:-

Frames were fastened to a keel or keel plank.
Stem and sternposts were fitted to the ends.
Planking was then carried up from the keel or keel plank across the bottom and up both

\(^{10}\) Alternatively the planks could have been formed by tangential splitting from the log, and then trimmed to thickness and shape with axe and adze.

\(^{11}\) Holes or notches cut in the underside of the floors to allow water to drain to a low point in the hull, from which it can be pumped or bailed overboard. See the Maritime Glossary.
sides, probably alternating between sides to prevent twisting of the hull, and the ends of each plank would be fitted into the rabbets in the posts. The separate side frames and reinforcing U crooks across the bottom at the bow and stern would be worked in as the planking moved up. Finally any extra strengthening at the gunwale would be fitted, and the ceiling planks for the cargo nailed to the tops of the frames.

A number of small isolated bored holes in the planking containing wooden pegs may have been temporary fastenings or fittings to help hold planks tightly in position during construction (Marsden 1994:101-103).

7. Propulsion and Steering

No evidence was found for propulsion or steering. It is possible that the barge was managed using current flow and two long sweeps. Dumb barges or lighters on the Thames into the mid-twentieth century had no motive power, and were navigated while moving with the tide by one man working two long oars, called sweeps, over the sides (Carr 1951:6, and personal observation).

8. Use of the Boat

This vessel is definitely a river barge. The ceiling of planks over the frames provided a platform on which to place its cargo. The pointed ends would make it unsuitable for moving cattle or wagons, unlike some of the Rhine area barges which had wide sloping ‘swimheaded’ ends over which livestock and wagons could be loaded, with the end pushed into the bank (Wilson 1987:41, Fig.26). It would be well suited to carrying general cargoes up and down the Thames. Loading would have been over the sides into the midships area, from low quays. If transhipping a cargo from a seagoing ship, the barge would be lashed alongside, and the cargo from the ship carried or swung over into the barge (Marsden 1994:100).

Using the Boatcad computer programme, and assuming the hull had a density/weight of 35 kg per square metre, Marsden has calculated a weight of 1.862 tonnes for the empty vessel, and a light load waterline of 0.144 m. When loaded with a total of 7.14 tonnes the craft would displace 9 cubic metres on a draught of 0.4 m, leaving c. 0.6 m of freeboard. After allowing for the weight of crew and fittings, Marsden suggests a cargo weight of six tonnes seems reasonable (Marsden 1994:104). I think that Marsden underestimates the weight of the bare hull. Working from the information in Marsden on the size of the various timber components, I have computed the weight of timber and nails to arrive at a bare hull weight of about 2.64 tonnes. This would not compromise his figures on the load carrying capacity of the barge, but would reduce the freeboard, although not by a significant or dangerous level, with a full load.

8. Discussion and Conclusions on the New Guy’s House Boat

This vessel, while still a harbour or river barge is considerably more sophisticated in its configuration and construction than the Zwammerdam type.
6.8 The Blackfriars Ship I

1. Site Location and Preliminary Work

Much more of this vessel has survived than in the case of the New Guy's House Boat. It was discovered in September 1962 in the bed of the River Thames during construction of a new riverside wall at Blackfriars on the north bank of the river. Preliminary excavation was done during low water spring tides in October. Further work was carried out in November, again during low water spring tides. This only gave a 'dry' site for about two hours twice per day. In July 1963, a coffer dam that was part of the civil engineering of the riverside wall project was utilized, thus permitting three days of continuous excavation working twenty-four hours per day to be carried out. The Roman date of the vessel became certain, and public support for recovering and preserving the timbers of the ship became overwhelming. The contractors were very cooperative. The vessel was separated into a number of sections by cutting through the planks across the width of the hull between the frames. Each section was boxed, lifted out and stored under polyethylene sheets in the central courtyard of the nearby Royal Exchange. The timbers were then cleaned and recorded. The after part of the ship remains in situ, on the inshore side of the new embankment wall under the roadway. At some indefinite time in the future, when the embankment needs replacing again, the after part could become accessible and be recovered (Marsden 1994:33-36).

2. General Construction (Figs. II.6.1.2a, II.6.8.1a, and b)

The ship was carvel planked with frames, or more correctly, floor timbers across the bottom planking, and separate side frames overlapping but not joined to the floor timbers. It had no defined keel, but two thick keel planks provided longitudinal strength. The hull was flat-bottomed, so that it could take the ground easily and safely at low water. The stem was at the south or recovered end of the wreck with a stem post 0.3 m wide, and the fore part of the ship had a V profile for cutting through the water, and was more heavily constructed than the stern. The stern post was only 0.15 m wide, and the bottom at the after part of the ship was almost flat. All the planks and frames were of oak (Quercus sp.), while the caulking used hazelwood shavings (Corylus avellana) mixed with pine resin, in a manner similar to the New Guy's House Boat. Some birch shavings (Betula sp.) were also used for caulking. Pegs used in the planking were also of oak. The ship’s planking was fastened to the floors and frames with iron nails, some over 0.7 m long, with cone shaped heads which could accommodate a caulking of slivers of hazelwood with pine resin in the space under the head. There was a mast step about one third of the ship’s length from the bow, but no mast or other components of the sailing gear have survived (Marsden 1994:37-8, 67). A worn coin of Domitian (emperor AD 81-96) minted in AD 88 or 89 was found in the mast step (Marsden 1994:49, Mattingley and Sydenham 1926: Domitian 371) and Roman pottery datable to c. AD 150 was found beside the wreck. Tree ring dating gave a felling range of AD 130-175. Marsden dates the ship to the middle of the second century AD (Marsden 1994:80).
3. The Planking, Caulking and Stem Post (Fig. II.6.8.1a and b)\(^{12}\)

There are no surviving tool marks on the planking. They are from tangentially cut boards, and it is suggested that they were sawn or hewn, rather than split from the log. The two keel planks were about 0.66 m wide and 0.076 m thick, probably cut from trees more than one metre in diameter. The widest surviving part of strake P3 was 0.81 m. Sapwood had been removed by the shipwright. The keel planks were placed with the side nearest the pith of the tree facing outboard. The forward end of each keel plank was tapered in breadth towards the stem, beginning at floor timber 4, and ending immediately aft of floor timber 2. It was presumed that a somewhat similar tapering was done at the stern. The cone headed iron nails used to secure the keel planks to the floors had flatter and thicker heads than the nails used in the side planking, presumably to take the wear and tear when the ship took the ground. This is unlike the St. Peter Port Ship (see Section II.6.10 below), which had the bottom nail heads recessed into the thicker bottom planks. The outer bottom planks were 0.03 to 0.05 m thick. Two narrow planks, P2 and S2, were fitted adjacent to the keel planks, about 0.075 m thick against the keel planks, tapering down to about 0.025 m next to P3 and S3. A chine was formed at the junction of P4 and P5 by an internal angle of about 150° shaped into the floor timbers. Side planking was about 0.05 m thick, fastened to the side frames with cone headed nails. The seams between the bottom planks were up to 6-12 mm wide, and caulked with hazel shavings and pine resin laid across the seams. There was no distortion among the shavings, indicating that they had been placed in position when the planks were fitted together, and that they were not driven into position with caulking irons, the common method in later centuries (Marsden 1994:38-40).

The bottom of the stem post was slotted into the two thick keel planks, P1 and S1. The bottom of the post had a rectangular section, 0.266 m wide and 0.076 m thick, so that its upper and lower faces blended into the keel planks. As the stem post curved upwards it developed a flat inboard surface and rounded outboard face, with rabbets cut into either side to take the ends of the planking. The stem post was secured at the bottom by being fastened to floor timber 3, which in turn was fastened to the planking (Marsden 1994:50). The ceiling planking lining the hold was nailed to floors and frames with a minimum number of short iron nails. This would have made for easy replacement when it became damaged or worn.

4. Frames and Floors (Fig. II.6.8.2b)

The frames and floor timbers at the bow, which needed strongly curved shapes, were made from naturally curved parts of trees, a practice which continues to this day in wooden boat building. The floor timbers across the flat bottom were, in general, shaped from substantial relatively straight logs. The dimensions of the floor timbers are about 0.3 m wide by 0.21 m deep. Limber holes about 0.05 m diameter were cut in their undersides to allow water in the bottom of the ship to drain to the low point for bailing or pumping out.

---

\(^{12}\) For control during excavation, the planking was numbered for each side from the centre line up to the sheer line. The two heavy keel planks were P1 and S1 for the port and starboard side respectively. P2 was the plank adjacent to P1, and so on. On the port side planking the strakes survive up to P11.
The side frames were 0.102 m to 0.127 m thick (the moulding) by 0.152 m to 0.241 m wide (siding), and used naturally curved timber of the required shape. The lower ends of the side frames and the upper ends of the floors overlapped and were both fastened to strake 5, the lower edge of which formed the chine. Floor timber 7 contained the mast socket, which was cut into a raised central portion of the timber, after the hull had been largely completed Fig. II.6.8.1b and Fig. II.6.8.4c. The forward side of the mast socket was reinforced with a board 0.05 m thick.

5. The Fastenings (Figs. II.6.8.3a, b and c, Fig. II.6.8.4a)

The ship was fastened exclusively with iron nails of various sizes. To facilitate driving them through the massive oak frames and floors, 19 mm diameter holes were first drilled through the frames and floors, and each hole was plugged with an oak peg. A smaller hole for the nail was then drilled from the inside through the peg and the relatively thin planking. The nail was inserted from the outside and driven home with caulking under its head, and the end clenched over into the frame or floor, Fig. II.6.8.3a. It appears likely that the slender drill for the nail would break too often when drilling across the grain through the 0.21 m thick oak floor, but could tolerate drilling along the grain in the peg, followed by a short distance through the 0.05 m thick planking. Normally 2 to 5 nails were used to attach a strake to each frame, the number of nails depending on the plank width. The nail shanks were circular in cross-section, about 17 mm diameter, except that about 10 mm of the pointed end was square. Nails had partly hollow heads to hold the caulking material. About half the length of the nail was left projecting from the inner surface of the frame or floor, for hammering over into the timbers and turning the point into the wood. The longest nails were 0.736 m from head to point, and there were 27 to 34 nails in each floor timber. It is estimated that about 1500 nails were used, with a total weight of about 622 kg (Marsden 1994:50-95).

The ceiling planking lining the hold was 0.025 m thick, secured with a small number of short iron nails. Presumably it needed replacing from time to time, and was nailed only lightly in place to make replacement easier. The ceiling planking did not extend beyond the mast step, but was carried some distance up the sides.

6. A Reconstruction of the Ship (Fig. II.6.1.2a, Fig. II.6.8.2a)\(^{13}\)

Length overall has been estimated to be c.18.5 m, based on the measured length of 11.3 m between the heels of the stem and stern posts, and the beam can be fixed at about 6.12 m from the excavated remains. The hold appears to have been about 5.7 m long, and placed fairly centrally in the ship. The minimum height of the hull is estimated to have been 2.85 m above the bottom amidships, with a deck height of c. 2.16 m. This gives a depth of the hold between the ceiling planks and the deck as 1.84 m, a reasonable depth for

---

\(^{13}\) The reconstruction proposed by Marsden in 1967 (Marsden 1967:24-8), is now considered incorrect and has been extensively revised by Marsden in the 1994 publication using information not available at the time of the excavation.
manhandling lighter objects from the hold. One loose knee shaped timber was found in the ship, Fig. II.6.8.4b. It could have supported a deck beam directly, or a beam shelf running along the inside of the hull which would carry a number of beams (Marsden 1994:56-67).

7. Propulsion and Steering

The Blackfriars Ship 1 was undoubtedly a sailing merchant vessel. The ship’s size, weight and configuration make any other form of propulsion impractical. There may have been a few sweeps for manoeuvring in harbour. No mast or steering oars were found with the wreck, but based on comparanda, particularly the Bruges boat, Marsden suggests a mast height of 12.6 m, and that it was probably a single pole (Marsden 1994:68, 70). The sail could have been a square sail on a horizontal yard with brailing lines, the type common in the Mediterranean, but with the known position of the mast this would tend to limit efficient sailing to times when the wind direction was from aft to about sixty degrees either side of directly astern. A spritsail, Fig. II.6.8.5, would have given much better balance, and even a modest performance to windward, with the wind forward of the beam. There is practically no iconographic evidence for sails from northern Europe, which contrasts with the hundreds of reliefs and mosaics from the Mediterranean area, but sprit sails were known and used in the eastern Mediterranean and Aegean by the second century BC (Casson 1995:244, Figs. 176-179). The earliest known depiction of a sprit sail from northern Europe is from a manuscript dated to c. AD 1420 (Carr 1951:29, Pl.1). Marsden thinks that the Blackfriars Ship 1 probably had a square sail, and that, unlike the Kyrenia II ship replica from the Mediterranean, “...the Blackfriars ship was probably only really effective with a following wind.” Marsden 1994:73. The sail would have been about 8 m x 8 m, with an

---

14 One hundred adult male skeletons from the Trenholme Drive Roman cemetery at York gave an average height of 1.7 m (RCHM 1962:10). Men of this height could comfortably manhandle cargo from a hold 1.84 m deep.

15 The problem with a square sail on a mast one third of the ship’s length from the bow is that the centre of effort of the sail and the centre of lateral resistance of the hull are not in line. This forms a couple (two equal unlike parallel forces, whose lines of action are not the same and which can only be balanced by another couple) which, unless the wind is more or less directly aft, forces the ship to turn to bring the wind aft. This effect can be counteracted to some degree by a heavy use of the immersed quarter rudder, but with the rudder at a large angle to the direction of travel, the rudder is heavily stressed, and in fact the Kyrenia replica suffered rudder breakage. For any sailing vessel the ideal condition of balance is with the centre of effort of the sails and the centre of lateral resistance very nearly in line, when the rudder will be aligned with the centre line of the hull, and very small movements with minimal stress on the rudder will keep the vessel on course.

16 The replica of the Kyrenia ship from the Mediterranean sailed well “...even while close-hauled 50° to 60° off the wind was still able to make over 2 knots.” A ‘couple’ would be set up between the forces acting on the centre of effort and the centre of lateral resistance. This “...would put considerable pressure on the rudders as they kept the ship on course, and may have been responsible for the breaking of a rudder while sailing close-hauled in strong winds.” (Marsden 1994:73). A further point is that the Kyrenia ship with its
area of 64 square metres. The rudders would likely have been similar to the one found with the Bruges boat, Fig. II.6.8.6.

7. Construction

The planks were cut tangentially from heartwood logs, either by sawing with large frame saws, Figs. I.1.4.1. and I.1.4.2 (D’Ambra 1998:79, Fig.47; Meiggs 1982:Fig. 14d), or possibly by splitting tangentially from the log and then hewing with axe and adze. The floor timbers were hewn from substantial whole logs, while the side frames were shaped with axe and adze from smaller naturally curved grown timber. The one knee found was made from the junction between trunk and a branch, Fig. II.6.8.4b. The hull could either have been built on stocks or supports raised at least 1.3 m above ground level, to provide clearance for driving in the 0.736 m long iron nails fastening the bottom planks to the floors, or built over a rather deep pit. The two keel planks would be laid down first and some floor timbers installed to hold the two planks together. During construction temporary pegs would be driven into holes drilled into the planks, and used to pull the edges tightly together with lashings. The stem and stern post, supported by temporary braces, and more floor timbers and bottom strakes would be added. Once all the floor timbers were in place, strakes P5 and S5 at the chine could be added. The side frames would be attached to P5 and S5 and temporarily supported with props and battens while the rest of the side strakes were added. Finally the decking and upper works would be completed and the ceiling planks installed (Marsden 1994:76-9). Each nail would be driven partway through its pre-drilled hole in planking and frame, then a short hook would be formed on the end, the nail driven fully home with the caulking under the head, and finally the protruding part inside the hull would be hammered down in a herring bone pattern on the inboard face of the floor or frame, and the hooked end hammered into the timber to hold the nail firmly. Nailing would be a two man operation, a skilled ‘clencher’ or ‘clincher’ on the inside doing the more skilled work, and a ‘holder’ (or ‘helder or ‘hayller’) first driving the nail part way in, then holding the head of the nail firmly against the planking with a shaped dolly or hammer, while the clencher hammered the nail over and into the frame. 18

8. Crew Size, Cargoes and Voyages

Marsden estimates a crew size of three men, which seems adequate for coastal and short

---

17 To drive an 0.736 m long nail with a heavy hammer would require a pit at least 2 m deep to obtain a reasonable swing with even a short handled hammer.

18 In AD 1295 clenchers were paid 2½d per day, and the holder 2d in medieval England (Friel 1995:43-44).
seagoing voyages to the Rhine or across the Channel. No living quarters or domestic items were found, but would most likely have been aft of the cargo hold. When sunk, the vessel was carrying a cargo of Kentish ragstone from the River Medway in Kent. A partly finished millstone, which appears to have come from outcrops around Namur on the River Meuse valley in Belgium, was found in the forward part of the ship ahead of the cargo hold, see Fig. II.6.8.1c. The fact that it was only roughly cut militates against it being part of the ship’s equipment, and it was probably left over from some previous cargo. The ship had quite severe damage from the *Teredo* ship-worm, and incipient damage from the *Limnoria* or Gribble worm. *Limnoria* cannot live for long in water with a salinity of less than 16-20 parts per 1,000, while *Teredo* need a salinity of at least 5-9 parts per 1,000. Seawater salinity is 35 parts per 1,000. The damage must have occurred while the ship was making coastal or seagoing passages, since low salinity kills *Teredo* in about fourteen days. Waterfront structures in Roman London have no *Teredo* damage, so the salinity was too low in Roman times for *Teredo* to survive more than a short period while the vessel was discharging or loading cargo. The conclusion must be that the ship spent most of its life in seagoing and coastal voyages and in saltwater estuaries (Marsden 1994:80-88).

The size of the ship, as noted earlier, was length overall 18.5 m, beam 6.12 m, lowest height of gunwale 2.86 m, deck height 2.16 m, with a total weight of hull, deck and superstructures of 29.73 tonnes. From stability considerations, the maximum cargo weight would be about 50 tonnes of a high density (low centre of gravity) cargo, such as dressed stone. Other possible cargoes would be twelve large wine barrels weighing 15.34 tonnes, 18.36 tonnes of grain or 36.4 tonnes of loose ragstone. (Marsden 1994:89).

9. Discussion and Conclusions on the Blackfriars Ship

This ship was a well built sturdy small merchant vessel, capable of trading voyages around the southern and eastern coasts of Britain. In moderate weather conditions it could safely make cross-Channel voyages and voyages to the Rhine. The quality of the shipwrighting appears to have been quite high. There are no obvious gross errors in the fit between the various timbers, and some of the technology is quite sophisticated, for example the use of oak pegs in the frames to facilitate drilling the holes for the nails (see page 61).

---

19 In the nineteen-twenties, West country sailing ketches and schooners with carrying capacities of 100 tonnes or more sailed with a crew of three men (Eglinton 1990:4-7).

20 Of 32 millstones found in the maritime part of the port of London, 3 were of British origin and 29 were imported stones, probably from the Rhine (King 1986).

21 The *Teredo* can close the entrance to its burrow in the ship’s timbers with a pair of paddle shaped plates, and remain inactive for some time (Turner 1963:946).
6.9. The Barland’s Farm Boat

1. Site Location and Preliminary Work

   The Barland’s Farm Boat is a Romano-British vessel which was found in the Caldicot Levels, part of the Gwent Levels, a low lying alluvium area on the north shore of the Severn Estuary, protected today by seawalls and banks, Fig. II.6.9.1. The boat has been dated by dendrochronology to the late third century AD. The site today is about 3 km from the shore line of the Severn Estuary. It was found in November 1993 during site preparation for a new supermarket distribution centre. The boat when found was orientated north/south, with the incomplete northern end, the stern, resting on a third century timber and stone structure beside a stream, which in Roman times flowed south into the Severn. The boat was located about 2 m below overlying clays and silt, in a silted up paleochannel. In late November-December 1993, Tesco Stores Ltd., the owners of the site, provided funds to excavate and record the wreck as found, and to dismantle and remove the remains for further study and preservation. The surviving timber was generally in good condition, but the iron fastenings were severely corroded, which fortuitously allowed for easy separation of floors, frames and planking when the remains were lifted. Floors and frames were removed first, and then the planking was cut into lengths which could be handled. The removed timbers were being conserved at York as of 1999, and in due course will be returned for display in the Newport Museum (McGrail and Roberts 1999:133, Nayling, Maynard and McGrail 1994:597).

2. General Construction

   The boat is carvel planked and flat-bottomed, with the planking nailed to the massive floors and frames with clenched iron nails. It is an open boat with a mast step, intended for both sailing and rowing, and suitable for operating on and around the Severn Estuary. As reconstructed it is 11.4 m length overall (LOA) x 3.16 m beam x 0.90 m deep (McGrail and Roberts 1999:137). Its draught is shallow enough that it could navigate up the local rivers to centres such as Gloucester and Bath, but it is also seaworthy enough to voyage around the Severn Estuary and the upper reaches of the Bristol Channel, Figs. II.6.9.2a and b, II.6.9.3, II.6.9.4.

3. The Planking, Caulking and Stempost

   The planking was sawn and fitted edge to edge, but the planks are not fastened to each other. Planking and all the timber is oak (Quercus sp). There is no defined keel, the longitudinal strength being provided by two thick keel planks about 0.065 m thick, giving the boat a flat bottom. The planking was held together by the framing of floor timbers and frames. Planking was nailed to the floors and frames with iron nails, driven from the outside through pre-drilled oak treenails (McGrail and Roberts 1999:135), a similar technique to that used for the Blackfriars Ship. The two keel planks, P1 and S1, were shaped from tangentially cut half logs, and taper in breadth along their length as the parent tree did. At both ends on the upper surface are rabbets to take the stem- and sternposts. The side planking is generally fashioned from planks 4 m to 5.5 m long in the centre of the hull, butt-jointed over frames with shorter pieces running to the ends. The butt joints are
staggered by between 0.5 m and 1.15 m in adjacent strakes. Caulking between the planks was a mixture of macerated wood with tar or resin, and was applied to the edges of the planks before they were fastened into position, cf. the Blackfriars Ship 1. Apart from the two thick keel planks, P1 and S1, the bottom consisted of two more bottom planks, P2 and S2, about 0.035 m thick, and two short stealer planks at the bow. These bottom planks defined the general outline of the plan of the boat. On the port side parts of five more strakes survived, P3 to P7, the lower two running almost the full surviving length of the hull. On the starboard side only parts of three strakes, S3 to S5, remained. The stem post curved upwards from a short horizontal length where it joined the keel planks. Its lower end was fastened into the rabbet on the end of the keel planks. The sides of the stem post were rabbeted to take the ends of the strakes. The stern post had been removed in antiquity, but was probably similar to the stem. The boat was definitely double-ended, pointed at both ends. (McGrail and Roberts 1999:133-35, Nayling, Maynard and McGrail 1994:601-2).

4. Frames and Floors

The framing is substantial and quite closely spaced, the centre to centre distance between floor timbers being about 0.56 m. On average framing timbers are about 0.09 m moulded (thickness at right-angles to the planking) by 0.125 m wide. Spacing of the timbers varies from between 0.40 m to 0.60 m. Limber holes are cut into the bottom of floors over both the keel planks. Floor timbers were recovered from almost the full length of the boat. The side frames overlapped the floor timbers, but were not fastened to them. The floor timbers were a mix of one piece timbers running from side to side across the bottom and a short way up the sides, while others were L shaped and installed side by side in pairs, with the long leg of the L across the bottom planking and the short leg forming a side frame running up to the gunwale. The shape of these pieces showed that above the flat bottom the sides were “...gracefully curving flared sides” (McGrail and Roberts 1999:133). The separate side frames, few of which survived, were fitted adjacent to the one piece floor timbers, the side frames on the port side being forward of the floor timber and the starboard side frames being aft of the floor timber. Abreast the fore and aft mast step timber, which was fastened on the centre line to the floor F6 and the pair of half frames F7 about one third of the waterline length from the bow, were two additional inter-frame side frames. Floor timbers in the bow have a section cut from their lower face to fit over the stem post (Nayling, Maynard and McGrail 1994:602).

5. The Fastenings

The fastenings were all iron nails, mostly in a very deteriorated condition. In disassembling the boat the floor timbers were lifted out without seriously damaging the planking beneath. Of two nails recovered during excavation, one had a rounded cross-section and the other a square cross-section. “The nails are badly corroded where they emerge on the inboard surfaces of the framing timbers, but they appear to have been clenched by turning the point through either 90° or 180°.” (Nayling, Maynard and McGrail 1994:602). Unlike the Blackfriars 1 Ship, no complete nails were recovered. Their length has to be deduced from the thickness of the planking and timbers.
6. A Reconstruction of the Boat

The hull reconstruction was made in several stages. All the remains were measured and recorded in the field, with scale drawings, photographs and photogrammetry (Nayling, Maynard and McGrail 1994:599). After excavation each timber was examined and individually recorded at 1:5 scale. From these records a 1:10 scale model was built of the recovered material, and dismantled and reassembled a number of times until a best fit was obtained with the records from the excavation, see Figs. II.6.9.2a and b. Drawings of the reconstructed boat were then made and faired, Fig. II.6.9.3. This gave dimensions of 11.4 m x 3.16 m x 0.90 m, with both bow and stern pointed, but the stern with a rather fuller section. In the reconstruction, as well as replacing all the missing strakes and framing, three cross beams were added at F6/7, F10 and F14, supported by a beam shelf along both port and starboard sides. Open boats of this size require cross beams to hold the sides at a fixed distance apart, and the beam shelf helps resist the hogging and sagging stresses due to wave motion when operating at sea or an open estuary (McGrail and Roberts 1999:136-8).

7. Propulsion and Steering

The boat could have been poled or punted, paddled, rowed or sailed, but most probably made use primarily of sail, with occasional use of oars in calms and for manoeuvring in harbours, and of poling in shallow water or narrow winding creeks. The mast step could take a mast about 0.09 m diameter or 0.06 m square, and is about one third of the boat's length from the bow. A fore and aft sail, such as a spritsail or lugsail would be the most effective rig, although as noted in Section II.6.8, there is scant evidence for their use in northern waters before the early medieval period. There is one tomb relief from the Rheinisches Landesmuseum, Trier, dating to the 2nd-3rd century AD showing a battened sail, possibly of leather, which might be interpreted as a dipping lug (Casson 1994: 135, Fig. 100). In the reconstruction McGrail and Roberts have proposed a dipping lugsail of 25 m² on a 6.00 m mast of 0.09 maximum diameter Fig. II.6.9.4. With one quarter or so of its area before the mast, this would give a rig with the centre of effort close to the centre of lateral resistance. The mast would benefit from, or possibly need, a shroud on the weather side to provide support. For poling in shallow water, poles of 3 to 4 m in length would work satisfactorily. Oarsmen could have sat on the cross beams, or in calm conditions stood facing forward and pushed on the oars. No signs of fittings for oars remained on the excavated hull, but simple rope grommets on an extended side frame could have been used for the pivot point. For steering, either a quarter rudder or steering oar could have been used, but for this type and size of boat in northern waters, a steering oar seems more likely (McGrail and Roberts 1999:138-40).

When under sail with between 2.57 and 6.57 tonnes of cargo the vessel could be sailed in winds of up to Force 4 (15 knots), and in wave heights of 1-2 m. Based on twentieth century data, from April to September winds of this strength or less would occur for 75% of the time in the Severn estuary and Bristol Channel. In good conditions a speed

---

22 See the Maritime Glossary. Fairing is the process of checking the various drawings of the ship's hull, the cross-sections, the plan views and the side elevations so that they all agree.
of 4 to 5 knots under sail would be expected. Under oars two men could propel the boat at between 1½ to 3 knots, depending on the weight of cargo carried (McGrail and Roberts 1999:142).

8. Crew Sizes, Cargoes and Voyages

With a crew of three it is estimated that the Barland’s Farm Boat could have carried:
- 15 medium-sized barrels of wine; or
- 90 sacks of grain; or
- 4½ tonnes of coal or salt in sacks; or
- 4½ tonnes of iron, slate, or stone laid on dunnage in the bottom;\(^*\) or
- 50 sheep or 8 cattle.

The routes on which the boat could have been used include voyages to and from the forts and other military installations, and the civilian towns and settlements on both the north and south shores of the Severn Estuary and Bristol Channel. Villas and settlements up the various tributary rivers, such as the Avon, could be visited. The Barland’s Farm Boat could also have been used in the distribution of the Dorset BB1 pottery, which is found in quantity at many sites in the Severn area, brought overland from Poole, using both river and land transport. Formal harbour facilities would not be necessary for a flat-bottomed boat of this size. She could be beached on a flood tide or anchored in shallow water at low tide, and goods could be landed in smaller boats, or transferred directly into carts, or carried ashore by pack animals or people (McGrail and Roberts 1999:142-4). This was done in the early part of the twentieth century in this area (Greenhill 1988: Figs 27 and 108), Fig. II.6.9.5.

In winds of Force 4 or less, the boat could sail along and across the Severn Estuary and upper Bristol Channel as far west as Cardiff and Bridgewater. Use would be made of favourable tidal streams, and the vessel would anchor for up to six hours to wait out a foul tide. In the right conditions she could make a passage across the St. George’s Channel to Ireland. Based on the recorded experience of early twentieth century small sailing trading ships in and around the Bristol Channel, average speeds made good between the point of departure and destination varied from 2 knots to less than a ½ knot (Eglinton 1990, McGrail and Roberts 1999:145).

9. Discussion and Conclusions on the Barland’s Farm Boat

The Barland’s Farm boat was a sturdy small open boat for carrying cargoes of modest size up and down and across the Severn estuary and its tributary rivers. Although it could with some risk have made seagoing voyages in good settled weather, it seems probable that it would have normally been used for river and short coastal voyages only. A crew of three would be convenient, but in fairly sheltered areas two men could have handled her quite comfortably. The third hand would be useful on longer voyages, or if much rowing and poling were anticipated. Whenever possible the boat was probably sailed,

---

\(^*\) No traces of ceiling planks were found in the vessel, so dunnage of some sort would be needed to protect the planking.
with rowing limited to calms and manoeuvring in confined waters. In shallow winding rivers poling was probably the most convenient means of propulsion.

6.10. The St. Peter Port Ship

1. Site Location and Preliminary Work

The wreck of the ship was discovered on Christmas Day 1982, by a professional diver, Richard Keen, who was diving for scallops in the harbour mouth at St. Peter Port on the island of Guernsey, the second largest of the Channel Islands group. He noticed the ribs of a wooden ship sticking out of the bed of the harbour. It appeared to be flat-bottomed and about 20 m long. At first the wreck was thought to be that of a nineteenth century stone barge. In the following year more of the wreck was exposed, Roman tiles were noticed scattered about the wreck, and its antiquity was recognized. During 1984 the wreck was visited several times, and it was noticed that it was being further exposed and destroyed. Timber from the hull was radio-carbon dated, and gave a date of c.AD 110 +/- 80, although this was later amended to c. AD 280-7. During excavation stratified pottery sherds gave dates of c.AD 275 and the coin assemblage of some 80 coins had a tpq of AD 270. The wreck probably occurred in the early 280s AD (Rule and Monaghan 1993:129). In 1984, as soon as the further damage to the wreck was realized, the remains were immediately covered with tarpaulins and sandbags to prevent further deterioration until a rescue excavation could be organized. A number of other wrecks are also scattered around the harbour area and its environs, but none is of Roman date. In 1982 the car ferries to the island were replaced by larger and more powerful ships, which barely cleared the harbour bottom at low water, and this was undoubtedly a major cause of the imminent destruction of the ship. Two main campaigns of excavation took place in November 1984 and March 1985, with a short third campaign in September 1986 (Rule and Monaghan 1993:6-7).

Gallo-Roman settlements are known on Guernsey and the other Channel Islands, although until the third century AD with the increase in Saxon piracy, Roman interest in the islands appears to have been slight. To date pre-Roman sites have attracted the most attention from archaeologists (Bender 1986:221-24). In the second and third centuries Roman activity in the area increased as evidenced by the finds of Gallic and British imported pottery. Pottery on the Islands is mostly imported, indicating both local and cross-Channel trading links.

The wreck was lost when it caught fire. Part of the cargo was pine resin which burned and melted during the fire, and set into a solid mass when the vessel sank after burning to the waterline. This pine resin or pitch encapsulated the remains of the hull and its contents, and together with rapid burial in the harbour mud and silt provided a secure anaerobic context, allowing excellent preservation of the organic material.

2. General Construction

The ship was a merchant vessel with timbers entirely of oak (*Quercus* sp.). It was

---

24 In the excavation report this pine resin, heat modified by the fire, is referred to as pitch.
flat-bottomed with three substantial keel planks, T1, T2, and T3, forming the bottom. The three keel planks and the bottom and side strakes were nailed to substantial floor timbers. Fig. II.6.10.1. Of the forty or so original floors, twenty-three were recovered more or less intact, and fragments of others were found. Side frames were inserted between each pair of floor timbers, but only a few were found in situ, together with scattered fragments of others. The planking of the hull was 0.05 to 0.07 m thick, with a mean thickness of 0.06 m. The majority of the recovered strakes were from the bottom of the ship. There was a fairly liberal use of short stealer strakes in the planking at the ends of the hull. The bow of the ship is missing, but the stern post has survived to a length of 3.73 m. Caulking was used throughout the hull at the joints between planks, and where necessary, between other timber components. Moss caulking was used under the heads of the iron nails. Overall what has been recovered is a substantial part of the ship’s bottom, part of the stern post and some of the ship’s side, plus quite a wide range of artefacts and some non-artefactual material such as cereal grains and insect remains. Up to this point no general reconstruction of the ship has been published, although much further work is planned when funds and personnel are available (Rule and Monaghan 1993:33, 71-124).

3. The Planking, Stern Post and Caulking

Lacking a true keel the ship depended on three thick keel planks for the longitudinal strength of the bottom. All three are butted together without scarfs in the length, and were held together by massive closely spaced floors. The keel planks were 14.05 m long, with a thickness ranging from 0.14 m to 0.11 m. The assemblage of three planks was 1.21 m wide amidships, tapering to 0.74 m at the stern and 0.93 m at the bow, Fig. II.6.10.2. The keel planks and all other strakes were removed tangentially from the log. The garboard strakes were fitted flush with the inner face of the keel planks, but being only 0.06 m to 0.09 m thick, the keel planks projected below the rest of the bottom, and the outer two keel planks show wear from beaching on their outer edges, Fig. II.6.10.3. There is an angle of about 5° between the keel planks and the garboard strakes, which was filled with caulking material. The keel planks were fastened to the floor timbers with iron nails driven through pre-drilled holes. The nail heads were sunk into 0.07 diameter depressions in the underside of the keel planks, presumably to protect the nails from abrasion when the boat was beached. This was peculiar to the keel planks, as the remainder of the planking was fastened with iron nails with the heads left protruding from the planks’ surfaces, Fig. II.6.10.4a. The central keel plank had a clear incised line along its full length, with setting out marks cut across this line at the approximate position of the floor timbers. The 24 marks correspond with floor positions along the keel, at 0.55 to 0.58 m spacings. The central keel plank T1, has a small piece, T1.10, let into it at the starboard bow, presumably replacing a knot, split area or other defect in the plank, see Fig. II.6.10.2. This inserted piece is not a repair, but part of the original construction. T.1.10 is caulked along all four edges. The central keel plank is 0.45 m wide at the stern and tapers evenly to 0.32 m wide at the bow. T2, the port side keel

---

25 A narrow timber that does not run the length of the hull, fitted between two planks: often used at the bow or stern to avoid excessively narrow ends on the planks.
plank is 0.21 m wide at the stern, 0.31 m at the bow, and 0.40 m amidships. The end is cleanly sawn with two to four nail holes for each floor. T3 the starboard side keel plank is 0.28 m wide at the stern, 0.29 m wide at the bow with a maximum width of 0.43 m, see Fig. II.6.10.2. The remainder of the hull planking was from 0.05m to 0.07 m thick (Rule and Monaghan :29-31). Most of the recovered hull planking is from locations below the floor timbers, with only fragmentary pieces from the sides of the hull. All the planks were tangentially sawn Fig. II.6.10.5, and then trimmed with the adze.26 All planking was caulked and fastened to floors and frames with iron nails up to 0.79 m long driven through pre-drilled holes (Rule and Monaghan :79). Strakes when made up of more than one piece were butted beneath a convenient floor timber. Conical rings of moss caulking were used under the partly hollow cone shaped nail heads. At the end of the keel short stealer planks were butted against the keel and fitted into a rebate in the stern post for part of their length, then twisted to fit against the outboard face of the post. The inside face of the stealer was heavily shaped to fit snugly. The next two strakes, T7 and T8, are notched to fit around the ends of the outer keel planks, and then butt up against the garboard strakes for the rest of their length. Planking and stealers were then continued around the hull, up to the fourth strake, the highest surviving piece of hull planking. The saw marks on the surface indicate that it was sawn from both ends, with the saw cuts overlapping in the centre (Rule and Monaghan :50-63).

The stern post has not survived, but from general considerations on the shape of the hull, was probably fairly similar to the surviving stern post, but probably somewhat more massive. The surviving part of the stern post is 3.73 m long, tapers from 0.48 m wide at the keel to 0.26 m wide at the surviving outboard end. The upper part was broken off at a point where seven holes had been drilled through it, probably recently, as the marks of the drill bit suggest a twentieth century tool.27 At the keel the cross-section is rectangular, with the first 0.18 m of the length being flat before it starts to curve upwards. For the first 2.33 m tapered rabbets are cut into the post to take two short stealer planks, T 5 and T 6. Above this point a step was cut into the outer face of the post, and the sides were bevelled to take the planking curving in towards the stern, Fig. II.6.10.6a, b, c, and d. From the adze marks on all surfaces, the post was shaped, possibly with an axe initially, and then with an adze for the final shape and surface finish. The bottom of the stern post was simply butted against the end of the keel with 3 mm of caulking at the keel and up to 13 mm at the junction with the garboard strakes. The stern post was secured in position by nailing to the aft floor timbers, T51 with 5 nails and T52 with 4 nails driven from the outside, and with the heads countersunk into the post. T53 was fastened with 2 nails driven from the inside, one of which projected slightly from the post, and T54 also nailed with 2 nails from the inside which went right through the post. T55 was also fixed with two spikes from the

26 A number of the planks have preserved clear saw marks on their surface, unlike the Blackfriars 1 Ship, where sawn planks are inferred, but not certain.

27 “Given the clarity of the drill marks, it is likely that this damage is a twentieth century attempt at removing an underwater obstruction, possibly undertaken during the Second World War.” (Rule and Monaghan 1993:15)
inside.

Caulking filled all the seams in the ship’s hull planking. Large amounts were recovered, wedged shaped from where it had fitted into the seam, with a flattened T shaped edge where it had protruded from the hull. Caulking was up to 0.02 m thick at the outboard edge, although 0.008 m to 0.012 m was normal. The caulking has a braided appearance on one face, while the other is flattened and has the impression of the edge of the timber impressed on it. This suggests that the caulking was applied to the edge of the plank before it was fastened in position. It was not driven into the seam after fastening. In the hull the caulking was applied from bow to stern. The actual caulking material has not yet been identified, but was probably similar to that used on the Blackfriars Ship 1. Caulking beneath each nail head was a ring of moss, Fig. II.6.10.4a, fitting into the partly hollow conical head (Rule and Monaghan :25, 50, 63).

4. Frames and Floors

The massive floors are of oak, and in general are shaped from naturally curved pieces of timber. The thickness generally varies from 0.20 m to 0.22 m, and the width from 0.30 m to 0.53 m, with the majority being at the 0.50 end of the range, and they taper in width towards the ends as they rise up the sides of the hull. The cross-section is rectangular, but tending more to a square cross-section towards the ends as the width narrows. Semi-circular limber holes, about 0.06 m wide were cut into the under sides over the keel planks, and some preserve the marks of chisel or adze, Fig. II.6.10.4b. One floor, T32 was larger, 0.60 m wide and about 0.40 m thick in the centre, and contained the mast step, but with the top edges bevelled down away from the hole for the heel of the mast, Fig. II.6.10.8.

Only four side frames were found in situ, fitting tightly between the floor timbers. All display prominent tool marks (adze type marks), and are shaped with a twist along their length to conform to the run of the planking. Fourteen others, or fragments of them were found loose, mostly showing tool marks where the surface has not been eroded by gribble (Limnoria sp.). One Teredo burrow noted was filled with pitch, showing that it was present before the fire which destroyed the vessel. The upper ends of some of the frames were charred from the fire. In general, because of the mode of destruction by fire, the recovered timbers are all from the bottom and lower parts of the hull. The side would originally have been up to 2 m high. The strakes were fixed to the frames by nails driven from the outside and clenched. Generally the grain follows the shape of the frame, and they were probably cut from selected naturally curved pieces of timber. In cross-section the surviving material is squarish, ranging from 0.12 m to 0.23 m thick and probably tapering somewhat in section as they rose up the sides (Rule and Monaghan :65-68).

5. The Fastenings

From the corrosion products remaining it is certain that the ship was fastened entirely with cone headed iron nails. All the nails had corroded away, but their shape and size was preserved as a ‘ghost’ shape in the concretion formed by the corrosion products. No metallic iron was left. Nail heads are roughly conical, in some cases partially flattened when being driven into the wood, Fig. II.6.10.9. The shanks are about 0.02 m diameter at
the strake, and about 0.012 m to 0.018 diameter where they leave the floor timbers. The cross-section is roughly circular at the head, some have an octagonal section along the length, and the last 0.03 to 0.04 m are square in section, c.0.006 to 0.008 m across. The nails are very similar to those found with the Blackfriars Ship 1. In rare case a wooden dowel was placed in the nail hole, possibly when repairs were being made. Nails through strakes and floor timbers ranged from 0.32 m to 0.69 m long. Nails through the keel planks and floors varied from 0.41 m to 0.73 m. The maximum length of the clenched part of a nail was 0.40 m. On average there were 33 nails per floor timber, giving c.1260 nails in total for the lower part of the ship. An average nail weighed c.1.2 kg, giving a total of over two tonnes of nails for the hull (Rule and Monaghan :79).

6. A Reconstruction of the Ship

To date a formal reconstruction is still pending, but Rule and Monaghan have made some preliminary observations: “The ship was a merchant vessel, originally some 25 m in length, with a maximum beam of some 6 m and a height to the gunwale of at least 3 m, possibly more.” (Rule and Monaghan :127). As noted previously, the ship was built entirely of oak, and was almost certainly double-ended. The planking was carvel with the strakes butted to each other with caulking between adjacent strakes. Narrow stealers were used quite extensively between the broader strakes, both to help with the curvatures of the sides, and to avoid feather ends on the strakes where they ran into the end posts. Side frames were fitted between the floor timbers. “Numerous minor constructional errors occur in the ship and a casual crudeness is evident wherever a watertight fit was not required.” (Rule and Monaghan :127). The hull is not exactly symmetrical. However, the ship is quite functional, if not exactly elegant.

On the internal arrangements in the ship, the evidence is from the artefacts found with the hull. Various fragments suggest that there was an after-hold with a galley above it (Rule and Monaghan :128). Pottery was found in the hypothetical galley area, directly over the last two floor timbers. Other finds suggest that the crew’s quarters were aft. Some 200 fragments of low fired ceramic were recovered and tentatively these have been identified as the remains of a hearth or oven (Rule and Monaghan :92). From the pottery sherds found in the after part, reconstructed vessels include 2 amphorae of Dressel 30 form, 4 Gallic flagons, 3 Black Burnished ware cooking pots, a mortarium, a Nene Valley beaker, a cup, 1 coarse and 2 fine flanged bowls, and fragments of several other vessels including one or two more amphorae (Rule and Monaghan :81). The mortarium is almost certainly from East Anglia (Rule and Monaghan :87). Other ceramic materials associated with the wreck were Roman tiles, both tegulae and imbrices, square pedales and at least two box flue tiles (Rule and Monaghan :87). Wooden objects included a lantern base, bowls, a spatula, a spoon blank, various handles and wedges. Cordage fragments preserved in the melted pitch include a length of three strand cable 21 cm in circumference plus various smaller sizes of cordage down to two strand twine 2 cm in circumference. Fragments of barrels or casks were recovered from the after end of the ship, with oak staves and hazel hoops. The staves were of varying dimensions suggesting several barrels of different sizes, rather than many fragments from one barrel. Parts of a Roman style rotary quern, were found, dating to after the second century, and possibly made from quartzitic sandstone outcrops in Normandy or
Brittany (Rule and Monaghan :99).

7. Propulsion and Steering

There would have been a single sail on a mast c.13 m high, stepped about one third of the hull length from the bow. A possible mast partner was found among the miscellaneous timber, which suggests a decked vessel.\(^{28}\) There was no evidence for rudders, but they would have been essential, and certainly of the quarter rudder type. As with other similar northern European vessels of this period, an unanswered question is whether it had a square sail, or a lug or spritsail?

8. Crew Size, Cargoes and Voyages

The amount and types of pottery suggest a crew of three, almost certainly civilians, as nothing of a military or naval nature was found with the ship. This crew size fits quite well with nineteenth and early twentieth century sailing vessels used in coastal traffic around Britain and across the Channel, see footnote 19 above. Thames barges carrying over 100 tonnes of cargo had a crew of two, the master and a mate, and the West Country ketches sailed with a crew of three (Carr 1951:1, 254, Greenhill 1988: 259).

There is little direct evidence for the cargo at the time of the wreck, except for the pitch. Most of the artefacts and other material recovered were either ship’s equipment or the personal possessions of the crew. The pitch, the heat modified pine resin, was originally in blocks c.0.23 x 0.48 x 0.30 m, weighing about 52.2 kg each. A number of intact blocks were found, as well as the melted mass that entombed the ship’s remains. About half a tonne was recovered, and much more must have been burnt in the fire or lost over the succeeding centuries. The quantity exceeded anything needed for the maintenance or operation of the ship, but was not enough for a full cargo. The overall impression is of a vessel engaged in moving mixed cargoes around the Channel area from Gaul, Britain and the Rhine, and possibly as far away as Spain. It was not a locally built vessel from Guernsey. Oak timber of sufficient size to build the vessel does not grow on Guernsey, so she was probably built on the Channel coasts of Gaul or Britain. The coin assemblage of some 80 coins found with the ship is either northern Gallic or British (Rule and Monaghan 1993:130).

9. Discussion and Conclusions on the St. Peter Port Ship

This vessel is definitely a seagoing and coastal trading vessel, probably operating in the Channel between Britain and Gaul, and in the southern North Sea between the Rhine and the East Coast of Britain. It could have voyaged as far as Spain. It is very heavily constructed, but the workmanship seems to be inferior to that of the Blackfriars Ship in the fit and joining of the various components. The overall impression is of a vessel built by a group who were not full time shipwrights. Elements such as the floor timbers appear to have been given the minimum shaping to fit the mating surface with the planks, but otherwise crudely trimmed. As noted by Rule and Monaghan, there are a considerable

\(^{28}\) Mast partner: A timber supporting the mast where it passes through the deck.
number of errors and "a casual crudeness" is evident in most of the workmanship.

6.11. The County Hall Ship

1. Site Location and Preliminary Work

This wreck was found in February 1910, when the County Hall Building in London was under construction. The site is on the south bank of the Thames, between Westminster Bridge and the next bridge upstream, the Hungerford Bridge. The remains were excavated and recorded by London County Council staff. The ship’s remains, after being left exposed until August 1910, were removed as a unit on a substantial wooden cradle, and taken to the new London Museum, and placed in a temporary exhibition annexe. By then the timbers had suffered serious degradation from the lack of any effective conservation measures, and much of the damaged timber was replaced with painted plaster. About 1913 the ship was transferred to the basement of Lancaster House where, after further patching with plaster, it remained until 1978. At its new location it was set up in a display mimicking the river bed site where it was found. During the 1939-1945 war the boat suffered further damage, not from enemy action, but from various groups using the basement of Lancaster House for civil defence and other purposes. In 1978, the Museum of London, the successor to the former London Museum, decided to dismantle the damaged remains, and place them in storage. It was found that most of the remains consisted of plaster mixed with wire, rags, and only small pieces of the ancient oak timbers. Very little of the original wood had survived. Some broken frames and several short pieces of planking were all that could be saved. The County Hall Ship was the first Roman ship in the world to be studied and published in detail, but nobody at the time really recognized its importance for scholarly research. For study of the ship today one is largely dependent on the drawings made in 1910, Fig. II.6.11.1a. The plans show only a selection of the structural features, fastenings, joints and other particulars, which would today be recorded in meticulous detail, Fig. II.6.11.2. It is not absolutely certain which end was the bow or stern. Since the wreck was lying roughly north-east to south-west, the sides have been designated west and east, rather than port and starboard (Marsden 1994:109-12).

2. General Construction

The surviving parts of the ship are entirely of oak (Quercus sp.), which after recent dendrochronological examination of ten samples of the planking is thought to have been felled about AD 287, and the tree ring pattern is typical of south-eastern England (Marsden :124). The vessel is incomplete, the remains run from about amidships towards the north-east end, but both ends had been destroyed before the wreck was found. The remaining timber structure was about 13 m long and 5.5 m wide. The keel was cut from a long fairly straight log with its pith in the centre. Remains of the keel were about 10.3 m long, 0.215 m wide and 0.165 m thick, with the lower edges of the sides chamfered to about 0.076 m wide on the flat bottom face. At the time of discovery treenails were noted in the keel, and were possibly used to secure an outer false keel. No traces of these treenails could be found in the short piece of keel surviving today. Planking was tangentially cut from oak logs. The ship was carvel planked, edge to edge with the Mediterranean style of pegged mortise
and tenon fastening joining the planks to each other. Most of the frames were cut from long pieces of naturally curved timber. The frames were fastened to the strakes with oak treenails, with an oak wedge in the inboard end. Above the upper strake 12E was a heavy wale to strengthen the hull fore and aft, and notched to receive the ends of the deck beams. The vessel was decked, with the deck structure supported on the beams, which were themselves supported by fore and aft stringers carried on stanchions set into a lower stringer running over the bottom frames, Figs. II.6.11.3, II.6.11.4. (Marsden :113-122).

3. The Planking

Because of the mortise and tenon system used for fastening the planks to each other, there was almost certainly no caulking, and no evidence was found for any (Marsden :114). As noted above, the planks were cut tangentially from the log, presumably sawn, although no tool marks survive on the fragmentary remains that exist today. In general, the strakes were fitted with the pith side facing outboard, which would tend to accommodate the way boards warp in wet-dry situations. The tree rings nearest the edges of the strakes were more closely spaced, giving greater strength at the point where the mortises were cut. From the records made in 1910-12, the garboard strakes, those butting up against the keel, were 0.38 m wide and 0.076 m thick, and 10.5 m long between the broken ends. The mortise and tenon joints in the plank edges were spaced at about 0.152 m at the north-east end. The rectangular oak tenons were 0.127 m long, 0.064 m wide and 0.007 m thick, and were secured by oak pegs 0.016 m diameter, Figs. II.6.11.5, II.6.11.6 (Marsden 1994:114). In general there does not appear to have been a regular spacing of the mortise and tenon joints. From the original 1910 drawings and recent examination of the surviving timbers the observable spacings were: 0.20; 0.37; 0.41; 0.43; 0.46; 0.484; 0.52; 0.61; 0.73; and 0.97 m. From careful examination of the best of the remaining mortises, it has been concluded that they were cut with the chisel, with no indications for the use of a drill (Marsden 1994 :115-6).

Strakes in general averaged 0.267 m to 0.381 m wide, with a thickness of 0.076 near the keel, and thinning to about 0.051 m at the sides. At the feather end of strakes and at scarfed joints in the timbers an iron nail was driven into the plank below. This was a common practice in the Mediterranean shell-first construction method, and there are a number of examples from Mediterranean wrecks. The exterior of the planking was coated with pine resin (Marsden 1994:117). The strakes were all or nearly all in place before the frames were fitted. The treenail fastening one of the frames to a strake went through a mortise and tenon joint; hence this joint preceded the fitting and fastening of the frame (Marsden 1994:124).

29 Marsden comments that “Nails in this position are also found in the Lake Nemi ships, Italy of the first century AD (Ucelli 1950, fig. 153), in the Yassi Ada ship, Turkey, of the fourth century AD (Doorninck 1976,121), and in a small boat of the first century BC-second century AD found on the shore of Lake Kinneret (the Sea of Galilee), Israel (Steffy 1987,326).” (Marsden 1994:116). The Kinneret boat is described in some detail by Wachsmann (Wachsmann 1995).
4. The Frames and other Timbers

The configuration and the arrangement of the frames is uncertain. Because only the bottom and one side of the vessel has survived, it is not possible to determine exactly how the frames were arranged. In the surviving parts of the ship there are apparently two types of frame visible, frames or floors which just run across the bottom and up to strake 8, and frames which cross the bottom and run up the sides to the gunwale. The two types alternate along the length of the surviving hull. Two interpretations are possible. One is that two types of frames alternated. Some just ran across the bottom, and other U shaped frames that ran from gunwale to gunwale alternated. The second is that all the frames were similar, that they were L shaped, and each one ran across the bottom and up one side. The end result of either possibility is that the bottom has twice as many frames as the topsides. The use of alternating L shaped frames is known from other types of vessel. For example, the Zwammerdam barges had a simple version of this, see page 55. The County Hall frames were almost all in one piece, and had been shaped from grown oak crooks. Scarf joints that were not repairs were found only in frames 8, 12 and 28 out of a total of 41 frames. Finding enough L shaped crooks of the size required, about 5 m long, would not be unduly difficult, the longest surviving frames were up to 4.8 m long. Finding naturally curved U shaped crooks, about 8 m long that conformed to the shape of the hull so that they could run from one gunwale, across the bottom and up the other side to the opposite gunwale, would be difficult. On balance it seems likely the frames were all L shaped, running from strake 8 on one side across the bottom and up the other side to the gunwale. This would need L shaped crooks about 5.1 m long for the amidships section, and shorter ones towards the ends. The frames were about 0.114 m wide by 0.165 m deep, considerably lighter than frames for the other vessels discussed earlier. Where the frames crossed the bottom V shaped limber holes were cut, probably with an axe judging from the tool marks. Limber holes were about 0.04 m wide and 0.02 m deep.

Other timbers surviving from the ship were a heavy strake, 12E, 0.152 m square, with the lower outer corner chamfered off, and fastened to the strakes above and below with mortise and tenon joints. Notches were cut into its upper inboard corner to take the ends of cross-beams, spaced at irregular intervals of 0.60 to 0.88 m. The end of the one surviving cross-beam in situ was 0.178 m wide by 0.038 m thick, and was fastened into the wale with two iron nails. A stringer ran along the tops of the bottom frames, and was nailed to them. Mortises were cut into its top surface, probably to hold stanchions to support an upper stringer to support the cross-beams. Without intermediate supports the cross-beams were not sturdy enough to support a deck (Marsden 1994:117-8). The cross-beams were originally at 1.3 m above the top of the lower frames, much too high for rowing benches. The spacing of the mortise holes in the lower stringer to take stanchions does not line up with the position of the cross-beams, hence an upper stringer as noted above must have

---

30 Another framing system is seen on the Madrague de Giens Roman wreck from the Mediterranean, which has two layers of classic mortise and tenon planking while “The framing system consisted of floor timbers alternating with paired half frames.” (Steffy 1994:63). This also gives the bottom twice the numbers of frames that appear on the sides.
been used to support the beams, reducing the unsupported span from 5m to about 1.6 m.

5. The Fastenings

Very few iron nails were used. The main fastenings were all wooden and of two types. All the planking was fastened edge to edge with pegged mortise and tenon joints, with the odd iron nail used at the feather end of a strake to fasten the end of the feather to the strake below. All the frames were fastened to the strakes with oak treenails 0.032 m in diameter, usually with two treenails through each strake, at about 0.015 m centre to centre. There was generally an oak wedge in the inboard of the treenail, indicating that they were driven from the outside. The wedge expanded the slightly tapered inboard end of the treenail into a tight fit in the hole. Scarfed joints were also secured with treenails (Marsden 1994:118).

6. A Reconstruction of the Ship

Although neither end of the ship had survived, Marsden believed it was possible to make a sound reconstruction by using other more complete vessels from the Mediterranean as guides (Marsden 1994:119-124). The top of the side would have been upright rather than flared out. A half-beam was calculated to be about 2.53 m, giving an overall beam amidships of 5.06 m. The depth from the bottom of the keel to the gunwale amidships was estimated to be about 2 m. The length of the bottom was calculated at 10.64 m, and the most likely overall length is estimated to have been about 19.1 m. From consideration of the shape of the reconstruction it was felt that the bow with finer lines was at the north end, with the fuller bodied stern at the south end. This is in agreement with the original excavators, who, without giving their reasons, placed the bow at the north end (Marsden 1994:120-1).

7. Propulsion and Steering

The ship could have been either rowed or sailed. Rowing is unlikely, however, the height of the deck being somewhat against rowing as the primary means of propulsion. There were no signs of fittings for rowing, although the destruction of the upper part of the side might have obliterated any traces of such fittings. No trace of a mast step or of its fastenings have been found. However, a gap in the frames over the keel at frame 24 might have been the site of a longitudinal mast step, resting on the keel and secured to the frames fore and aft of the step. This would place the mast about halfway along the length of the ship. This is the optimum position for a single mast with a square sail, putting the centre of effort and the centre of lateral resistance about in line.

Because the ship’s hull is of a wholly Mediterranean type, propulsion and steering probably followed the Mediterranean canon. It probably had a single square sail and two quarter rudders. A two sheave pulley and possible belaying pin were found with the wreck, and these may have been part of the sailing gear (Marsden 1994:123).

8. The Origins, Crew Size, Cargoes and Voyages

The hull is wholly in the Mediterranean style in its method of construction. A recent study of the tree-ring pattern from the surviving timbers conforms to patterns for
south-east England. A completely oak built ship would be unusual in the Mediterranean, but quite normal for vessels built in northern Europe. As noted previously, the dendrochronological dating places the felling of the timbers about AD 287. A construction date between about AD 290-300 is possible, but it seems likely that the style of building would fit better after AD 296, when the usurpers Carausius and Allectus had been eliminated, and Marsden proposes a construction date of c. AD 300.

The use or function of the ship remains puzzling. It is certainly not a warship, nor does it fit with the known merchant ships of the period, such as the Blackfriars Ship 1 or the St. Peter Port ship. It is too lightly constructed to be capable of seagoing, and its use would be limited to rivers and quiet estuaries. The coin finds and some pottery suggest that the ship was abandoned sometime shortly after AD 300. It had few repairs, and was not old or worn out when taken out of service. The site where it was abandoned was some distance away from the Roman port of London (Marsden 1994:127-8). With the evidence available one can only speculate about the possible use of this vessel. One possibility is that it was built for some ceremonial or official purpose on the Thames after the restoration of the central government’s authority in AD 296. If this were the case it could have been constructed by craftsmen from the forces brought over by Constantius to Britain. A comparison can be made with the Mainz ship Type B, a late third to early fourth century Roman ship from Mainz, which Höckmann believes is neither a warship nor a merchant vessel, but functioned as a transport for state officials (Höckmann 1985:142, 1993:133). The Mainz ship’s dimensions have been estimated at c.17.2m long by 3.3 m breadth by 1.2 m deep, somewhat smaller than the County Hall Ship.

9. Discussion and Conclusions

The County Hall ship remains an enigma and an anomaly. It is neither a warship, nor really at all suitable for use as a cargo carrying vessel. Compared with other vessels examined in this paper it is distinctly on the fragile side. It does not appear to be suitable for use in the seas around Britain and Gaul. The known trading vessels in these waters, from the Roman period through to the medieval period cog were flat-bottomed and sturdily constructed. They had to contend both with the often rough sea conditions, and the lack of harbours, such as the Roman harbour at Portus, where ships could lie afloat while loading and discharging cargo. Both the vertical and horizontal movement of the tidal effects were of a totally different magnitude from those experienced in the Mediterranean. The techniques and skills needed to build a vessel like the County Hall Ship on a regular basis in Britain seem unlikely to have existed, even if it had been a desirable type for service in the area. In an investigation of the technology and economics of transportation systems in Britain, the County Hall Ship has to be considered an anomalous, perhaps even a unique artefact. The fact that it appears to have been abandoned while probably still in good condition, suggests that it had no practical day to day use. As a type it will not be used further in this paper.

31The comparison is only in size and function. The Mainz ship’s strakes and frames are all nailed.
Section II.7: The Literary, Epigraphic and Iconographic Evidence

Section II.7.1: The Literary Evidence

The limited literary evidence for early Roman maritime and riverine activity in and around Britain is largely concerned with naval and military affairs, Caesar’s two invasions, the Claudian conquest and Agricola’s campaigns. In the period from the departure of Agricola in AD 84, to the start of the building of Hadrian’s Wall in AD 122 there is an almost complete absence of literary evidence of any kind concerning Britain. In the third and fourth centuries, particularly concerning the activities of Carausius, Allectus, Maximian and Constantius, there are a few more scraps of information. Although technology and costs are not mentioned directly, a certain amount of useful information can be inferred from the texts.

Strabo lists the four crossings used to sail from the Continent to Britain, from the mouths of the Rivers Rhine, Seine, Loire and Garonne (Strabo IV.5.2). These departure points suggest contacts along the south and east coasts of the island. Caesar comments that the Veneti “....have very many vessels and in these they are accustomed to sail to Britain.” (Caes. B Gall. III.8). This confirms that the Veneti used seagoing vessels. Tacitus describes how a Roman fleet under Agricola circumnavigated Britain (Tac. Agr. 10.4). Agricola must have had sturdy seagoing vessels for this, as the west and northern coasts of Scotland, the Western Isles and the Orkneys and Shetlands can be very hazardous and difficult even for small modern sailing vessels (personal experience). Dio Cassius, writing some 250 years after the event, says that Caesar “....had built ships that were half-way between his own swift vessels and the local cargo-boats. This was so they might combine as far as possible lightness of construction and the ability to withstand the waves, and also so that they would not come to any harm when left high and dry.” ( Cass. Dio. XL.1). This statement suggests flat bottomed vessels with a sturdier construction than Roman warships. Tacitus, describing Suetonius Paulinus’ attack on Anglesey writes “Flat-bottomed boats were constructed to contend with the shallow water and shifting bottom, and in this way the infantry made the crossing.” (Tac., Ann. 14.29). This crossing of the Menai Straits, which are only about one km wide, could have been achieved with simple to crude flat-bottomed barges. After the final suppression of the Boudiccan rebellion, Suetonius was recalled “....because he lost a few ships and their crews on the coast....” (Tac. Ann. 14.39). Agricola in the fifth year of campaigning “....crossed in the leading ship....”, most likely the Solway Firth, which implies flat-bottomed transports, as the Firth is shallow and encumbered with extensive sand and mud banks (Tac. Agr.24.2). Later Agricola explores the harbours of the east coast with his fleet, and as the forces advance “...often infantry, cavalry and marines, sharing their rations in a joint celebration, magnified their several feats....” (Tac. Agr. 25). This passage shows that the ships were able to parallel the advance of the army, and implies solid competence in coastal operations and piloting. Some deserters, a cohort of auxiliaries of Usipi from the Rhine, seized three warships in the Clyde area, and sailed round the west, north and east coasts of Scotland, finally being wrecked on the coast of Holland (Tac. Agr. 28). The Usipi were a tribe based along the Lahn and Rhine, basically river folk, and their voyage is a tribute as much to the seagoing qualities of the vessels as to the seamanship of
the men who stole them. In the last campaign Agricola sends the fleet forward up the east coast of Scotland to alarm the enemy, and after the defeat of the Caledonians at Mons Graupius orders it to make a circumnavigation of northern Britain (Tac. Agr. 29, 38). In summary, by the late first century AD, the Romans had a large number of seagoing and coastal vessels adapted to the conditions in British waters, as well as a number of oared warships. They also built and used shallow draft flat-bottomed boats for military water crossings. The seagoing and coastal vessels would almost certainly have been of the sturdy Romano-Celtic type with flat bottoms and iron-nailed planking.

From the time of Antoninus Pius to the end of the third century AD, there is little literary information on maritime activities in Britain. In AD 285, Carausius, a Menapian from the area of the Rhine delta, was put in charge of suppressing piracy in the English Channel and southern North Sea. By this period piracy had become endemic and very damaging. Based on Gesoriacum (Boulogne) on the coast of Gaul, he built up a fleet of new ships, and initiated a policy of intercepting the pirates on their return journey, when laden with spoil. He was very successful in suppressing the piracy, but was accused of keeping the recaptured loot for himself, rather than returning it to the owners or turning it over to the imperial authorities. To avoid execution by the western Augustus, Maximian, Carausius seceded from the Empire and in AD 286 set himself up as ruler of Britain and the territory that he controlled around Gesoriacum. An unsuccessful attempt to overthrow Carausius in Britain was made by Maximian in AD 288-9. He set out from the Rhine with a fleet, but was foiled, either by the weather or Carausius’ fleet. The sources are silent or vague on this episode. In AD 293 the western Caesar, Constantius captured Gesoriacum, ending Carausius’ foothold on mainland Europe. Carausius was assassinated by his minister Allectus. Constantius then spent three years in building up a fleet, and in AD 296 crossed the Channel, defeated and killed Allectus, and brought Britain back into the Empire (Haywood 1999:60-65). Piracy continued on a lesser scale in the first half of the fourth century, but by the mid-350s the Franks and Alamanni had crossed the Rhine Frontier in strength, cutting off the supply of grain from Britain. The situation was restored by Julian, later to become emperor:

“It had long been the practice to bring grain from the island, first by sea and then up the Rhine. Since the barbarians had gained control, they had not allowed it passage, and the ships had long been hauled ashore and left to rot. Some few continued to ply, but since they discharged their cargo in coastal ports, the corn had to be conveyed by waggons instead of river transport, and that was a very expensive

---

1 Carausius, had established a reputation as a soldier in the suppression of the Bacaudae. He was probably very conversant with the treacherous waters and sandbanks off the east coast of Britain and the coasts of Holland, supposedly from working as a pilot in his early life. The Bacaudae were rebellious peasants and others in north-west Gaul.

2 By the early part of the third century the classis Britannica had faded from the records, and may have been disbanded or reduced to an insignificant size. The classis Germanica may have lasted longer; lusoriae of this fleet were burnt, probably by the Franks, in AD 280 (Starr 1943:151, 155, Haywood 1999:60).
undertaking. Julian therefore set about renewing the practice and was sadly disturbed should he not put the carriage of grain on its former footing. So he promptly produced more ships than before, and considered means whereby the river should be opened up for the passage of his grain.” (Lib Or.XVII.83).

“Julian had timber gathered from the forests around the river and 800 boats larger than galleys built. These he sent to Britain and had them convey grain.” (Zos. III.5.2), (Ridley 1982).

These rather fragmentary sources imply very uncertain conditions for maritime commerce and the movement of Romano-British shipping in the Channel and southern North Sea from the late third to the mid-fourth century. By contrast, the internal situation was mostly prosperous and peaceful.

The only Roman author of the imperial period with technical details on ships and navigation, whose writings have survived is Vegetius. He gives detailed instructions on the proper times and methods for felling timber, recommends bronze nails rather than iron as being less subject to corrosion, specifies the sizes for various warships, and how scouting vessels may be camouflaged. On navigation he describes the winds, the seasons in which it is safe to sail, how to forecast the weather, the tides, and emphasizes the importance of good local knowledge to avoid rocks, shoals and other dangers (Vegetius IV, 31-43). Although much of his advice concerns ships and navigation in the Mediterranean, a substantial part would be equally applicable to northern waters; unfortunately he is concerned solely with warships.

Section II.7.2: The Epigraphic Evidence

For Britain there are nine inscriptions on stone related to maritime affairs, one of which RIB I, 2315 concerned a foreigner, a medicus, probably in the Roman fleet at Misenum commemorated on a marble tombstone from Puteoli. RIB I, 66 from Lemanis (Lympne, Kent) is the dedication on an altar set up by L. Aufidius Pantera, a prefect of the classis Britannica. RIB I, 653 from York, also on an altar, was dedicated by M(arcus) Minu(cius) Aude(n)s, a soldier and gubernator (pilot) of the Legio VI Victrix. RIB I,662-3 are two small bronze plaques, originally silvered, with the inscription in Greek, “To Ocean

---

3 Julian himself, while Caesar in charge of Gaul and Britain before he was proclaimed Augustus by his army, specifies that he built 600 ships, 400 of them built in less than 10 months (Jul.Epist. ad Ath.279d). Zosimus’ comment, ‘larger than galleys’, implies the larger and more heavily built sea-going cargo ship rather than the rowing galleys used on the the Rhine, such as the Mainz type A boats.

4 “....the remarkable phenomenon of a relatively undisturbed and moderately prosperous Britain without looking at the state of the empire in general in the third century.” (Salway 1993:174).

“During the first half of the fourth century Britain enjoyed peace and prosperity.” (Frere 1987:336)

5 Possibly MVDE(NS), RIB I, p.770,653 .
and Tethys, Demetrius (set this up). RIB I, 1340 records the building of a granary at Benwell on Hadrian’s Wall by a vexillation from the classis Britannica. RIB I, 1944 and 1945 both record the length in feet of a section of the Wall built by men from the fleet. RIB I, 1319, on an altar from the site of the Roman bridge across the Tyne was dedicated to Neptunus, and has a trident and fish on the front panel. RIB I, 1320 on an altar from the same site was dedicated to Oceanus, and has an anchor on the front panel. Both dedications were made by Legio VI Victrix, and were probably on opposite sides of the bridge, where the river under Neptunus met the tidal waters under Oceanus.

Of the nine inscriptions, only RIB I, 663 set up by the gubernator has immediate relevance to this paper. Gubernator is usually taken to mean helmsman or steersman, but has also been translated as pilot. If it does refer to a pilot, he would probably be a river pilot for the Yorkshire Ouse. He would pilot vessels up and down the river Ouse to the Humber estuary and probably as far as the mouth of the Humber. It seems highly unlikely that he would be the only pilot in Britain. A vital part of the safe navigation of ships into and out of the numerous rivers, estuaries and harbours is current local knowledge of the various hazards. In many of the estuaries and rivers, constantly shifting sandbanks in the estuaries and bars at the mouths of numerous rivers make this type of detailed knowledge essential. The interpretation as pilot would have more force if the inscription had come from somewhere like Brough-on-Humber or Reculver on the Thames, in a known hazardous estuary.

---

6. Demetrius may be the Demetrius of Tarsus who had made a voyage among the Western Isles while on a visit to Britain. Shortly after his return he had taken part in Plutarch’s dialogue de defectu oraculorum, just before the Pythian festival in AD 83-84.

7. This anchor looks remarkably modern. It appears very similar to the iron anchor and chain found at Bulbury, Dorsetshire (Cunliffe 1972:300, Plate LIV). The anchor depicted on the altar was almost certainly made of iron, with a long shank or stem, curved arms tapering to a point, and with a ring for attaching the mooring chain or rope at the end of the shank opposite the arms. A stock is not shown, but this would be difficult to depict on a flat surface, as it would project out at right-angles to the surface. An interesting aspect is the hole shown in the shank where it projects beyond the arms. This hole also occurs in the Bulbury anchor. This hole could have been used in two ways. One would be for simply suspending or securing the anchor when not in use. The other possibility is that it was used for “tripping” the anchor when a fluke became jammed under a rock or some other obstruction on the sea bed. In this situation, pulling on the rope or chain simply jams the anchor more firmly. To free it a pull from the crown end is needed. With a modern small vessel, if one suspects foul ground, it is common practice to buoy the anchor. A strong rope, long enough to reach the surface with some slack at high tide, is bent to the crown of the anchor, and attached to a small buoy. If the anchor is foul, a strong tug on the buoy rope will usually free it.

8. Adler has argued that gubernator should be considered the equivalent of the term ‘master’ or ‘sailing master’. This was used in British naval terminology from medieval times to the first part of the nineteenth century. The master/sailing master was a professional seaman specifically charged with conducting or navigating the ship safely from place to place (Adler 1998:76-78). Hughes has written an extensive rebuttal of this view, quoting among other sources a summary petition of 1538 that lists “pilotam et gubernatorem!”
Inscriptions on other materials include tile stamps of the *classis Britannica*, found in large numbers from London, and along and inland from the south coast, from Richborough to Pevensey, together with a number from Boulogne. Stamping of tiles by the fleet, CL.BR, started in the second century and continued into the third. No tiles stamped CL.BR have been found north of London or west of Beachy Head (*RIB II, Fasc.5*, p.1). One hundred and nineteen tile stamps are recorded in *RIB*, but new ones are constantly being found from ongoing finds of the thousands of tiles made by or stamped for the *classis Britannica*. Study of the clay fabric suggests that a single central tilery was used, probably in the south central Weald. (*RIB II, Fasc.5*, 2481.1 to 2481.119). This suggests that the fleet, like the legions, was involved in various industrial activities, as well as in the iron industry of the Weald (see Appendix D). A problem with all armies and navies is that they need to be kept busy and occupied when not engaged in active campaigning. The *classis Britannica* would normally be kept fairly busy in transporting men and supplies, but there would be slack periods. They could be kept occupied with a fairly low skill occupation such as tile making, which could be picked up or dropped at short notice.

Another inscription with a doubtful connection to the *classis Britannica* comes from the temple settlement at Lydney Park on the north shore of the Severn estuary. It is part of a mosaic found in 1805, since destroyed, with various readings by different authorities. It concerns a certain *Titus Flavius Senilis*, who is described as PR REL. This has been variously interpreted as pr(aepositus) rel(iquationis), ‘officer in charge of a supply depot of the fleet’, or more recently as pr(aepositus) rel(igionum), ‘superintendent of the cult’, which is the version accepted in *RIB II, Fasc.4*, 2448.3).

**Section II.7.3: The Iconographic Evidence**

Iconographic evidence from Britain on marine transportation is almost non-existent. On maritime technology the stone altar to *Oceanus* from Newcastle, described in 7.2, page 83 above, depicts an anchor (*RIB I*, 1320). A number of mosaics show fish or marine mammals, and one shows three Mediterranean type ships in a mythological context. No mosaics show ports or harbours. There is nothing to compare with the Althiburus mosaic from Tunisia, in which thirty different types of boats and ships are shown, albeit somewhat crudely (Dunbabin 1978:127, Pl. XLVIII.122).

On a few coins there are stylized ships or maritime artefacts. The reverse of an *Antoninianus* of Allectus from the London mint shows Laetitia holding a wreath and anchor (Robertson 1978:280, Plate 63.3). A number of *quinarii* of Allectus, c.295, show warships on the reverse. There are several variants. One depicts a galley rowed over waves with six rowers, a mast and sails. Another shows a galley with a cabin at the stern, mast and sails, and between five and seven rowers. One has a Victory on the bow of the galley holding a wreath and palm (Besley 1987:Fig. 53; Robertson: 287-8, Plate 64.62-68). A gold medallion of Constantius from Trier shows him being welcomed by the citizens of London, and below is a depiction of a warship (Casey 1994a:Pl 7.4; Toynbee 1986:182-3, Pl.VIII,

(Hughes 1999:320-325). The disputation is probably ongoing!
4). All these illustrations on coins are on a small scale, lack detail, and can only be used for very general conclusions. All are side views. Coinage in the imperial period rarely shows merchant vessels. The emperors would proclaim their military and naval prowess, but would not generally want to share a coin with a vulgar merchant ship.

In general, the iconographic evidence from Britain, apart from the altar with an anchor, is not helpful for the purpose of this thesis. From Gaul and Germany there is a useful amount of iconographic evidence, mostly in the form of relief sculpture, which does give technological detail on both boats and ships. Where useful and relevant, this material has been used, on the assumption that certainly by the second century AD there would be similarities in the technology used in geographically and ethnically close areas.
Section II.8: Harbours, Havens, Wharves and Warehouses

Section II.8.1: Introduction

For the Romans in the almost tideless Mediterranean the provision of harbours where ships could lie afloat alongside wharves, as at the harbours of Claudius and Trajan at Ostia and Portus, the harbour of Herod the Great at Caesarea Maritima, or the harbour at Alexandria, was practicable and within the bounds of their technology. In the north-west, the Atlantic, Channel and North Sea coasts of Spain, Gaul, Britain and Germania Inferior, have tidal ranges from about 2 to 3 m along open coasts, and in constricted areas such as the Channel Islands and upper Severn Estuary, the tidal range can be up to 12 m or more at spring tides.

In Britain the only major harbour for which there is substantial surviving evidence for wharves and warehouses is on the Thames at London. At a number of other ports of importance, Exeter, Colchester, Brough-on-Humber, Chester, Carlisle and Tynemouth there were almost certainly harbour facilities. At various smaller places there is evidence for some simple wharves, or in some cases ‘hards’.1 For many small coasting vessels a harbour or wharf would not be necessary for taking on or discharging cargo. They would be able to take the ground on either a natural or artificial hard, and be unloaded and loaded with carts and wagons at low water. This practice continued into the first quarter of the twentieth century around the coasts of Britain, Fig. II.6.9.5 (Greenhill 1988:25, Fig.27). Craft on inland waterways above tidal effects could moor to the bank at a convenient place, or where there was regular traffic the use of a very simple wharf or jetty would be cheap and practicable. Loading and unloading would involve the use of gangplanks if stevedores were used, or for heavy loads either some sort of tackle rigged from the vessel’s mast or the use of a shore-side crane.

In Britain the need for large artificial harbours would have been minimal. The east and south coasts have a succession of natural inlets, havens and estuaries suitable for small craft, although a number have significant natural hazards in their approaches, in the form of river mouth bars and sandbanks. Many have dangerous approaches in onshore winds. A similar situation prevails along much of the opposite continental coast. The west of Britain, including Wales, with steep rocky coastlines is not so generously supplied with good natural harbours, and the prevailing westerly and south-westerly winds make the west coast a dangerous lee shore for much of the time.

Much of the east and south coast of England is low lying with alluvial soils and slow flowing rivers which debouch into estuaries and inlets with shelving sand, gravel and mud bottoms. With normal precautions vessels of reasonably sturdy construction can take the ground to discharge cargo on the natural surface, without significantly stressing the hull. From the seventeenth to the early twentieth century, small coastal sailing cargo vessels with cargo capacities up to the 100 tonnes range routinely transferred cargo ashore while sitting

1 See page 3, Fn. 3 or the Maritime Glossary for the definition of a hard.
on a beach or hard. On the east coast and Thames estuary the Thames sailing barges traded up and down the coast until the nineteen fifties (Carr 1951:283-302).

**Section H.8.2: Roman Water-borne Transportation Requirements**

Once Caesar had decided to investigate Britain, with his expeditions of 55 and 54 B.C., and once Gaius and Claudius in the first century A.D. had decided to invade and conquer the island, they were committed to maritime activity on a substantial scale. They needed both transports for the army and its supplies, and naval forces to cover and protect the transports for the initial landings in this major amphibious operation. In the follow-up phase there would be an ongoing need for supplies and munitions, and a requirement for secure all weather havens and harbours with unloading facilities. After the successful initial conquest, the new province would need harbour facilities for both the expanding intra-provincial trade and movement of goods and supplies, and to support the new Roman administration with its permanent provincial garrison, legionary fortresses and auxiliary forts, as well as the transportation services for the activities of the native inhabitants. In addition to local agricultural production and distribution sufficient to feed both Romans and Britons, industries, internal trade and exports would need to be built up, to provide the surplus needed to justify the conquest. These transportation activities would involve the economical movement of a wide range of goods, some bulky and heavy, such as cargoes of grain, pottery, bricks, tiles and stone, and some smaller containers and packages of manufactured goods, varying from modest pottery to high value luxury items.

Maritime trading contacts between Britain and mainland Europe go back to the Bronze Age, see pages 33-4. By the LPRIA, after about 120 BC, trading contacts were flourishing, and included a significant volume of Roman goods from the Mediterranean lands, including wine in Italian Dressel 1A amphorae, figs, and coloured glass (Cunliffe 1987:339-41). By the first century BC trade in both directions across the Channel was well established. Evidence comes from the sites at Hengistbury Head (Cunliffe 1987), Mountbatten, Plymouth (Cunliffe 1988), Camulodunum (Hawkes and Hull 1947) and the wide-spread distribution of amphorae, imported pottery and ironwork, and coinage in southern England before 55 B.C. (Macready and Thompson 1984). Trade from Europe originated from Spain, Gaul and the Rhine; with the conquest this trade expanded in the first and second centuries, both in the variety and quantity of material traded, but certain patterns and routes were already firmly in place before A.D. 43.

With the advent of the Romans a new factor was the introduction of a permanent regular naval presence in the English Channel and southern North Sea, until at least the mid-third century A.D. Once Rome's hold on Britain was secure, the *classis Britannica*, with its headquarters at Gesoriacum (Boulogne-sur-Mer), and with bases in Britain at Rutupiae (Richborough), Portus Leman (Lympne) and Dubris (Dover) was established. Later, in the third century A.D. a number of other bases were established from Branodunum (Brancaster) on the East Coast in Norfolk round to Anderidos (Pevensey) on the South

---

2 See Annex 1 to this section for discussion of the *classis Britannica*. 
In the initial stages of the Claudian conquest, most supplies would have been landed at Richborough, where a Claudian period supply base was developed (Cunliffe 1968:4), but as Leg II Augusta under Vespasian moved to the west, Fishbourne, at the head of the east branch of Chichester harbour became another stores base. A timber building 6.71m by 30.5m, probably a granary and similar to buildings at the Richborough base, dates to the immediate post-invasion period (Cunliffe 1971:40). Camulodunum (Colchester) was an entry point for imports before the conquest, and by the time of Boudicca's rebellion in A.D. 60, a supply base nearby at Fingringhoe on the River Colne was in operation. Leg II Augusta, by this time based at Isca Dumnoniorum (Exeter) in a fortress above the River Exe, probably had a supply base at Topsham about 6.5km downstream (Bidwell 1979:12, Fig.1). Londinium (London), by the time of the Boudiccan rebellion had become a flourishing town and port, and after the rebellion became the headquarters of the procurator and the civil administration of the province (Hall and Merrifield 1986:6-8).

As the extent of the conquered area expanded, and Roman towns grew up, as taxes in kind (mainly grain for the army), and as trade and commercial activities increased, a number of seaports and river ports would have been needed to cope with the growing overseas trade, and to serve local needs. Goods in bulk arriving at the main ports of entry would be distributed by local craft to subsidiary centres. Exports and internal bulk movements of material would follow a reverse route, from the point of origin to regional centres, and then on to the major ports.3 Burnham and Wacher in The Small Towns of Roman Britain, commenting on the movement of goods in the northern provinces, note that: Carriage by road was expensive but by water it was comparatively cheap....there was an abundance of navigable rivers, while Britain in particular had easy access to coastal transport. There is a good deal of evidence from these provinces to show that inland waterways were major thoroughfares: it ranges from the idiosyncratic distribution of pottery and other hardware to discoveries of boats used, including the great flat-bottomed lighters which plied the Rhine. (Burnham and Wacher 1990:43)

Pritchard, reviewing the sources for ornamental stonework in London has identified overseas material from the Aegean, Italy and Gaul (see Fig. II.8.2.1), and British material from Purbeck, Alwalton, Somerset and Surrey (Pritchard 1986:169-189). Cunliffe, in an analysis of the stonework employed in the villa/palace at Fishbourne, has identified structural stone from western France, from the Mediterranean, Caen stone from the Maladrerie quarry near Caen, and stone from Brittany.4 In addition, British stone from the south coast from Cornwall to the Weald, and from the Channel Islands was used. The decorative stonework came from the Côte d’Or, Lez (Haut Garonne), and the Pyrenees in Gaul; from Balikesir in Turkey; from Docimium in Phrygia; from Carrara and Venata

3 An interesting point is that overseas trade may have been more important in the first and second centuries A.D., but declined later as Britain became more self sufficient.

4 The structural stone from the Mediterranean is Lower Eocene white foraminiferal limestone, possibly from more than one source.
Crocicchio in Italy; from Skyros and Marathonisi in Greece; and from other sources around the Mediterranean (Cunliffe 1971, Vol.II:1-3, and 16-17). All of this material must have come by sea and river transport. The volume of decorative stone from the Mediterranean would be much less than the amount of structural stonework, and was probably shipped to the south of France, then up one of the river systems, and finally across the Channel. On the military requirements for large scale movement of materials, Breeze, discussing Agricola's campaigns in Scotland, notes that his army required 78.73 tonnes of grain, 50.17 tonnes of animal feed and 447.29 tonnes of water per day (Breeze 1987:25, Table 1). Water would be easily found locally, but most of the cereals and other foodstuffs would have to come from the south. For the building of the legionary fortress at Inchtuthil on the River Tay in Scotland, Shirley has calculated that 16,800 tonnes of timber, 10,000 tonnes of tegulae, imbrices, shingles and mortar, 1,555,000 iron nails and 19,200 cubic metres of wall cladding and infill would be required (Shirley 1996:111-128, 2000:82-90). For the building of Hadrian's Wall Kendal has computed the land transportation requirements for the locally obtained materials, and notes that in addition over a ten year building period very large amounts of food and animal fodder would have to be imported to the area (Kendal 1996:129-152).

Section II.8.3: The Types and Sizes of Ports

Civil port and waterside facilities can be grouped into three broad classifications.

1. Major ports
   These would be able to accommodate sea-going cargo vessels, possibly as large as 100 to 200 tons capacity. The Gallo-Roman trading vessel from Guernsey at 25m overall length, 6m beam and 3m depth of hold is at the lower end of this size range (Rule and Monaghan 1993:127). By comparison with sailing coasters of the nineteenth century with similar dimensions, I estimate that it had a cargo capacity of about 100 tonnes. Facilities could include timber or stone quays alongside which vessels could safely take the ground. These would be provided with warehouses for the security and storage of goods in transit, and possibly special unloading equipment such as cranes. Where taking the ground was not possible, the large vessels would need a sheltered deep water channel in which to anchor, while lighters transferred the cargo ashore. Because of the tidal range around Britain, ranging from about 3.0m in a few places to 13.1m in the upper Bristol Channel, with ranges of 4.5m to 7.3m for most harbours, with the technology available it would not have been possible or economic to build deep water stone or timber quays where vessels could lie

---

5 In the Roman imperial period ships from the Mediterranean were certainly sailing through the Straits of Gibraltar to Cadiz and along the southern coast of Spain. Whether there were regular voyages from the Mediterranean out into the Atlantic, across the Bay of Biscay and into the English Channel is doubtful. Along the Atlantic coasts of Spain and Gaul there would certainly be local fishing activity and local coastal traffic, but there is really no evidence for regular long distance Atlantic voyaging.
afloat alongside at all states of the tide. This contrasts with the almost tideless Mediterranean situation, where large artificial harbours such as Portus Traiani or Caesarea Maritima were built. An alternative in a few places with low tidal ranges would be to build simple wooden jetties at right-angles to the stream out into the deeper water.

2. Minor Seaboard or Estuarine ports

These would have facilities for small coasting vessels. Facilities could be similar to those at major ports, but on a more modest scale. Round much of the east and south coasts of England, where sand, silt or mud borders most rivers and estuaries, the vessels could almost certainly dry out with safety. At some small sheltered coastal and estuary sites with a firm sandy bottom it would be quite practicable to let a small boat with a firm bilge or flat bottom simply sit more or less upright on the bottom and unload into small shallow draft lighters or into carts. This was common practice in the coasting trade round Britain into the early twentieth century (Greenhill 1988:25,106,107,114,141, fig.27).

3. Inland River and Lake harbours

These would be intended primarily to accept local river craft of the flat bottomed punt or barge type, such as the Zwammerdam boats (de Weerd 1978:15-21). Facilities could vary from very simple wooden wharf structures, infilled with rock and gravel, and surfaced with gravel and dirt, to a natural river bank with some revetting and hard surfacing of the bank's surface. On rivers, above the tidal limit there is no diurnal or semi-diurnal tidal effect, although allowances may have to be made for variations in water level due to heavy rainfall or drought. In this situation boats can lie afloat alongside a wharf at all times, especially as the vessels' draft is likely to be less than 1 m in the case of flat-bottomed barges.

A problem with most of the types of waterside structures described above is that the archaeological remains will be very slight or non-existent. Also, due to natural forces, sea level changes, coastal erosion and littoral drift since Roman times, the harbour location can be submerged off the coast, silted over or eroded away (Cunliffe 1977:37-55, Jones 1977:87-102, Simmons 1977:56-73).

Section II.8.4. The Search for Roman Harbours and Harbour Installations in Britain

Apart from the major Roman mercantile port in London the problem of locating Roman harbour installations in Britain has been approached in several ways. One has been

---

6 Annex 2 to this section lists a number of estuaries and havens around the coast of Britain from the Moray Firth to the Firth of Clyde with their tidal range. The range of a tide is the height difference between successive high and low waters. These were extracted from Admiralty tide tables for 1965, a period before modern barrages and other structures altered tidal patterns in a number of estuaries.

7 A significant problem, particularly on the east coast south of the Humber and on the south coast east of the Isle of Wight, is that in the past two thousand years subsidence, silting, coastal erosion and littoral drift have substantially altered the coastline. See Annex 3.
a speculative suggestion for a harbour for any town or settlement site on the sea, an estuary,
or with a river. For a number of excavations Cleere has commented that although there is
no hard evidence in the archaeological record, "....excavators of Roman civil and military
settlements tend to be prodigious with inferred locations for harbour installations." (Cleere
1978:36). There are a limited number of sites with solid archaeological evidence for a port
and port facilities, the most notable example noted above being London. Fryer and Cleere
have identified a number of waterfront sites with something other than pure speculation to
support their case (Cleere 1978, Fryer 1973), Burnham and Wacher have noted some minor
harbour facilities at small towns (Burnham and Wacher 1990), and recently a wharf and
possible jetty have been found at Barland's farm in Gwent, South Wales (McGrail and

4.1. Sites with 'Hard' Archaeological Evidence

Fryer prepared a summary of the 'hard' archaeological evidence for harbour
installations for the 1971 Colston Conference on Marine Archaeology. On the west coast at
Chester and the nearby Heronbridge settlement there are remains of early wharves. At
Caerleon there are the remains of a massive stone and timber wharf, which at high tide
could take ships of up to 1.67m draft. Gloucester has a considerable frontage of wharves
in stone and timber in a now silted up creek, protected from the worst of the Severn tides
and the tidal bore (Fryer 1973:261-273). On the east coast the most extensive remains of a
Roman waterfront are in London. Since 1980 extensive rescue excavations, ahead of, or in
some cases concurrent with new building developments, have taken place along the north
shore of the Thames, centred around the probable site of the Roman bridge. The remains of
over 800m of substantial timber wharves have been recovered, covering the period from ca.
AD 100 to the end of Roman Britain and beyond. Remains of warehouse and other
buildings have also been found (Milne 1985). More recent excavations on the south bank at
Southwark have exposed a substantial Roman timber building, probably a waterside
warehouse and a Roman wharf with mooring posts (Dillon 1989:229-231, Mills and
from 1987-1990 have discovered a shelving foreshore with a Roman period hard standing,
approached by metalled surfaces running down to the water's edge (Chitwood and Donel
1992:373). Wacher had earlier suggested that a 6m length of dressed stone wall was a
possible wharf or part of a water mill (Wacher 1995:148-9), but the more recent work
suggests that this wall would be post Roman. At York, like Lincoln an inland river site,
wharf structures have been found in the River Foss (Fryer 1973:267). Burnham and
Wacher identify port facilities at Springhead, Kent, where the headwaters of the creek were
revetted with flints and backed by a hard surfaced area forming a 'dock' (Burnham and
Wacher 1990:192). At Brampton in Norfolk two metalled roads from the town converge on

---

8 This is at high tide. At low tide the ships would be left high and dry as the tidal range at Caerleon is
about 13 m.
a wharf on the old course of the River Bure (Burnham and Wacher :203, fig.63). The wharf, excavated in 1973, was made up of a platform of used timbers, kept in place by large wooden beams alongside a side channel at right angles to the main course of the river. The timbers were covered with a layer of rammed sand, chalk and gravel. About 30m to the west some vertical timbers suggest a jetty built out into the river (Burnham and Wacher :206). Other sites with remains of port installations are Scole with some timber piles, Ilchester with possible built quays, and at Sea Mills (Burnham and Wacher :50). At Barland's Farm, south Wales, vertical wooden piles with cross-members have been found, together with a second stone jetty structure and a boat, all dated to the third century A.D. from associated coin finds (Burnham 1994:253-4, Nayling et al 1994:599).

4.2. Sites with Inferred Waterside Installations

Cleere has made a survey of possible harbour sites based on the known Roman roads in Britain. His hypothesis is that where a road terminates on the coast there should be a harbour site of some sort. Using the Ordnance Survey map of Roman Britain (3rd. edition 1954) he postulates that a harbour should be found "...where proven roads end at coastal settlements or where settlements are located on navigable rivers of major estuaries...." (Cleere 1978:36). From this hypothesis he has compiled a list of 45 coastal and inland sites where wharves and other facilities might be found (see Annex 4 to this section for this list). He divides the possible harbour sites into military harbours and civil ports, using the Severn-Wash line as an approximate boundary between the two types.

4.3. The Problem of Finding Roman Harbour Sites in Britain

There appear to be three problems with the archaeology of Roman ports in Britain. Firstly, there is to date very little archaeological evidence, and the probability of finding more is limited by the insubstantial nature of the original structures. Secondly, for sites occupied fairly continuously through the medieval and modern periods, the Roman remains have either been destroyed or are inaccessible beneath centuries of more recent structures. Thirdly, if a site is inferred, but no port facilities are accessible or can be found, how can the inference be confirmed?
Section II.8.5: An Alternative or Supplementary Hypothesis

5.1. Possible Sites for Small Ports

Cleere's hypothesis is a good one, particularly for the known towns and military sites, but an alternative though somewhat similar one is proposed to locate smaller installations. In Britain, with the manpower and technology of the first and second centuries A.D., the use or simple modification of good natural harbours or havens would be a much more attractive and economic proposition than the construction of expensive artificial harbours. This would be particularly true for Britain with its extensive coastline, many sheltered inlets, havens and river mouths. Apart from a few major centres such as London, the Tyne, and certain major manufacturing sites, such as the iron industry of the Weald and the major locations for pottery production, such as Poole Harbour, the traffic density, except for grain, would be low, probably a dozen or so ships in a year. Many parts of the English and Scottish coasts are well endowed with natural havens, particularly along the south and east coasts. The west and north coasts have fewer natural sheltered inlets, but there are still sufficient to provide good shelter for those with local knowledge. As well as many small havens, there are a number of large estuaries running well inland, and connecting to a river or river systems. South of the Severn-Wash line and north of that on either side of the Pennines much of the countryside is only a few miles from a navigable piece of water. For this thesis a list has been compiled of the natural harbours and small havens from the Tyne in the north, down the east coast and along the south coast as far as the River Exe, all of which would be possible sites. Each site has been checked for published archaeological material indicating Roman period activity. The evidence usually takes the form of artefacts of some sort, sufficient in some cases to indicate the presence of a settlement. Artefacts could be strictly local in origin, could be imports from elsewhere in Britain, or could be imports from elsewhere in the Roman empire. If not of local origin, how did they reach the site? Land transport could be by humans, packhorse or cart. Water transport could be by seagoing ships, coastal vessels, or by barge or lighter on inland waters. If there is evidence for a waterside settlement then it is probable that some sort of water transport would have been used. If the site has evidence for the manufacture of heavy or bulky objects, such as pottery, tiles, bricks or large scale iron production, or evidence for extractive industries, mining, quarrying, large scale timber felling, salt production and the like, or evidence for large scale agriculture, then it is almost certain that some sort of water transportation would be involved. The army, supported by taxation and with its large resources of manpower, might be able to afford to use expensive man and animal powered transport, but the civilian manufacturer, contractor or merchant would be concerned to find the least costly means for moving his products to market. Annex 4 to this section lists the

---

For the volume of grain shipping see Section III.5.3, page 165.
natural small havens, rivers and inlets that could have been used in the Roman period.\footnote{Three factors affect the configuration of the coast line over time, sea level change, siltation of estuaries and coastal erosion. Roman high tide levels were from 0.4 to 3.0 m below present levels. Large estuaries tend to silt up. For example the Saxon Shore fort at Brancaster is now 2 km from the sea, and Burgh castle is 6 km from the sea. Due to coastal erosion Bradwell is mostly submerged and Walton Castle has been completely lost. Although there have been changes in the configuration of the coast since Roman times, particularly on the south and east coasts, most of the rivers and inlets accessible today would have been useable in Roman times, although their extent and configuration could be considerably changed (Burnham. 1989:12-17).}

5.2. The Possible Sites for Minor Ports and Harbours

From the possible 118 sites listed in Annex 5 and Appendix O, a total of 53, or 45\%, have produced published evidence of Roman settlement or use. In many cases only a limited number of small finds have been found, but in a few cases, such as Heybridge in Essex and Poole Harbour in Dorset, large settlements with extensive domestic and industrial activity have been excavated and reported in the past few years. A review of sites with evidence for occupation as a whole, yields several points of interest. At a number, occasional surface finds have been known for many years, but the major discoveries were almost all due to site clearances for new housing and industrial development. These resulted in rescue excavations, often by local groups, and with the usual time pressures involved in working just ahead of the developer's construction schedule. There are hardly any cases of a pre-planned excavation with well thought out objectives, aimed at answering specific research questions. In some instances, such as Heybridge, far more was found than was anticipated. Many of the sites have emerged as significant only with the work of the past ten years. Of the 53 sites with finds, listed in Annex 5, two thirds are from the past twenty years, and thirty-one from earlier work. With the increasing pressure on undeveloped land for new suburbs and industrial sites, more sites are constantly being discovered, but new discoveries tend to be largely "accidental", rather than part of a planned archaeological programme. Of the 71 sites listed, from which nothing has been reported in JRS and Britannia since 1923, some such as Chatham and Gillingham are now large residential and industrial towns. Unless major re-developments are undertaken, these areas are likely to remain relatively undisturbed for the foreseeable future. Other towns have medieval, or early modern cores designated as heritage or preservation zones. A number of the 71 sites are still in relatively rural areas, and could be the subject of preliminary field walking or geophysical surveys, particularly if development schemes are planned, or seem likely. For the immediate future most new discoveries are likely to continue to occur as a result of an accidental find or of the clearance of areas for new housing and light industry. In a number of places with known Roman period occupation, such as Bristol, Chester, Exeter, Gloucester, Harwich, Hull, Ipswich, Kings Lynn, Lincoln, Norwich, Plymouth, Poole, Portsmouth and York, Saxon, medieval and later port facilities have largely obliterated remains of the Roman period (Milne and Hobley 1981:103-107, 119-135, 138-149). London is one of the few sites where the Roman quays were sufficiently massive to
survive later over-building.

5.3. The Direct Evidence for Small Harbours and Harbour Facilities

The direct evidence for harbours at the possible minor ports listed in Annex 5 is so far minimal. Only two places from the River Tyne to the River Exe, Heybridge and Hullbridge, have signs of a wharf, jetty or hard standing. However, consideration of other sites such as Poole Harbour, with its extensive import and export trade, the distribution of its manufactures around Britain and Normandy, and its fine sheltered natural harbour, makes it almost inconceivable that there would not have been wharves, jetties or hards in the Roman period. Another site, of much less economic significance, Barland's Farm in south Wales had a simple wooden wharf structure and a possible jetty (Burnham 1994:253-4). As noted previously, there are several problems with small harbour installations: the structures, wharves and jetties will generally be constructed with timber of a relatively small size and an infilling of convenient local gravel, rocks or building debris. Unless buried fairly early in their life in an anaerobic stratum, the timbers are not likely to be preserved. If they are preserved, the surviving part will most likely be the lower parts of the upright posts sitting in the mud or silt. These stumps would be difficult to locate, even in likely positions, for example at the end of a metalled track terminating on a river bank or at the foreshore. In general, it is probable that these types of slight structural remains could not be located by site surveys or as part of a planned excavation. The discovery of small wharves and jetties will, therefore, probably continue to be a matter of accident for minor harbours.

5.4. Features and Structures other than Harbour Facilities

Features and structures on the land at sites of possible minor ports may provide useful indications that there was probably a harbour. Storage buildings near the waterside, like the building at Fishbourne, would be suggestive. More useful would be evidence for an extractive or manufacturing process, the output of which would exceed local requirements, and which would require the transport of heavy and bulky objects. Quarrying, tile and brick making, and the manufacture of pottery on a large scale would be obvious pointers to a need for water transport. To a lesser extent, large scale metal working and salt production might also utilize carriage by water. The large scale production of grain to supply the army granaries and large urban centres, such as London, would also require shipping by coastal or river craft.

5.5. The Artefacts and Finds

Certain types of artefacts could be one of the best indicators for a transportation system. Many, such as pottery, amphorae, bricks, tiles, bronze and lead objects, and stonework are both very durable in the normal archaeological context, and in many cases their origin can be determined on stylistic grounds, and in many cases from epigraphic evidence. For example, many Roman lamps and much fine pottery have makers’ names
incised or moulded into the underside of the base.\textsuperscript{11} Tiles of the \textit{classis Britannica} are found with CL.BR. Amphorae frequently have various markings on the handles and shoulders indicating the place of origin. Scientific analysis of the material, as, for example, quarried stone, can often determine the area from which it came, and in some cases the actual quarry. Artefacts can appear at both the point of origin and at some final point of use. For example, Allen and Fulford have demonstrated that Black-Burnished ware from Poole has a wide distribution over Britain, in some places making up 40\% of the local assemblage, as well as appearing in modest amounts in Normandy. There is also evidence for a secondary distribution within Britain. Pottery from the Poole area is found at Maryport on the coast of Cumberland, and from there spreads eastwards along the line of the northern frontier, but in diminishing amounts at the sites farther to the east (Allen and Fulford 1996:238-251).

5.6. The Problem of Defining and Finding Minor Ports and Harbours

From the preceding section it appears that the chance of locating a minor port from the archaeological remains of man-made harbour facilities or the remains of Romano-British ships and boats is minimal. When it does occur it will likely be accidental. It is suggested that a more productive line of investigation would be to use an indirect approach, utilizing material that survives quite well in the archaeological record, the relatively imperishable artefacts. Any artefact is made somewhere, and may be used at the point of manufacture, or may travel tens or hundreds of kilometres to its point of final use. Any artefact found away from its place of production has been transported there by some means. By examining the dispersal patterns of artefacts from their point of origin, the trading and exchange network can be established. Where the nodes in the network occur at a waterside site, there is a strong presumption that water transport was involved. For an investigation of minor ports, the starting point would be a list of possible natural harbour sites on the coast, and in tidal estuaries and inlets for salt water sites. For possible inland sites, they would have to be on navigable rivers or lakes. Some rivers through relatively flat country are navigable without artificial aids. Others may require some artificial structures, such as small dams or weirs, both to maintain a minimum depth of water and to avoid natural difficulties such as rapids (Eckoldt 1984:3-10). A slow flowing river has the possibility of a landing stage at almost any point along its length, unlike a sea coast where topography limits the number of natural havens. For the river at least two options appear to exist for locating sites. One is to look for waterside facilities where there is a known city, town, settlement, or industrial site. In the case of Britain this immediately produces a large number of possibilities. The second possibility is that a field walking survey along the banks and immediate hinterland of a river might perhaps add to the known sites.

For each possible site identified, whether coastal, estuarine or inland, and known

\textsuperscript{11} Some lamps and fine pottery were copied by making a mould from the original fine piece and then making copies locally. These 'reproductions' were of lower quality artistically and can be distinguished fairly readily from the originals. However, they are not indicators for long distance trade.
from published material to have had a Roman period settlement or activity of some sort, the
finds can be classified as locally produced, imported from elsewhere in Britain, or imported
from overseas sources. If the material is of such a nature, or occurs in such quantities that
water transport would have been the only economic or practicable method of
transportation, then a loading/unloading facility of some sort can reasonably be inferred.
Some sites would be predominantly importers: for example, a fort or fortress on the
northern frontier would tend to be a consumer rather than a producer. Other sites, such as
Poole Harbour, would be producers and consumers, exporters and importers.

In an investigation based on the sites listed in Appendix O, it becomes clear that the
practical difficulties are threefold. One is that the investigation would be dependent on a
large number of excavation reports, possibly of uneven quality, or not reporting the data in
a useable form. Allen and Fulford encountered this problem in their study of the
is that for many minor sites the results are reported in the publications of local or county
archaeological societies, and these are not readily available except at the source, or a major
institution such as the British Library in London. The third difficulty is that the study
would be very tedious and time consuming, unless done as a team effort with a fairly large
group. Any one team member could then concentrate on one or two sites for the initial
data-gathering and classification, with the team leaders assembling the data into networks.
This approach does, however, offer a method of defining and finding a number of minor
ports and harbours in a planned and orderly manner. A trial with one or two well
documented sites with recent quality publications would seem an appropriate starting
point.

For tidal rivers and in shallow waters, surveys of the foreshore can be very
productive. Recently, extensive surveys have been made of the foreshore of the Thames.
These have produced structures and artefacts from the mesolithic to the early modern

Section II.8.6. Canals and Artificial Waterways

6.1. Introduction

Canals and artificial waterways have been included in this section because, like
ports, they are man-made rather than natural facilities. There is only one certain Roman
period navigation canal in Britain, the Foss Dyke, about 16 km long and 8m wide joining
Lincoln to the River Trent. Because of changing use over the centuries, its depth in the
Roman period is uncertain, but a depth of about 1.5 to 2 metres seems likely, to judge from
its use in early modern times. Until fairly recently the Car Dyke was also thought to be a
navigable canal, but south of the Witham peat it has been shown that where a number of
Roman roads cross it, the crossings have always been solid causeways. This makes its use
as a long distance waterway impossible, and a more likely use was for drainage (Salway

12 The Witham peat is an extensive layer of peat in Lincolnshire, between Lincoln and the Wash.)
1980, Simmons 1979). A further consideration is that it runs in a series of straight alignments joined by sharp corners, around which it would be difficult to manoeuvre a barge of any length. Short sections may have been used for local and limited movements by water. In general, any fairly substantial drainage ditch could have been used for local movements with a logboat or simple punt, as was the practice in parts of Holland until recently. 13 There would be practically no trace of this sort of activity in the archaeological record, unless the remains of such a vessel were found in an anaerobic context in a datable ditch. In general, Roman cuts in the Fens, on Romney Marsh and along the shores of the Bristol Channel appear to have been concerned with drainage and land reclamation rather than transport.

6.2. The Piercebridge Formula and its Rebuttal

In 1983 Raymond Selkirk, at that time an avocational archaeologist, pilot and aerial photographer, published his book The Piercebridge Formula. From his work in aerial photography and surveys on the ground, he developed a hypothesis that many Roman forts in northern Britain had barge harbours, and that some dams and possibly locks would have been required on certain rivers to manage the water level (Selkirk 1983:73). He then set out to see if he could locate canals or locks related to known Roman sites. He believed that he had identified a canal at Binchester. From studies on the maps and on the ground he believed that most forts along Hadrian's Wall and in its hinterland could have been supplied by water transport, rather than the road system (Selkirk:101-112). He felt that the road system, in part because of the steep gradients in places, carried only "...fast moving cavalry, infantry and dispatch riders." (Selkirk:73). He also looked widely across the Roman Empire for parallels. Selkirk's theory has not been generally accepted, and in 1992 James D. Anderson published Roman Military Supply in North-East England: An Analysis of an Alternative to the Piercebridge Formula. In this he takes each of the sites identified by Selkirk, gathers the evidence for and against his theory for each site, and in general refutes the main argument of Selkirk's theory (Anderson 1992:1-54). At this point it should be said that Selkirk's hypothesis, although not widely accepted as such, has been invaluable in drawing attention to the problems of the movement of bulk commodities in Roman Britain, and to the possible extent of water transportation for this purpose. After refuting Selkirk, Anderson goes on to develop an overall hypothesis for the Roman supply system in northern Britain, which would use sea-borne transportation to the major ports, followed by a mixture of land transport and river transport to the final destination. River transport might be used either directly to the final destination, or to an intermediate point at which goods would be transferred to ox-cart or other land transportation facilities (Anderson:1992:58-88).

---

13 Personal observation while sailing a small boat through Holland in 1950.
Annex 1 to Section II.8: The *Classis Britannica*

By the time of the Claudian invasion and conquest of Britain in A.D. 43, Rome already controlled the coast-line of northern Europe from Gibraltar round to the eastern boundary of what is now the Netherlands. On the Continent there was no other major naval power, and the Britons did not have a fighting fleet.14 A fleet, eventually known as the *classis Britannica* was probably created to support the invasion of A.D. 43, although construction may possibly have been planned a few years earlier, when Gaius was making his abortive preparations for an invasion.15 During the first century A.D. it supported the advances to the north and west, and the consolidation of the northern areas. Tacitus has a number of references to the activities of the fleet in support of Agricola's campaigns. Once Roman rule in Britain had been consolidated, there was no major sea fighting role for the *classis Britannica* until the later second century and third century A.D. The Chauci and Frisian pirates became a nuisance to Britain in the later second century, and in the third the advent of Saxon raiders and pirates on the east and south coasts became a serious problem (see pages 39-40). The role of the *classis Britannica* until the end of the second century was thus largely confined to the transport of men and materials to and from the Continent for much of its existence (Cleere 1989:18-19, Starr 1941:152-53).

The fleet was commanded by a *praefectus* from the equestrian order, and there is epigraphic evidence for four of its commanders (*RIB I, 66, CIL VI 1634, CIL XI 5632 = ILS 2735, CIL XIV 5341*).16 The crew of each vessel constituted a military *centuria*, irrespective of its actual size (Cleere 1989:19). An auxiliary centurion commanded each ship, but with an experienced *trierarchos*, to direct the vessel's operation under sail or oars.17 “The exact relationship between the trierarch and centurion is unclear (Adkins and Adkins 1994:75). The total establishment of the fleet was about 5,000 men, distributed between *Bononia/Gesoriacum* (Boulogne) ca. 3,500 men, *Dubris* (Dover) ca. 700 men, and

---

14 As noted on page 39, in the campaigns of Drusus the Elder and later Germanicus beyond the Rhine and along the coastal areas of north-east Germany, the Romans encountered native fleets, and for various reasons were not always completely successful in maritime matters.

15 There is no evidence that Gaius built a fleet for his projected invasion, although he had at least a few triremes, in one of which he launched himself into the English Channel. Later “He had the triremes in which he had entered the ocean carried overland to Rome for the greater part of the way.” (Suet. Calig. 47). Barrett has studied this episode, and concludes there is no evidence for the building of an invasion fleet by Gaius (Barrett 1989:135-9).

16 For the prefects listed in CIL VI, XI, and XIV, the epigraphic evidence is not from Britain, but from elsewhere in the Empire in inscriptions recording their careers. *RIB I 66* is from the Saxon Shore fort at Lympne, where the stone was re-used in building the fort.

17 Adler has argued that “Each Liburnian carried two ranking officers: - The military Commander: the *Navarchos*, - The Sailing Master: the *Gubernator/Trierarchos*” (Adler 1998:78).
500 to 700 men working at iron production in the Weald at six major sites (Cleere 1974:244). From the archaeological evidence, it is clear that these two bases were already functioning in the early second century, Gesoriacum with a fort of about 12ha, and Dubris with a fort of 1.05ha. Gesoriacum from its dominant size was almost certainly the headquarters. There is also evidence in the form of classis Britannica tile stamps from Lympne and Reculver for more or less permanent subsidiary bases. There were undoubtedly a number of temporary bases established around the east, south, and west coasts of Britain in support of the military campaigns of the first century A.D, and the later Severan campaigns in the north, but there is no substantial evidence for permanent bases other than those mentioned above.

The original base in Britain was probably at Richborough, from which a few stamped tiles have been recovered. By A.D. 117 work was begun on a new fort at Dover, but it was left incomplete when the garrison went north to help in suppressing the northern revolt, where at least part stayed on to take part in the building of Hadrian's Wall (Philp 1981:91-93). RIB I, 1340, a building slab inscription from the portico of the Benwell Granary, and RIB I, 1944 and RIB I, 1945 record work done by vexillations of the fleet. classis Britannica tile stamps are known from London, Southwark, Cranbrook, Bardown, Bodiam, Beaufort Park, Pevensey, Richborough, Dover, Folkestone, and Lympne (RIB II, Fasc.5:2481.1 to 2481.119). About A.D.130 work was resumed on the fort at Dover, but on a different alignment. With a few breaks in 150-55, 180-90 and 196-200 the fort was used by the fleet until 21018. From the fleet's iron manufacturing sites in the Weald, where Severan coins have been found, it seems probable that iron production continued into the first half of the third century. Philp has suggested that after 210 the fleet may have been involved in the first phases of the construction of the Saxon Shore forts (Philp 1981:118). A funerary inscription from Arles (CIL XII 686) implies that the fleet was still in being in A.D.240 (Cleere 1989:22). Sometime after this it was disbanded, as were other provincial fleets at the same time. Ships and their crews may have become attached to army units, as suggested by the inscription from York, showing a gubernator or pilot as a soldier in Legio VI Victrix (RIB I, 653). With the programme for the building of the Saxon Shore forts, it is possible that a new type of unit was formed, with the capability to fight on both land and sea (Cleere 1989:22).

In summary, the classis Britannica appears to have existed as a formation from ca. A.D. 40 to ca. A.D. 250. After that the role of coastal defence seems to have devolved on to the "Forts of the Saxon Shore" and their garrisons, while it is possible that army units had their own vessels and crews for supplying and supporting military operations. The garrisons of the forts may have included certain light scouting vessels, with "...the sails and rigging dyed Venetian blue, which resembles the ocean waves; the wax used to pay19 ships'
sides is also dyed. The sailors and marines put on Venetian blue uniforms also, so as to lie hidden with greater ease when scouting by day as by night” (Milner 1993:136. Translation of Veg. Mil. IV.37).

**Annex 2 to Section II.8: List of Tidal Ranges around Britain**

Tidal range is the difference in height between successive high and low waters. The ranges tabulated below are equinoctial spring tides. Neap tidal ranges will be somewhat less. Heights are given in both feet and metres. Figures have been taken from the 1965 tide tables. This pre-dates the installation of various barrages and other control devices on a number of tidal rivers, such as the Thames.

<table>
<thead>
<tr>
<th>Location</th>
<th>Feet</th>
<th>Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firth of Tay</td>
<td>16.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Moray Firth</td>
<td>17.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Firth of Forth</td>
<td>17.6</td>
<td>5.4</td>
</tr>
<tr>
<td>River Tyne</td>
<td>16.0</td>
<td>4.9</td>
</tr>
<tr>
<td>River Tees</td>
<td>17.4</td>
<td>5.3</td>
</tr>
<tr>
<td>River Humber</td>
<td>23.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Kings Lynn</td>
<td>23.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Harwich</td>
<td>13.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Colchester</td>
<td>15.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Maldon</td>
<td>9.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Sheerness</td>
<td>18.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Thames, London</td>
<td>22.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Chichester</td>
<td>14.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Portsmouth</td>
<td>14.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Southampton</td>
<td>15.4</td>
<td>4.7</td>
</tr>
<tr>
<td>Weymouth</td>
<td>6.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Dartmouth</td>
<td>16.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Plymouth</td>
<td>16.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Plymouth</td>
<td>16.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Falmouth</td>
<td>18.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Bristol Channel</td>
<td>43.0</td>
<td>13.1</td>
</tr>
<tr>
<td>River Mersey</td>
<td>30.1</td>
<td>9.2</td>
</tr>
<tr>
<td>Solway Firth</td>
<td>28.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Firth of Clyde</td>
<td>14.6</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Notes:**

i. Firth of Tay tides are for the Tay River bar. Carpow tides would be about 15 feet or 4.6 m.

ii. London tides are at London Bridge and were probably of a lesser range in Roman times.

iii. Bristol Channel tides are for the upper reaches where the Channel narrows into the mouth of the Severn. At the entrance to the Channel the tidal range would be much less.

iv. Firth of Clyde tides are for Glasgow.
Annex 3 to Section II.8: The Problem of Subsidence, Silting, Coastal Erosion and Littoral Drift on the East and South Coasts of Britain
(See Map 5)

In any discussion of, or work on Roman port and harbour installations in Britain, a great deal of caution is necessary on coastal, estuary and river configuration, and on the relative heights of sea and land. For most of Scotland, the west coast of England and Wales and the south coast from Land's End to the River Exe, the main coastline with its rugged rock formations and rocky cliffs has been relatively stable in shape, if not in relative elevation. On the east coast south of the River Humber, however, and along the south coast as far as Devon the coastline and estuaries in many places have undergone substantial changes in shape and configuration. This is particularly so for the area from the Wash round the Thames estuary and from Richborough along the south coast to beyond Dungeness. A number of estuaries around all the coasts have changed significantly from the effects of silting and varying relative sea levels. Cunliffe has reviewed the effects of changes in the coastline and land areas of Romney Marsh as it affected the fort at Lympne in Kent (Cunliffe 1977:43-47, Eddison 1995, Eddison and Green 1989). At Richborough the southern part of the fort site has been lost, while what used to be a navigable channel for ships in Roman times and later from Richborough to the Thames estuary, the Wantsum Channel, is now largely dry land, although in the 1950s it was still possible to paddle a kayak along the channel. D'Olier has postulated an average sea level rise and/or subsidence of about 12.7cm per century, or about 2.4m since the early Roman period in the Thames estuary (d'Olier 1972:129).

For the Wash area, Simmons has shown that the configuration of the coast line was not only significantly different from the present one, but that major changes took place between 200 B.C. and A.D. 200 (Simmons 1977:65-68). On the north-west coast in the Solway to Liverpool Bay area there appears to have been major changes, with the mean high water mark in later Roman times up to 5m higher than present levels (Jones 1977:102) Akeroyd in her paper of 1972 comments:

The recorders of archaeological and historical remains have failed frequently to allow for the many factors involved in the assessment of relative land and sea level changes in the past, or to appreciate fully the complex inter-relationship between man, society and the environment: their estimates of past sea level heights (and of other situational factors) must therefore reflect these omissions....there are for southern Britain too few inter-disciplinary studies of estuarine and coastal deposits....(Akeroyd 1972:165).

Apart from relative changes in sea level, any estuary or slow flowing river in an alluvial plain will be subject to silting, and major relocations of the navigable channels. Notable examples from the eastern Mediterranean are Miletus, Priene and Ephesus, once seaports, but now several kilometres from the coast. Ostia and Portus, the port and harbour at the mouth of the Tiber for Rome, are now almost 2 km from the sea.

In summary, in dealing with Roman period port and harbour sites on the sea coast, in estuaries or on inland waterways, it is most important to try and establish what were the exact conditions on the coastline in antiquity. An area such as the Wantsum channel was a
navigable water-way for seagoing ships, at least in the early Roman period. Today it is no longer a continuous waterway, and in parts that still have a water channel, navigation is limited to kayaks. Coastal changes around the Wash have affected not only navigation but farming and industry.
Annex 4 to Section II.8: Cleere's List of Harbours from the Roman Road System
(See Map 6.)

1. The Tyne estuary
2. Scarborough
3. Filey
4. York
5. Brough-on-Humber
6. Winteringham
7. Lincoln
8. Brancaster
9. Caister-by-Yarmouth
10. Burgh Castle
11. Colchester/Fingringhoe
12. Bradwell
13. London
14. Rochester
15. Reculver
16. Richborough
17. Dover
18. Lympne
19. Hastings
20. Pevensey
21. Chichester/Fishbourne
22. Porchester
23. Bitterne
24. Hamworthy
25. Radipole
26. Exeter/Topsham
27. Sea Mills
28. Gloucester
29. Caerwent
30. Caerleon
31. Cardiff
32. Neath
33. Carmarthen
34. Pennal
35. Caernarvon
36. Caerhûn
37. Chester
38. Wilderspool
39. Ribchester
40. Lancaster
41. Ravenglass
42. Moresby
43. Maryport
44. Beckfoot
45. Bowness
Annex 5 to Section II.8: Possible Minor Havens around Britain from the River Tyne to the River Exe, and Havens in Scotland (Map 8)

This annex lists only places where Roman material has been found. A more complete list of possible minor havens, which includes those in this annex, is given in Appendix O. To avoid repetition, references for material in this annex are given in Appendix O.

The list of minor havens, which excludes those certain or probable harbour sites already listed by Fryer and Cleere, has been compiled from a study of the 1/50,000 Ordnance Survey maps, relevant nautical charts, and the author's personal knowledge of many, gained while sailing small boats around the East and South Coasts of Britain in the late 1940s and 1950s. Material of Roman date found at the various sites has been compiled from published excavation reports in, Britannia, JRS and some other sources. For the purposes of this thesis, the search has been largely limited to the east and south coast havens. On the west coast and Wales, because of the rugged and mountainous terrain, there are few really sheltered natural havens until one reaches the estuaries of the Rivers Dee and Mersey, and farther north the Solway Firth. The Bristol Channel on both shores has a good number of sites suitable for small vessels, but because of the large tidal range and prevailing westerly winds, often strong, without extensive local knowledge it is not a very safe area for small sailing ships.

List of Possible Haven Sites with Evidence for a Roman Presence
(Note: A complete list of possible sites, with references for those with archaeological evidence is given in Appendix O.)

English East Coast Havens

Hartlepool
A double burial of a man and woman, a necklace of glass beads; 4th-5th c. A.D.

Whitby
A Mayen sherd from Germany.

Hull
Bronze Age and Roman material; boundary ditches of 2nd to 4th centuries; sufficient ditches, tombs and structures to suggest a small town. Roman period river bank, a riparian settlement?

Brough-on-Humber
Probable hard surfaced area. Brough was a haven and fortified site and almost certainly a supply base at different periods, see Wacher 1969.

Selby
Fourteen Roman period coins found.

Wisbech
Coin finds, gold stater, coins of Gallienus, a cruciform brooch.

Hollesley
Roman ditch system and a number of storage pits; a nearby settlement suggested, but not found.
Waldringfield
A large number of clay moulds (30+) for bronze casting found; late Iron Age to mid 1st century A.D.

Woodbridge
Finds include pottery, roof and other tiles, small bronze figurines, lamps, cosmetic set, coins, date range 117-346 A.D.. Gallic and British coins found, suggesting pre-Roman use of the site.

Rivers Stour and Orwell

Felixstowe
Ditches, pits, postholes, large quantities of pottery, tile, bronze cosmetic mortar set, lead seal Legio VI *Victrix* with officer's(?) initials, aureus of Marcus Aurelius, A.D. 160. Material spans 2nd to 4th century. First century A.D. Roman rubbish pits, ditches, structures and well preserved Roman deposits.

Ipswich
Three sides and part of interior of a ditched enclosure, 1st to 3rd centuries; two bronze brooches, one enamelled, 2nd-3rd century. Ditches, pits, post-holes and cremation burials dating to the first century A.D.

Shotley
Gold quarter stater of Addedomarus.

Rivers Colne and Blackwater

Brightlingsea
Pieces of Roman brick, box flue tile, septaria, a villa?

Mersea Island
Five denarii to c. A.D. 37

West Mersea
Roman wall, floors, associated deposits.

Tollesbury
Salt recovery site; hearths, briquetage, includes fire bars, pedestal and clay lined gully.

Heybridge
Late Iron Age levels with large amount of pottery including significant amount of imports: it was concluded that Heybridge was a trading port in the Iron Age. Roman period: metalled roads, large metalled areas with traces of timber structures, pits, post holes, ditches, wells, domestic areas, manufacturing areas, evidence for 1st century brick built structure (a mansio?), five well preserved pottery kilns, mould fragments and other evidence for metal working, four timber lined wells, cemetery. An early Roman gravel digging area levelled off with industrial waste including iron slag, charcoal, ash, kiln debris, lead droppings, later gravelled over to make a yard, probably associated with a wharf on the river Blackwater. Other finds include a tegula fragment with graffito CCXX cut retrograde before firing (from a batch of
220?): Samian bowl fragment found with 2nd century material, stamped BORILUS I of Lezoux (c. AD 150-60), graffito cut after firing on inside of foot ring VET FIR[...]. A plank from a well lining is stamped SV. The general conclusion is that it was the site of a small town of about 9ha (22 acres), most active in the 1st and 2nd centuries, but fading out of use by the 3rd century. Local research has suggested important trading connections with Chelmsford (Caesaromagus). The River Chelmer, partly canalized in the 19th century connects the two. The most recent excavations and publications have downgraded the Roman site to a "market village", rather than a small town, partly because of the lack of good road communications. On the other hand there is the river which connects to Chelmsford. This could have substituted for a road for the movement of goods.

**Maldon**
A substantial settlement, ditches, flue tiles, Roman cremations, pottery, silver brooch. Salt pans, two main groups of clay lined evaporators, tanks, artificial basin, many fragments of pedestals and firebars of three types. Sherd of Italian Arretine, an amphora stamp reading PIRP.C. A farming settlement and salt manufacturing area. Three gold staters of Dubnovellaunos found, dating to c. B.C. 25.

**River Crouch**

**Burnham-on-Crouch**
A 1st century settlement with 3rd century occupation.

**Hullbridge**
A brushwood platform, possibly used as a jetty, dated to 340-450 A.D.
In the area twelve "Red Hill" sites, late Iron Age and Roman salt production.

**Rochford**
2nd and 3rd century Roman occupation.

**River Thames**

**Southend-on-sea**
Hoard of 33 Gallo-Belgic E staters.

**Canvey**
Wall sherd of a Samian cup. From an eroded foreshore deposit, an Upchurch ware beaker with a graffito cut in neat capitals after firing.

**Benfleet**
Salt workings, Leigh Beck Marshes.

**South Coast**

**Ramsgate**
Hoard of 27 sestertii, from Hadrian to Postumus.

**Sandwich**
Pits and ditches covering more than 4 ha, coins, terra nigra platter with graffito
COMMUNIS, winged corridor house, ovens, walls of chalk and flint lumps set in clay. Occupation 1st to 4th century, but most intense in 1st-2nd centuries. Samian ware and cremation burials.

Minster
Site of a villa, much building debris, floors 30m long, internal masonry wall 4m long. Two hoards of 3195 and 99 radiates down to AD 282. West wing up to twice width of east wing.

Eastbourne
Greensand stone used as Roman building material, probably from Maidstone, and shipped from the River Medway. One complete voussoir tile found.

Newhaven
Rescue excavation, ditches, enclosures timber structures, painted plaster, tiles, window glass, dated to early 2nd century. Extensive timber building with ironstone and flint foundations, timber granary 14m x 5m, and several other large buildings. Pottery suggests site abandoned before 4th century.

Littlehampton
Evidence for crops, spelt, barley, rye brome, vetch (as a fodder crop?).

Chichester Harbour

Bosham
Claudian base known. Tiles, fragments of tiles, painted plaster, opus signinum.

Chidham
Two salt production sites on the foreshore, Late Iron Age to 2nd century A.D.; solar evaporation pan, shallow trenches for further evaporation, fragments of salt cake moulds. Much briquetage and pottery, from the rescue excavation.

Hayling Island
A circular Roman temple 13m diameter in temenos 30m x 30m, surrounded by ambulatory with its own entrance, dated to A.D.60, enlarged c. A.D.100, no activity after c. A.D.200. Agricultural and domestic activity to 4th century, from coin evidence. Fragmentary inscription of Legio IX Hispana. Below Roman levels Late Iron Age, with imported Celtic bronzes, votives, hearths. A separate site at South Hayling has ditches and pits with 1st to 3rd century pottery.

Langstone Harbour
A surface scatter of roof tiles.

Havant
Romano-British pits and pottery, 3rd to 4th century ditch and pit, no trace of possible Roman road found.

Portsmouth Harbour
Coins of Iceni found.

Fareham
Cobbled area, flint footings, drainage ditches, ditches, pottery, tiles, two hearths,
animal bones, pits densely packed with remains of shellfish, 30 coins, 16 dated 253-337, remainder 364-392.

**Hamble**
2nd and 3rd century pottery.

**Southampton**
Structures, occupation and demolition deposits, including material up to 3rd and 4th century. Roofing tiles, calcareus roofing tiles with unusual rounded tegula flanges are a significant part of tile assemblage. These unusual tiles have a distribution from London to Devon. Movement of tile from the as yet unidentified tilery was almost certainly by ship along the south coast. Many sites no longer used locally produced tiles, but depended on specialized production centres. Dating is difficult, but 3rd and 4th century probable (Betts and Foot 1994:33-34).

**Isle of Wight**

**Bembridge**
Hoard of 26 sestertii, Domitian to Commodus. 27 coins found in intertidal silt c. 130m offshore, Domitian to Faustina II.

**Cowes, River Medina**
Gurnard Bay, 3km east of Cowes, hoard of counterfeit lead-tin denarii of Lucius Verus and the two Faustinas, together with residue of copper alloy smelting. Site 300m from Roman building destroyed by coastal erosion in 1864.

**Yarmouth**
East of harbour mouth, 16m deep, Dressel 1A and 20 amphorae found, late 1st century mortaria and sherds of BB1, and a tegula fragment of Armorican origin.

**Poole Harbour**

"Poole Harbour and the Isle of Purbeck appear to be the scene of one of the most remarkable varied and substantial concentrations of later iron Age and Romano-British export industry to be found anywhere in Britain, supported by settlements that were comparatively large (c. 10ha) and evidently planned... there is evidence that imports from overseas were flowing into the area for much of the period" (Allen and Fulford 1996:240). Purbeck marble for mortars and architectural decoration, Kimmeridge shale for personal ornaments, iron, salt and vast quantities of Black-burnished pottery were produced. Fish caught and oysters raised in the area were also exported. Twenty-three Romano-British sites have been positively identified in the area, and the total number of sites is probably in the tens. Pottery was moved by sea, road and inland waterways. The extensive study by Allen and Fulford has enabled them to trace the movement of pottery to its final destination, and to evaluate the different roles of road, river and sea as transport media (Allen and Fulford 1996: 241-2, 260,271).
Wareham
Extensive system of ditched enclosures Late Iron Age to 3rd century A.D. Some indications of iron working in Iron Age. Mid 2nd century activity switched to production of Black-burnished ware. Large quarry pit producing fine white clay, preparation trough for clay, a pit clamp, five kilns excavated, single chamber, single flue design with no permanent raised floor or portable kiln furniture. One kiln still contained its final load. Various coin hoards to A.D.282.

Weymouth
Remains of Roman building on cliff edge, south-east of temple on Jordan Hill. Floor of building sealed pottery of 3rd to 4th century, but no occupation material overlying it.

River Exe

Exmouth
Excavations produced box tile fragments, pottery, suggesting a hypocausted building.

Topsham
Large number of features from gravel subsoil, mostly 1st century A.D. Three roomed building 10.6m x 4.3m with veranda on south-east front. Second building 4.5m wide, length uncertain, a four post structure, a circular structure c. 6m diameter, cremation in Black-burnished cooking pot in small square timber structure. Pottery Durotrigan and native forms, but surprising amount of samian20 and other imported finewares. Ditches of a rectangular enclosure.

Exeter
Extensive excavations and investigations over the past thirty years on the fortress and its surroundings. Excavation reports and annual reports in Britannia have delineated the fortress, the Legionary Bath-House and the Basilica and Forum plus a number of other structures (Bidwell 1979). Buildings possibly used as store house sit above the River Exe. Barrack blocks and part of city wall identified.

Channel Islands

Alderney, The Kennels, Longy Common
Excavation of a short length of wall, 0.9m thick, of massive granite and sandstone blocks, dated to late first-early second century. Part of Roman harbour works?

Scotland

There are several probable sites for harbour facilities. All are military sites

20 In reports on Roman Britain the term samian is used almost exclusively for terra sigillata pottery, and has been used in this paper when using British sources.
connected with the Antonine and Severan advances.

**East Coast**

**Carpow** (on the Firth of Tay). Carpow is possibly the place named *Orrea* by *Ptolemy* (Keppie 1986:153).

The fortress of about 12 ha is set back about 300 m from the Firth of Tay, on rising ground. A slab from the East Gate has a dedication to the emperor Caracalla from the Legio II *Augusta*. Roof tiles stamped by Legio VI *Britannica* (*RIB* 11. Fasc.4., 2460.71-74) have been found on the site. Internal buildings were a mixture of stone and timber. To date no harbour facilities have been noted, but possibly no one has looked for them. The Firth is about 200 m wide at the fort, and it would have been possible with care to beach ships on the foreshore, preferably on a prepared hard.

**Camelon**

Camelon, a small fort, is situated on a plateau beside the River Carron, off the Firth of Forth. It was a probable Antonine period harbour, and supply base for the Antonine Wall, and may have been used for this purpose both earlier and later. The fort covers about 2.4 ha, and the internal buildings are all of stone. A Flavian fort probably preceded the Antonine structure. It was a staging post for more than one campaign, since at least ten temporary camps lie west and south of the fort. In the Roman period the river was easily navigable from the Firth of Forth by vessels the size of the Blackfriars Ship 1 (today it is somewhat obstructed by bridges and weirs). No traces of Roman wharves or quays have been reported to date. It would have been a convenient transhipment point. The Roman road leads north from it to Stirling, where it crosses the River Forth, and continues on to the Gask Ridge, to *Bertha* and beyond (Margary 1973: 491-5, Fig. 16).

**Cramond** (on the Firth of Forth)

The first major excavation of the site was carried out in 1954 to 1966 (Rae 1974:163-224). Since then the work has continued and is currently still active in conjunction with the construction of a major new sewage outfall for Edinburgh and Leith (personal observation, June 2001)

Cramond is a fort site on the east bank of the River Almond, where it runs into the Firth of Forth. Occupations include the Antonine and Severan periods, with civilian occupation extending into the fourth century. The estuary of the Almond, although it almost dries out at low tide, is an excellent haven for small craft. It is only open to winds from the north, and provides shelter from all other winds. Today it is full of small yachts. The bottom of the river at the mouth is soft mud, and Romano-British ships of all sizes could safely sit on the bottom. No remains of harbour installations have been reported, but one or two small jetties built out into the river, or a simple wharf would have been adequate. The banks of the Almond are quite steep, and it would probably have been possible to let ships take the ground close to the bank and use a gangplank for discharging cargo.

Keppie has commented "Cramond in Roman times can be envisaged as a port of some importance." (Keppie 1986:111).
Inveresk (on the Firth of Forth)

The fort at Inveresk is on high ground close to the mouth of the River Esk where it joins the Firth of Forth. It has a substantial civilian settlement to the east. There are two phases of military occupation, and three phases of civilian use. There was deliberate demolition between the two phases of military occupation. A small amphitheatre was noted in 1998. The River Esk where it flows into the Forth is a little smaller than the Almond, and also almost dries out at low water. It could accommodate small craft that could take the ground, certainly up to the size of the Blackfriars I ship from the Thames. The entrance is an awkward and narrow channel between gravel banks, and would need local knowledge. Some beacons on the banks would have been helpful.

West Coast

Glenhead Fort (near Ardrossan)

"...Glenhead Fort, near Ardrossan (Ayrshire), might give a hint of the location of the presumed Roman harbour on the Ayrshire coast..." (Robertson 1970:204). This comment by Robertson appears to be the only information on possible Roman harbours on the West Coast. Agricola’s main campaigning thrusts were up the East Coast, although in A.D. 81 he placed garrisons in the area south of the Clyde, and in Ayrshire and Galloway, and placed troops on the coast facing Ireland. He also established forts along the Forth-Clyde line (Tac. Agr. 23,24). With troops along the coast and on the Clyde, some local maritime traffic may have been established. Certainly by the period of the Antonine Wall with its west end on the Clyde, there would be advantages in having maritime transportation links up the West Coast, from Chester and Maryport at the west end of the Hadrianic defended area to the Clyde. South-East Dorset Black Burnished pottery is found on both Hadrian’s and the Antonine Wall (Allen and Fulford 1996:247-9, Fig. 11a). It certainly reached Hadrian’s Wall by sea, followed by local distribution by land. It could have reached the Antonine Wall from depots on the Tyne-Solway line either by sea or up the Roman roads running to the Forth-Clyde area. There is no firm evidence to date from either the archaeological or literary record for harbour or port facilities on the West Coast of Scotland.
Section II.9: Discussion and Conclusions on the Technology of Romano-British Vessels and Harbour Facilities

9.1. Introduction

This section summarizes what the people of Roman Britain might have hypothetically achieved in maritime technology, and what they actually achieved as demonstrated by the material that has survived in the archaeological record, and the material from the written and iconographic sources. It discusses the constraints on both what it was practicable to build with the tools, materials and technology available in Roman Britain in the first and second centuries AD, and the natural forces that effectively controlled the range of designs and construction which would be functional in the ambience of those natural forces for all sizes of vessel.

9.2: The Constraints

The constraints were of four types, those over which people had no control such as tides and winds, those over which they had some measure of control, as in the shaping of wood and iron to make a ship, those which they largely controlled such as the number and size of vessels to be built, and the constraints imposed by the availability and harnessing of energy sources.¹

2.1. The Natural Constraints, Tides, Topography and Winds

Around Britain and the Channel and North Sea coasts of Gaul and Germania Inferior, a major natural force, the tidal range, imposed constraints on the design of seagoing and estuary vessels. This tidal effect represents a major difference between the Mediterranean area and the sea beyond the Pillars of Hercules. In northern waters all ships had to be able to take the ground safely, even where man-made wharfage facilities were available as in London. This mandated a vessel with a flat bottom, or at least with a very full form with a hard turn at the bilge. A corollary to this technological constraint was the requirement that the vessel be constructed with a hull sturdy enough to support its own weight plus the weight of the cargo when the hull was wholly out of the water. This would require heavier framing and planking than for a vessel that remained afloat at all times. When fully afloat the weight of the vessel is supported over the whole immersed area, while when aground the weight is carried by the keel or keel planks. Other specialized small craft of relatively light construction, such as the currach or skin boat, may have to be unloaded while still afloat in shallow water. For larger vessels, such as the Blackfriars Ship 1 or the St. Peter Port Ship, which could be required to take the ground for loading and discharging cargo, the framing and planking has to form a structure strong enough to hold the loaded

¹ Even the size, type and number of vessels to be built would have economic constraints, controlled by how much of a social unit's resources could be diverted from subsistence activities.
vessel without distortion of the hull when it is supported only by the keel planks. As noted above, when fully afloat the hull is supported by the water over the entire immersed surface of the hull. In the case of a large vessel, a precondition for secure beaching or taking the ground is a relatively calm water surface. A small boat can be beached quite safely in rough weather by the crew leaping over the side and running the boat up on to the beach or hard. A large vessel going aground in rough seas will be pounded, damaged and even broken up by the force of the waves. The sandbanks encumbering the Thames estuary and the southern North Sea, and the Goodwin Sands off Richborough are littered with wrecks of the last two thousand years from this hazard.

Although humans could not control the tides, currents and winds, with long practical experience and observation they could anticipate the consequences of these phenomena to some extent. For example, sound knowledge of the phases of the moon and the diurnal position of the sun made it possible to predict fairly accurately the times and heights of high and low water. The strength of tidal currents correlates to some extent with the heights. The winds would be more difficult to predict, but with experience and traditional knowledge passed on through generations, and by observation of the current cloud patterns, both seasonal wind patterns and local wind conditions over the next day or so could be forecast.

2.2. The Constraints of Materials and Tools

Timber was the principal structural material used for the construction of Romano-British ships. Forest grown oak (*Quercus sp.*) was readily available in early Roman Britain and northern Gaul. Oaks grown in forest or woodland tend to have fairly straight boles of moderate diameter up to one to two metres, with branches concentrated towards the top to catch the light needed for photosynthesis. These oaks are very suitable for conversion into planks, and the upper part with branches can provide a number of naturally curving pieces for conversion into stem and stern posts and frames. Free standing oaks have a much more spreading configuration with large branches. This makes them less suitable for planks, but they provide an excellent source of large crooks, naturally curved lengths of timber in a wide range of sizes for heavy timbers.

The five basic woodworking cutting tools available to the Romano-British shipwright were the axe, adze, chisel, spoon bit (for drilling holes) and the saw. All these are known from the archaeological record. In addition a number of iconographic sources from the Roman world depict these tools being used, Fig. I.4.1.1., I.4.1.2, I.4.5.1.a, b, and c. Of this tool kit the axe and the adze did most of the work, being used to hew the bottom transverse timbers, the floors, the side frames and the end posts to shape. The planking could be either hewn or sawn. The St. Peter Port ship had sawn planking, the saw marks being clearly visible on the surviving planks, and the Barland’s Farm Boat also had sawn planking. With the Blackfriars Ship 1, and the New Guy’s House boat the planking surface

---

2 The potential and kinetic energy of a wave is proportional to length x height squared. A seven metre high wave hitting the coastline or a grounded ship strikes with a force equivalent to about 563 kW per metre of length, an extremely destructive force (Meteorological Office 1967:46).
is too deteriorated to make a positive identification for sawing. Because of their dates, from c. AD 130 to AD 300, it seems possible but not certain that they used sawn planking. The vessels known from the pre-Roman Iron Age and the Bronze Age, such as the Hasholme and Poole log boats, the Brigg Raft and the Dover Boat, were fashioned entirely with axe and adze without the use of saws. Technically it is quite possible to build a large ship without using saws. The eleventh century AD ships from Skuldelev at Roskilde in Denmark, ranging in length from 11.6 to 30.0 m, had no sawn timbers. “During the careful examination of every single piece of wood from the Skuldelev ships not a single trace of a saw cut was found. Everywhere there are clear signs of axes and planes....” (National Maritime Museum 1977:10).

The other major component of the ship’s hulls were the iron fastenings in the form of wrought iron nails, some over 0.7 m long3. With the arrival of the Romans in AD 43 the production of iron in Britain increased dramatically, see Appendix D. Interestingly, the production in the first century of the occupation was predominantly from the Weald in the south of England, and was strongly associated with the classis Britannica, which seems to have supervised the production, even if not actively engaged in it. The wrought iron nails had two technical qualities that made them very suitable for shipbuilding. They were very malleable and could be cold worked, which allowed them to be clenched, bent over into a hook driven into the inner face of the frames and floors, thus preventing the nails from working loose, and wrought iron, unlike steel, rusts or corrodes very slowly, even in salt water, as long as other metals are not present.

2.3. The Economic Constraints in Britain

In Roman Britain an individual or group may have had the technical resources and skill to build ships of the Blackfriars Ship 1 or St. Peter Port type, but may have lacked the economic resources, or ‘capital’, after providing for the food, clothing and shelter needs for themselves and their families. Julius Caesar, and 350 years later Maximian and Constantius could have 600 or more ships built within a year, using the manpower available from their armies and probably some impressed local skilled labour. To build his 600 transports and 28 warships in the winter of 55-54 BC Caesar had the resources of five legions, or about 24,000 men. Assuming that only about half would be available at any one time, after attending to the normal military administrative activities and keeping an eye on the Gauls, this would make 12,000 available for ship building. In the six months of the winter, after allowing for festivals and other public holidays about 160 days would be available for work. This would allow about 3,000 man days to build each vessel, which seems reasonable, amounting to a team of about eighteen to nineteen men to build each vessel in the 160 day period.

3 Iron nails seem to have been introduced by the Romans. They occur in quantities at many Roman sites, but are not present at LPRIA sites.
2.4. The Energy Input

Energy is used in two ways, predominantly human, and to some extent animal energy in the activities required to provide timber and iron for ship building, and a combination of human and natural energy in moving ships and boats from point of departure to destination. The human energy input in building ships and boats is discussed in Section III below. Energy use is considered in this section because its availability or lack thereof is a constraint on the movement of ships, and controls the possible mode and speed of movement. Only small boats could use oars or paddles as their primary means of propulsion. Larger merchant vessels had to use energy from the wind through the use of sails, and to utilize the tidal currents to make their voyages. As in the Mediterranean, there are some large scale oceanic currents around Britain and Northern Europe, such as the Gulf Stream, the North Atlantic Current and the Norwegian Current among others, generally with relatively low velocities (Espenshade 1990:14-15), but the main currents useful to coastal mariners are those caused by the tides. Tidal currents around Britain can reach speeds of 2½ knots (4.6 km per hour) or more, and reverse approximately every six hours, enabling the mariner to use them both going and returning. From the trireme trials with the replica trireme *Olympias* it was established that an oarsman could maintain a power output of about 70 watts in steady rowing (Morrison 1996:323), or somewhat more if rested for 20 minutes in each hour. In the trireme, with its three banks of oars, this could be achieved by having only the two upper banks in use, while the other third of the crew rested in the lowest and least effective bank. With the full complement of 170 oarsmen the effective power at 7.05 knots was 14.4 kW (Shaw 1993:42-3). The Blackfriars Ship 1, with its inferred sail area of 8 x 8 m, or 64 m², in a fresh breeze of Beaufort force 5 (15 miles per hour) was utilizing a power input of about 4 kW, the equivalent of about 47 oarsmen. The use of oars was generally only practicable for merchant ships in manoeuvring up to a wharf in harbour, and in similar activities. The Blackfriars Ship is estimated to have had a crew of two or three, and even if the crew were larger only about six to eight oarsmen could be deployed. Sails are obviously the only practicable means of propulsion for merchant vessels over long distances. When operating in estuaries or coastal waters in light winds or calms, the tidal currents could be used by vessels of any size from a small row-boat to the largest ships, and would be particularly useful in the larger estuaries, those of the Thames, Humber and Severn where the velocities of the tidal currents are high. The wind can be a somewhat uncertain source of energy for propulsion. It may not blow at all, it may take the form of a headwind driving the ship back, or it may be so strong, a gale for example, that no sail can be carried. The tidal currents have the advantage of being predictable, relatively constant in speed at the various states of the tide, and can be used for both upstream movement on the flood tide and downstream on the ebb. The tidal currents are effectively zero at high and low water (slack water), and a maximum at approximately halfway between the times of high and low water. Tidal currents along the coast are generally weaker than in confined waters, but follow the same general pattern. In using the tidal current the ship can just allow itself to be carried along on the tidal stream, the only serious possible hazard being the risk of being set on to a sandbank or shoal. With a rising or flood tide this may not be serious, as the vessel should soon float free as the tide rises. On an ebb or falling tide this could be disastrous if the vessel has grounded on the edge of a steep
bank, causing her to fall over on to her side as the water recedes. A worse scenario can occur in a narrow river if the vessel grounds with her bow on one side and her stern on the other, so that the centre is unsupported as the tide falls. If loaded she will probably break her back at low tide and become a ‘constructive total loss’. To maintain steering control with a flow of water past the rudder while using the current in rivers or estuaries, a technique called dredging could have been employed. An anchor or weight would be trailed along the bottom with just enough rope or chain to keep it on the bottom, but not enough to cause an anchor, if used, to dig in and hold. This would pull the ship’s bow round to head into the current and slow her down so that the quarter rudder(s) would become effective, and the ship can be sheered to one side or the other as needed. There is no literary or iconographic evidence for the use of this technique in Roman Britain, but the method requires no special equipment and could have evolved from practical experience while attempting anchoring or trying to sheer into a wharf. It is thought that on rivers like the Rhine and Danube the Romans, and probably their Iron Age predecessors, used ‘flying ferries’, simple punt- or barge-like vessels tethered to one bank with a long rope. The vessel was moved across the stream by the action of a large rudder or steering oar, using the force of the river current on the rudder or oar to produce a sideways movement. The mechanics are similar to those of ‘dredging’. The term dates back to Middle English, c. 1200-1500 AD, so that the technique was known in the medieval period.

9.3 The Technology of Hull Construction for Romano-British Vessels

3.1. Sea-going and Coastal Sailing Ships

The technology for the construction of sea-going and coastal merchant ships’ hulls in northern waters was in good part dominated by the rise and fall of the tides. This required a form of construction for vessels which would allow them to take the ground safely when fully loaded. The ships had to be able to sit reasonably upright when aground. They had to be sturdy enough to contend with the variable and often strong winds found around the coasts of Britain. They would also need the structural strength to operate in the short steep waves usual around Britain and the southern North Sea. These requirements could only be satisfied by ships with massive bottom frames (floors) and side frames, heavy planking, and good longitudinal strength resulting from a substantial keel structure, the whole fastened together with numerous clenched iron fastenings. Water-tightness was achieved by a reasonably close fit between planks and the use of caulking made up of wood.

---

4 A ‘constructive total loss’ is when a vessel is damaged beyond economic repair.

5 In the deep open ocean wavelengths between crests may be 300 m or more. Even with wave heights of a few metres this poses no problem for small vessels, apart from the wind strength which created these heights. As wave patterns run into the mouth of the English Channel, where the depth shoals rapidly from c. 3,600 m in the Atlantic to less than 180 m in the Channel, and as the wave moves up into the ever narrowing Channel, much shorter and steeper waves build up. The entire North Sea is less than 180 m deep, and is further encumbered with sandbanks and shoals, causing similar conditions of short steep waves. Short steep seas impose considerable stress on the hulls of small vessels. See also fn.2.
shaving or moss combined with pine resin. An interesting comparison is between the Romano-British ships, the Kyrenia ship of the fourth century BC from the Mediterranean and 19th century wooden sailing coasters, many hundreds of which operated around Britain carrying both local and long distance cargoes, often between places with no harbour facilities.

Table II.9.1: Comparison of the Dimensions of the Hull and Components for Romano-British Vessel, 19th Century Wooden Coasters, and a Mediterranean Built Ship

<table>
<thead>
<tr>
<th>Category of Dimensions</th>
<th>St. Peter Port Ship</th>
<th>Blackfriars Ship 1</th>
<th>19th century Coaster</th>
<th>Barland’s Farm Boat</th>
<th>Kyrenia Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>19.1 m</td>
<td>18.5 m</td>
<td>21.9 m</td>
<td>11.4 m</td>
<td>14.0 m</td>
</tr>
<tr>
<td>Keel planks, thickness</td>
<td>0.14 m</td>
<td>0.076 m</td>
<td>0.35 m</td>
<td>0.065 m</td>
<td>0.12x0.20 m (see note)</td>
</tr>
<tr>
<td>Floor frames cross-section</td>
<td>0.2x0.5 m</td>
<td>0.3x0.21 m</td>
<td>0.2x0.2 m</td>
<td>0.09x0.13 m</td>
<td>0.09x0.09 m</td>
</tr>
<tr>
<td>Side frames cross-section</td>
<td>0.2x0.2 m</td>
<td>0.13x0.21 m</td>
<td>0.2x0.2 m</td>
<td>0.09x0.13 m</td>
<td>0.085x0.085</td>
</tr>
<tr>
<td>Frame Spacing</td>
<td>1.1 m</td>
<td>0.886 m</td>
<td>0.6 m</td>
<td>0.56 m</td>
<td>0.50 m</td>
</tr>
<tr>
<td>Planking thickness</td>
<td>0.07 m</td>
<td>0.05 m</td>
<td>0.076 m</td>
<td>0.035 m</td>
<td>0.038 m</td>
</tr>
</tbody>
</table>

Note: The Kyrenia ship had a regular keel projecting below the bottom planking, rather than the heavy flat plank keels of the northern vessels, but even so it is on the light side.


Even allowing for the smaller size of the Kyrenia ship the framing and planking of the Romano-British vessels are much more substantial than those of the Mediterranean ship. The Romano-British ships and the 19th century wooden coaster operating in the same area and conditions and with the same constraints are remarkably similar in their scantlings, which reflects the need for sturdy construction for vessels sailing in the English Channel and southern North Sea, whether in modern times or two thousand years ago.

3.2. An Estuary and Inshore Coastal Boat

The Barland’s Farm boat is the only surviving Romano-British vessel of this type found to date in Britain. She would have operated principally in short coastal voyages from one haven or river mouth to another one, and could also penetrate upstream for long distances on suitable rivers. She would have worked both sides of the Bristol Channel and into the rivers discharging into it. Quite similar boats would have been used along many
reaches of the south and east coasts of Britain. Compared with the Kyrenia vessel, a ship considerably larger than the Barland’s Farm Boat, the Barland’s boat is substantially built and fastened. Frames and floors are about 50% heavier, the frame spacing is about the same, and the planking thickness is comparable on both vessels. The construction of the Barland’s Farm Boat is generally similar to that of the seagoing and coastal ships described in 3.1 above, heavy timbers and planking fastened throughout with clenched iron nails.

3.3. Inland River Barges and Punts

a. The New Guy’s House Boat

The only Romano-British planked vessel intended exclusively for inland use in sheltered waters found to date in Britain is the New Guy’s House boat, a shallow, open, beamy boat about 16 m long and 4.25 m wide, pointed at both ends. The planking is lighter than that of the Barland’s Farm boat, planking 0.025 m thick (Barland’s 0.035 m), and the frames have very nearly the same cross-sectional area although of slightly different proportions, 0.146 x 0.076 m deep (Barland’s 0.13 x 0.09). Compared with the Zwammerdam barges described below, this is a more sophisticated vessel, and for service on quiet inland rivers its construction is unduly complex, and therefore expensive to build. The type may have been limited to London. There were oak ceiling planks, 0.02m thick nailed over the frames. Because of the pointed ends it was not suitable for carrying cattle or wagons. The ceiling planking is relatively thin, making rough cargo such as quarry-run stone unlikely. Two uses seem possible. It may have been used to move low density cargo which would not damage the ceiling planks, such as grain in sacks, or it may have been used as a ferry for people.

b. Flat-Bottomed Barges, Rectangular in Plan Amidships

There are no barges of this type from the archaeological record in Britain, but several flat bottomed barges of the Roman period in a range of sizes have been recovered from Zwammerdam in Holland. The common features are the bottom made up of several planks and the chines are formed by L shaped pieces hewn from a quarter log. The chine logs and bottom planks are held together with L shaped frames, alternating to left and right, with some additional side frames slotted into the plain ends of the frames. The sides are

---

6 ‘Similar’ is used advisedly here. In the late 19th and early 20th centuries there were over forty different types of small craft, mostly small undecked working boats in use around Britain, plus many local variants within each type to suit the peculiarities of the area. The diversity arises from use in different waters to meet the particular conditions of wind, weather, tides, and shoreline topography. They were engaged in every sort of occupation from fishing to ferrying passengers (McKee 1983:69-105).

7 Two barges from Pommeroeul in Belgium were made by splitting a logboat, inserting planks in the bottom, and adding a bow and stern section hewn out of logs. From Lake Neuchâtel in Switzerland two barges were recovered with a flat bottom made up of several planks, plus chine logs or ‘iles’, L shaped pieces hewn out of a quarter log to make the transition from the flat bottom to the low vertical sides, as in the Zwammerdam barges (Arnold 1975, 1978, 1991; Boe 1978).
formed by an additional plank fastened to the frames, Figs. II.9.3.1a, b, and c. In plan the sides curve in somewhat to give a square end about two thirds of the width amidships. All the barges are built of oak and fastened with clenched iron nails. The cargo capacity varies from about 30 tonnes in the smallest to 105 tonnes in the largest.

Table II.9.2: Dimensions and Capacities of the Zwammerdam Barges

<table>
<thead>
<tr>
<th>Barge No.</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Strakes</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>22.75 m</td>
<td>2.8 m</td>
<td>0.95 m</td>
<td>0.08 m thick</td>
<td>c. 30 tonnes</td>
</tr>
<tr>
<td>4</td>
<td>34.0 m</td>
<td>4.4 m</td>
<td>1.20 m</td>
<td>0.10 m</td>
<td>c. 105 tonnes</td>
</tr>
<tr>
<td>6</td>
<td>20.25 m</td>
<td>3.4 m</td>
<td>0.90 m</td>
<td>0.06 m</td>
<td>c. 30 tonnes</td>
</tr>
</tbody>
</table>

(de Weerd 1978:16-17)

The design and building of this type of barge requires only reasonable carpentry skills, and if the plan is strictly rectangular they would be simple to build, particularly in small sizes. It seems probable that on a number of the rivers in Britain barges of this general type in a range of sizes would have been built and used. In pre-Roman times the Iron Age Britons made sophisticated logboats, such as the Hasholme boat, and once the technique of fastening with clenched iron nails had been adopted it would not be a large step to split the logboat, add some bottom planks and ribs, and fasten the structure with iron nails. In Britain the concept of a bottom made of several planks laid side by side goes back to the Brigg Raft of over eight hundred years earlier, and the Dover Bronze Age Boat of c.1550 B.C.

It is of interest to compare the inland water craft of Britain of the medieval period and later which faced the same operating conditions, and which carried similar types of cargo. From the early medieval period and later, on into the mid-twentieth century, a number of Britain’s inland river systems used substantially constructed planked flat-bottomed vessels with ‘bluntly double ended hulls’, or later with flat transom sterns. Examples include the Humber Keel, built of oak and with a single square sail, working the Rivers Humber, Trent and Ouse. They were about 18.25 m long by 4.6 m wide, with a cargo capacity of 60 to 100 tonnes. In this form they date back to at least the fourteenth century AD. The crew was one man and a boy, and one, the Nar, was still working under sail in 1949 (Carr 1951:142-46). On the West Coast the Severn Trow has a pedigree going back to at least Saxon times, and they appear in the Pipe Rolls of Parliament as early as AD 1411. Originally double ended, like the Barland’s Farm Boat, they later used a flat transom, and like the Humber Keel carried a square sail. The cargoes they carried included wheat, barley, flour, malt, tin, lead, iron, coal, wool, wine, timber, and stone, very much the sort of cargoes moved in Roman times (Farr 1946:68-71, Greenhill 1940:286-91). Farther north on the River Mersey, the Mersey or Weaver Flat was a similar sturdy vessel, but always double-ended and with a fore and aft rig. The bottom planking was 0.10 m thick, similar to
that of the Zwammerdam barges. Other vessels of this genre plying local and inland waters include the Tyne Keel (Viall 1942:160-2), the Tyne Wherry, the Norfolk Keel, and the Norfolk Wherry.⁸ Smaller numbers of similar vessels with local variations in shape and rig were used on the rivers of Cornwall and Devon, and in the harbours and rivers from Poole to Chichester (Carr 1951:151-60).

The entry points for cargoes carried by coastal shipping would tend to be where the clusters of Roman military installations, industrial sites, major towns and large areas of settlement were concentrated. These would be the Tyne and its hinterland, the Humber and its hinterland, the Wash backed by the Fens, all of south-east England including the Thames, the south to beyond Poole, the Severn and its hinterland up to Wroxeter, and the north-west around the Mersey, Dee and Solway Firth. The cargoes distributed by the inland river vessels would be quite similar to those known from the medieval records, and the quantities involved, while somewhat less, would still have been substantial. Although we have no purely river-type boats from Roman Britain, apart from the New Guy’s House boat and County Hall ship from London, it is inconceivable that the province could have functioned without a goodly number of river craft, ranging from simple barges to more sophisticated vessels, probably in a variety of sizes. In the Roman and early medieval period the materials and tools used for building wooden ships were the same, English oak, wrought iron nails, and the axe, adze, chisel, plane, spoon bit for drilling holes and saws of modest performance. The product should be similar.

c. The Energy Input to Propel Inland Water Craft

Inland river craft operating above the tidal limit had five possible methods of propulsion: sailing; rowing or paddling; poling (also called punting or quanting); towing with human or animal power; and in the downstream direction the river current. Rowing, except in special circumstances could have been rather rare. There are two problems. The configuration of the vessel has to provide space in which the rowers can work, and pivot points for their oars. Moreover the river or stream has to be wide enough to accommodate the beam of the boat plus the outboard length of the oars. If vessels such as the Zwammerdam barge were rowed, it was probably done with the oarsmen standing facing forward and pushing on the oar looms. Poling could be used in most areas where the water was not too deep, and if poling upstream, where the current was slight.⁹

Logboats were probably paddled or poled, and coracles were certainly paddled. The barges of the Zwammerdam type and more sophisticated vessels could be sailed, poled or

---

⁸ Carr, commenting on the heavily built Tyne keels notes that, “The price of a keel depended on the closeness with which these timbers were spaced, and in the most costly they were so close that only the width of a man’s fist would go between them.” (Carr 1951:140).

⁹ Poling in still water produces at best a slow walking pace. The technique with a trading vessel is for the man to start at the bow, plant the pole, push on it and start walking aft along the side of the vessel to the stern. He then repeats the process. In the historic period in Norfolk, quants, a sort of glorified punt pole with a spiked foot, could be up to 7.3 m (24 feet) long (Carr 1951:157).
towed. As with the seagoing and coastal ships, sailing would be the most effective means of propulsion for larger vessel, and even with a single square sail like the later Humber Keel, with a wind from aft to a few points either side of directly astern the speed made good would exceed that possible from poling or towing.\textsuperscript{10} For small vessels on fairly narrow local streams poling would be the most effective means of propulsion. Towing can be done either from the bank, or in very shallow smooth bottomed streams by walking up the stream bed. Towing from the bank requires a crew of at least two, one to tow or lead the towing animals, and one to steer the vessel. The bank has to be reasonably level, with no fringing obstructions such as clumps of bushes, waterside trees or extensive reed beds.\textsuperscript{11} If it were in regular use for a particular waterway, it might be economic to form a regular towpath and clear any obstructions to its use. By the medieval period tow-paths were part of the Severn navigation system.\textsuperscript{12}

In general it seems most likely that small boats were paddled or poled. Larger barges would have used sails for longer distances whenever possible, backed by poling in headwinds or where channels were very sinuous. Towing could have been used on rivers with sufficient traffic to justify the development and maintenance of a towpath, for example from the Humber up the Rivers Ouse and Swale to York, from the Humber to Lincoln via the River Trent and the Foss Dyke, or on the Thames up to Oxford. Rowing might be limited to open areas where there was sufficient space to deploy oars. Everyone would have utilized the downstream hydraulic current in the rivers.

\textbf{9.4 The Technology of Harbour Installations in Roman Britain}

\textbf{4.1. Harbours or Havens?}

There is at best minimal evidence for artificial built harbours in Roman Britain with moles and breakwaters after the pattern of Ostia or Caesarea Maritima in the Mediterranean. At Dover, in the former tidal estuary of the River Dour, which ran in the valley between the eastern and western heights, there is a timber framed chalk block

\textsuperscript{10} Carr commenting on the sailing qualities of the Keel with its single square sail says ".....it is really surprising how close to the wind these craft will sail, and how quickly and easily they can be put about (Carr 1951:144)."

\textsuperscript{11} Casson has described vessels, the \textit{naves codicariae}, specifically designed for towing up the Tiber with cargoes discharged from ships in the docks at Ostia or Portus, with a mast or post set well forward of amidships. The tow rope is fastened at the top of the post: "This serves to keep the line clear of the water and from rubbing along the bank." (Casson 1965:37). The technique could well have been used in Roman Britain to clear minor obstructions such as rushes.

\textsuperscript{12} From an act of 1532: "Whereas the King's subjects, passing upon the river Severn have used time out of mind, to have a certain path of one foot and a half broad, on every side of the said river, for drawing by lines their vessels passing on the said river Severn, with wine, or other merchandise, without any imposition...." (Farr 1946:70).
seawall or mole over 30 m long, which lay across the mouth of the estuary. With the flood tide filling the estuary this mole would have protected the area behind it, sheltering the vessels lying on the mud or alongside jetties from wave motion from the Channel. This is the only structure of this type known to date from the Roman period in Britain. Other finds from the former estuary of the Dour include piles, groins, mooring rings, a 15 m long section of chalk block quay reinforced with piles and planks, and traces of smaller timber jetties. Dover also has the distinction of possessing the only Roman lighthouses known in Roman Britain. The lighthouse on the eastern heights is inside the Norman Dover Castle, extant to a height of about 13 m. Originally it may have been as much as 24 m high with eight stages. The light house on the western heights has been buried beneath 19th century fortifications, but is shown on prints from the 18th century (Philp 1981:7-8, Fig. 2).

Apart from the Thames at London, there is very little evidence for harbour installations such as wharves, jetties, warehouses and equipment such as cranes for handling cargo on a major scale. There are probably two reasons for the lack of built harbours and major loading and unloading facilities, such as wharves and jetties. Firstly, the English coast line, apart from Wales, is liberally supplied with tidal inlets, river mouths and estuaries at fairly close intervals, many of which make first class natural havens. Secondly, apart from London, no town or settlement had shipping activity on a large enough scale to justify the construction of an extensive system of riverside wharves and warehouses. Many of the fortresses and forts which lie on navigable rivers, such as Chester, Gloucester, Lincoln, York, and Caerleon, have produced traces of modest quays of stone revetted with timber. Some were above significant tidal influences, for example York, but others such as Caerleon would dry out at low water. At Caerleon Boon has estimated that at high water ships drawing up to 1.67 m could get alongside the timber wharf built out from a stone quay (Boon 1964:152-3). The auxiliary forts in Wales at Cardiff, Neath, Loughor, Carmarthen, Pennal, Caernarvon and Caerhun were placed on navigable rivers (Fryer 1973:261-9). As noted in Annex 4 to Section II.8, p.104, Cleere has identified forty-five probable harbour sites from where Roman roads terminate on the sea coast or places on navigable rivers. Of the 118 natural havens and estuaries on the east and south coasts of England listed in Annex 5 to Section II.8 (pp.105-112) and Appendix O, as many as 53 have varying amounts of artefactual evidence for a Roman presence or activity.

Consideration of the evidence from the archaeological record and of the topography of the coastline of England and Wales suggest that in the Roman period there was no need for major civil engineering works to create artificial harbours. Given the moderate size of military installations, towns and settlements, the natural tidal inlets, estuaries and rivers would have provided sufficient sheltered areas for the safe operation of the vessels of the period. The qualifying corollary was that the vessels had to be of a sturdier and heavier construction than was used in the Mediterranean because on every voyage at both the starting point and destination they would have to take the ground safely when fully loaded with cargo. They also had to withstand the bumps and shocks imposed on their structure by

---

13 Today the remains lie beneath the East Kent Bus Garage! (Elsted 1856:101; Philp 1981:9, Fig. 2)
even small waves or surface disturbances in the period when they were either taking the
ground as the tide ebbed, or lifting off the ground with the flood tide. In the cases where
they could not reach their berth until fairly close to high tide, this situation would be
aggravated by the fact that the vertical motion of the tide changes very slowly near high and
low water, and is at a maximum at mid-tide.\textsuperscript{14}

4.2. The Technology of Shore-side Installations (Wharves, Quays, Jetties and
Warehouses)

The land-based structures for loading and discharging vessels were fabricated
predominantly from stone and timber, with rubble and gravel fills and surfacing. Where
necessary timber piles were driven to provide support. The technology is in general very
similar to that used for other functional civil engineering works, bridges and buildings, but
with a few interesting variants. The only substantial and definite surviving works come
from London, where several hundred metres of Roman quays and landing stages have been
found. The earliest structure was a chalk and flint hard on the site of the later Roman
bridge. This would have been used both as a place to beach vessels for unloading and as
surface for carts to use while unloading cargoes. Later, quays were constructed on both the
upstream and downstream sides of Roman London bridge on both sides of the river, along
with warehouses to store goods in transit. On the north shore the quays were constructed
with a box framing of massive timbers, parallel to and at right-angles to the shore line, and
joined by carpentered joints, lap joints in the first century, but the more sophisticated
dovetail joint in the second and later centuries (Marsden 1994:19, 24-5, Milne 1985:65).
There were no iron nails used in this type of construction, the structure being held together
by the interlocking joints in the timber components. On the south shore the best example of
a Roman wharf was found in a side creek, the site of the New Guy’s House boat find, with a
post and plank revetment of the late first century, repaired in the mid-second century and
further re-worked in the third century when mooring posts were added. In the same area the
intact timber floor and substructure of a substantial Roman warehouse was found in 1990
(Mills and Whittaker 1991:159-61). Cargoes to be unloaded and moved into storage in
warehouses would have included bulk goods coming in quantity, grain, building stone,
timber, olive oil in amphorae, wine in barrels and amphorae, and at a later date, probably
coal from the Tyne. Miscellaneous material of higher value, such as glassware, fine
pottery, small bronzes and marble veneers would have been part cargoes. Most of these
goods could have been man-handled. The largest amphora when filled did not weigh more
than 100kg, and most were 50 kg or less. The barrels of wine pose an interesting problem.
Large barrels of wine held about 900 litres (see page 11), and the full barrel would weigh
about 0.97 tonnes. Once ashore a barrel is easily handled by rolling, either along the flat or

\textsuperscript{14} In the normal tidal interval of a little over six hours, the tide rises about 1/12th in the first hour, 2/12th in
the second, 3/12th in the third, 3/12 in the fourth, 2/12th in the fifth, and 1/12th in the sixth (Carr
1944:167). For a location with a 6 m tide, the tidal height will increase by only 0.5 m in the first and sixth
hours. With a 0.25 m wave height, a normal situation with a wind speed of 5 to 10 km/h, a light air to light
breeze, a vessel could bump very uncomfortably for 20 to 30 minutes.
up a ramp into a warehouse or onto a cart, but to transfer it from a ship's hold to the quay side would probably have needed a lifting device. This might have been a shore-mounted crane, or a tackle hung from the ship's mast. Certainly there is ample iconographic evidence for the use of cranes by the Romans for building purposes, and sockets for mounting cranes have been identified at a number of sites.

9.5: Summary and Conclusions on the Technology of Roman Water-Borne Transport

5.1. Maritime

The controlling factor is the range of the tides in the tidal system in northern waters. Because of the range, seagoing vessels had to be able either to take the ground or anchor offshore in deep water whenever they needed to load or discharge cargo. Anchoring offshore round the coasts of Britain and Gaul is difficult. Many areas have offshore sandbanks and shallows which prevent a vessel anchoring close enough to the land to make discharging into smaller vessels practicable. Others have cliffs and rocky shores with deep water close inshore where anchoring was not possible with the ground tackle available in Roman times. In both situations described above, the onset of bad weather would put the anchored vessel in serious peril. Unloading into smaller vessels from ships at anchor would only be possible in certain of the larger rivers such as the Humber and Tyne, and some large sheltered inlets such as Portsmouth and Poole harbours. The range of the tides precluded the building of wharves or jetties which would allow ships to remain afloat in harbour. This is a completely different situation from that in the Mediterranean where the tidal range is minimal. The requirement that vessels must be able to take the ground when fully loaded controls the technology for hull construction, leading to the flat-bottomed massively framed and heavily planked iron-fastened hulls of northern waters. In the process of taking the ground the vessel may be subjected to quite severe pounding and bumping on the bottom, which increases the need for a very sturdy hull construction. It is uncertain who originated the Romano-British type of seagoing hull construction, but the earliest literary reference is Caesar's description of the qualities of the ships of the Veneti. Interestingly, the Veneti came from a seacoast area with some of the largest tidal ranges in Europe. When they started to build seagoing vessels of a size that could not be run up on to the beach by their crews, they had to fashion sturdy vessels, and fortunately had access to ample supplies of oak and iron, the prerequisites for a successful solution to the problem. Britain in the Iron Age had the oak, but not the ample supplies of iron, and it needed the coming of the Romans to develop large-scale iron production, at first in the Weald in the south and later in the Forest of Dean in Wales.

5.2. Inland Waters and Rivercraft

From Britain we have nothing yet from the archaeological record on simple barges to compare with finds from Germany and Gaul. The New Guy's House boat fits into the heavily framed and iron fastened group, was certainly used on the tidal Thames around London, and had to be able to take the ground when loaded, but is unduly sophisticated and therefore costly for a simple inland river craft which could spend its working life afloat. It is probably reasonable to infer something on the lines of the Zwammerdam or Lake
Neuchâtel barges being used in Britain for carrying cargoes along waters such as the Foss Dyke and inland rivers. The County Hall ship from London with its Mediterranean mortise and tenon planking is considered an oddity, possibly built for some special purpose. In the hard working conditions in and around Britain it cannot have had many fellows.
SECTION III: THE ECONOMICS OF WATER-BORNE TRANSPORT
SECTION III: THE ECONOMICS OF WATER-BORNE TRANSPORT

Section III.1: Introduction

1.1. A System for Measuring Costs and Economic Activity in Roman Britain

Before developing a system for calculating the economics of water-borne transportation in Roman Britain, I examined the work of scholars who have recently attempted to compute the cost of major building projects in the Roman world. These include the publications of Delaine on the Baths of Caracalla (DeLaine 1997), Shirley on the construction of the legionary fortress at Inchtuthill (Shirley 1996, 2000 and 2001), and Kendal on the transport logistics associated with the building of Hadrian’s Wall (1996). They calculate the quantities of materials and man-hours involved in various operations, and arrive at totals for man-power and materials. Because I wished to calculate not only the cost of building and operating the water-borne transportation systems of Roman Britain, but to relate that cost to the whole economy, I have chosen a somewhat different approach, based on the human energy available. I have also utilized my practical knowledge and experience from forty years as a professional engineer and manager in the mining, metallurgical, oil, and metal working industries, supplemented by a life-long interest in building, sailing and repairing wooden boats.

In investigating problems involving any aspects of the economy of Roman Britain, one must address the fundamental problem of deciding what units to use for measuring the economic activity. In the modern world analysis of economic problems is often based on the world’s monetary systems, and concepts such as gross domestic product, output per man-hour, and other measurements tied to a country’s monetary system. In Roman Britain Roman coinage was in regular circulation, originating in the pay for the army, and to a lesser extent the civil administration. The troops spent part of their pay for the purchase of small luxuries, such as oysters and wine to supplement the official rations, and on the procurement or maintenance of concubines in the vici which grew up outside all the fortresses and forts. Much of this coinage of small denomination continued to circulate in local markets. This currency however, was only a minor part of the total economic activity. Tribute and taxes were paid largely in kind, to provide grain, leather and other materials for the maintenance of the army and Roman civil administration. Outside the larger towns and military establishments, much local trade among the indigenous population was almost certainly in the form of exchange or barter.

It seemed therefore appropriate to establish a different approach from that of Delaine, Shirley and Kendall for my purposes. The concept adopted here is based on first principles, concerning the expenditure of human energy. In a water-borne transportation system human energy is expended in gathering the materials to build the boats and ships, in shaping and forming the timber and metalwork, in assembling them into the hull and its ancillary components, and finally in operating the completed craft. The basis of the Romano-British economy was the peasant farmer, producing both enough food to support
himself and his family, and a surplus, partly to pay taxes and tribute, and partly to acquire necessities or small luxuries, which he could not make himself, such as iron tools, specialized pottery such as mortaria, and similar items. For the purpose of this thesis, and possibly for wider use, I have devised a unit, the basic economic unit or BEU. This is discussed in full, with the method for deriving it in Appendix B. I have calculated that a peasant family unit in Roman Britain can produce two BEUs per year, one of which it has to retain to feed itself, while the second is available to meet tax and tribute demands, and to 'buy' goods not made within the family unit. All the cost and economic calculations that follow in this Section III use the BEU to establish both the relative and absolute costs of the water-borne transportation system.

1.2. An Overview of the Economics

In this section the economics of the Romano-British water-borne transportation system, primarily that of the late first to the mid-second century A.D., will be examined. This period has been chosen because it represents the system at its full development, at a time when it was most active in importing and exporting materials, and precedes the diminution of imports as Britain became more self-sufficient in some products such as pottery. An attempt will be made to estimate the number of vessels of various types that would be needed at the time for the level of agricultural and manufacturing activity. For each type of craft the following factors will be evaluated:
   a. The cost in BEUs for building each type.
   b. The operating and maintenance costs for each type.
   c. An average working life expectancy, allowing for normal wear and tear, decay of the wooden structure and marine casualties.
   d. The seasonal pattern of shipping for various types of cargo. For example, the cereal harvest would normally take place in July in the south, but autumn weather patterns would slow down shipping grain to the military stations in the north.

   In addition, the cost and size of the land-based infrastructure, wharves, jetties, hards and warehouses will be considered. Finally, an estimate will be made of the total BEUs expended in providing water-borne transportation services, and what proportion this was of the total economic output.

1.3. The Background

The key requirement for a successful conquest and occupation of Britain by the Romans, followed by pacification and incorporation of the island into the Roman military and civilian administrative system as a Roman province, was the use of water-borne transportation. To effect a conquest of the island, a continental army, no matter how large and powerful, had to be able to cross the English Channel or southern North Sea. Eighteen hundred years later in 1805, Napoleon lay at Boulogne with a large army of four corps, but was foiled in his plan to conquer Britain by his inability to transport that army the thirty kilometres across the sea to the south coast of England. Even more recently the German Third Reich ultimately failed in its plans for the complete conquest of western Europe.
because it could not convey its large, successful and superbly equipped army across the same barrier.

For the Romans, once the initial conquest had been made, there was an ongoing requirement for the periodic movement of troops between Britain and Europe, and for the regular movement of the civil administrative staff, and their reports and documents, between Britain and Rome. Following the conquest there was a substantial increase in the sea-borne trade between Britain and continental Europe. This increase met both the needs of the conquerors, principally those of the army, and also the growing demands of the romanized British élite for luxury goods of all sorts, from wine, olive oil, garum and fine pottery, to marble and other exotic building materials.¹ Internally there was a vast increase in the movement of both agricultural and manufactured products, both to sustain the military establishment, and to supply the ambitions of the growing British élite, including the needs of client rulers such as Cogidubnus and Cartimandua.

Section III.2: The Cargoes and Types of Vessel Needed

2.1. The Cargoes

The cargoes fall into three categories, imports, exports and internal movements in and around Britain. The local trade in Britain, and around the British coasts, was almost certainly carried in British bottoms. At least some portion of the imports and exports would be carried in vessels belonging to Spain, Gaul and the Lower Rhine provinces. There is very little evidence that would allow the carriage of imports and exports to be allocated between British and continental ships. A reasonable hypothesis might be that wine, olive oil, olives, garum and similar goods came in continental bottoms, which would return with full or part cargoes of British products. If grain were a major export, British ships might carry a large part of the trade, with mixed return cargoes, which might include stone and masonry, and some pottery, glass and other material shipped in small quantities.

a. Imports

Traffic from continental Europe included a wide range of food, drink and manufactured goods not produced in Britain. Two major items were wine and olive oil. There was possibly a small wine producing industry in Britain, but the quality was probably poor.² Olive oil and olives had to be imported, the cultivation of olive trees being

¹ It seems certain that following conquest and pacification, in much of Britain the pre-existing élite continued to fulfil the élite role, as the backbone of the local civil administration of towns and major settlements, and as land owners and owners of the larger villas.

² At Wollaston in the Nene valley in Northamptonshire planting trenches for vines have been excavated. An estimated 6 km of trenches, sufficient for about 4,000 vines have been identified. This would yield about 10,500 litres of white wine. For the whole area the yield could be as much as 30,000 litres. This could link with the pottery industry of the Nene valley. A joint project of the Universities of Exeter,
impracticable in the British climate. Wine was imported in amphorae and also in barrels. Garum from Spain was imported. Pottery was imported from Gaul, the Rhineland, and a little from North Africa. Mortaria also came from Gaul and Germany, see Appendix F. Glassware was imported, and probably at least some tesserae for mosaics. Marble and other decorative and architectural stonework came from as far afield as the eastern Mediterranean, see Annex 3 to Appendix H.

A necessary 'cargo' both as an import and export was people, soldiers, civil service staff, merchants, skilled artisans, and slaves. Britain was still a likely source of slaves until the whole country was pacified in the second century. On a daily basis the human traffic could be quite light, perhaps a few dozen people, and this could be handled by one or two ships making routine daily runs from Dover (Portus Dubris) to Boulogne (Gesoriacum). Periodically large numbers of soldiers would need transport, for example when a cohort or even a legion left or came into Britain.

b. Exports

Grain, according to the literary sources, was a major export, together with lead, iron, silver and gold and some pottery. In particular Black Burnished Category 1 ware from the Poole Harbour area, a hard, dense black fabric widely distributed throughout Britain, was shipped to Gaul and is found in coastal areas from Flanders to Brittany.

c. Internal cargoes

All the material listed under imports and exports would also be moved around Britain, both in coastal voyages and by river. Internally the largest single cargo was foodstuffs, principally grain for military establishments and towns, and for areas where livestock rather than cereals was the main rural activity. Quarryed stone was another material produced and moved in very large quantities. Timber and wood, coal and tiles were other bulk cargoes. Pottery was distributed around Britain. For example the BB1 pottery from Dorset was supplied to Hadrian’s Wall by both east and west coast routes. Some metals were moved by water, but the volume compared with grain would be fairly modest. Salt may also have moved by water in modest amounts, particularly to the north and west, but a large portion of salt production probably moved by road, particularly in the east and south where salt production sites were spread along much of the coastal area.

---

Leicester and Northampton Archaeology has been set up to assess Roman viticulture in Britain (Brown and Meadows 2000:491-2). Williams has examined the evidence for Roman viticulture in Britain and concludes that vines were cultivated at Gloucester, an area pre-eminent in medieval wine production (Williams, D 1977:333).

---

3 Something over one million tonnes of grain would have been produced in Roman Britain each year. In contrast Cleere has estimated that peak production of iron in the Weald was 750 tonnes in the peak production years. About 45,000 tonnes of quarried stone for the London city wall was shipped from the Maidstone area in Kent. See Appendices, D, E, F, G and H.
2.3. The Types of Vessel Needed

A range of vessels of different types and sizes would be needed. For cross-channel and coastal voyages of longer distance, ships of the Blackfriars Ship 1 and St. Peter Port type would have been used. They could carry cargoes in the range of twenty-five to fifty tonnes or more. In the Mediterranean the Romans used much larger ships. In the grain trade from Egypt vessels with a capacity of 150 to 350 tonnes were normal. A number of even larger ships with cargo capacities of 1,000 tonnes have been reported in the literature (Casson 1995:170-3, 183-90). The normal Mediterranean merchant ship appears to have been in the range of 15 to 37 m long. The Blackfriars Ship 1 at 18.5 m and the St. Peter Port ship at 25 m long fall in the middle of this range. For the volume of trade from the Continent to Britain, and the longer coastal voyages, such as from the Thames to the Tyne, ships of this middle size would be well suited. In general, shipping of goods round the British coasts had a very large number of points of origin, and a large number of destinations. Agricultural products such as grain from East Anglia and south-eastern Britain would be loaded at a number of riverside sites, and could go both north to the Tyne and beyond, and to the west to the Bristol Channel forts and fortresses. With many of the imports coming into major centres such as London or Colchester, the cargoes would break bulk at that point, and be further distributed by both coastal and river transport.

For short coastal voyages with moderate loads, either undecked boats of the Barland’s Farm type or smaller versions of the Blackfriars Ship would fill the gap between the seagoing vessels such as the Blackfriars Ship 1 and inland river barges. With a length of 11.4 m and a cargo capacity of 4.5 to 6.5 tonnes, the Barland’s Farm boat could comfortably make short day or overnight voyages with a crew of three. Possible cargoes suggested are 15 medium-sized barrels of wine; or 90 sacks of grain; or 4.5 tonnes of salt or coal in sacks; or 4.5 tonnes of iron, slate or stone on dunnage in the bottom of the boat (McGrail and Roberts 1999:142).

River traffic would need simple barge-type craft in a range of sizes, and it is probable that dugouts continued in use in some areas for traffic in small local loads (see pp.53-4 above). Although only three dugouts datable to sites of the Roman period have been found in England, they are known from Late Iron Age sites immediately before the Roman period, and from early Saxon sites on to the medieval period.4

Three main groups of vessels for inland waterways based on size seem probable. The largest with cargo capacities in the range 25 to 50 tonnes, a medium size with capacities in the range 8 to 12 tonnes, and small ones able to carry 1 to 3 tonnes. For river traffic two factors come into play, one natural, the size of the stream or river, and the other man-made, the average size of the cargo. For small shallow winding rivers and streams only a small shallow-draught barge would be practicable, such as a dugout or the small barge 5 type shown in Appendix N. Even on large rivers the small barges, probably built by

---

4 A dugout dating to as late as A.D. 200 is on display in the Museum of Scotland in Edinburgh, in the Roman section, case P1 (personal observation).
the owner, would be adequate for a peasant farmer taking produce to market. At the other end of the scale, on the larger rivers such as the Thames, Humber, Tyne or Dee, barges capable of carrying large loads in the 25 to 50 tonnes range would have at least two possible uses (Appendix N, barges 1 and 2). One would be the transhipment of cargoes from seagoing ships of the Blackfriars type for onward movement to major inland centres such as Lincoln or York. The second would be for moving bulk cargoes between points on the inland waterway systems. Bulk cargoes could include loads of quarry-run stone for city or fortress walls and large stone buildings, roofing tiles, grain, timber and wood. It seems probable that the Zwammerdam barges from the Rhine in the Netherlands were used for exactly this purpose. In the middle range of sizes, barges of about 7 m to 10 m long with a cargo capacity of about 4 to 12 tonnes could be used for cargoes of grain, manufactured goods such as pottery, or even livestock. These loads could be carried over moderate to longer distances, in the 10 to 80 km range, to market centres or points of consumption such as military installations with good river access. The smallest vessels, the planked barge c. 5 m long or the dugout, with a load-carrying capacity in the 1 to 2 tonnes range would be used for local traffic. For example, a small farm or villa, or a small manufacturing enterprise could use craft of this size to supply a weekly market at nearby towns or other points of consumption. These smallest barges and dugouts would probably be built and operated by the production site that used them. Hide-covered boats of the curragh or coracle type were probably in use in some areas, both for fishing, fowling and moving small cargoes.
Section III.3: The Cost of Building Four Representative Vessels

3.1. Introduction

In this section an estimate is made of the cost of building four representative types of vessels. Two are hypothetical river barges of the Zwammerdam type, which would have been very suitable for use on many British rivers and sheltered estuaries. No vessels of this type have been found in archaeological contexts in Britain to date, but a number have been recovered from the Rhine. The other two craft are the Barland’s Farm boat from the Severn estuary, suitable for estuary and river work, and short coastal voyages, and the Blackfriars Ship 1 from the Thames at London. The Blackfriars ship could make both coastal voyages and open sea journeys across the English Channel to Gaul, or cross the southern North Sea to the Rhine.

Certain assumptions have been made for all four vessels. The assumptions are:

a. That they were built on the bank of a river or protected estuary so that launching was not a major technical problem.
b. That the building site was within five to ten km of a source of suitable timber.
c. That the timber was all oak (*Quercus sp.*).
d. That to haul about 1 tonne of timber for 5 to 10 km would take about eight hours, using a wagon and a yoke of oxen.
e. That they were constructed in the Romano-British tradition of heavily framed hulls with carvel planking secured with clenched iron nails.
f. That the average effective working day was eight hours after allowing for rest periods from the heavy manual labour, meals and getting to and from the building site.\(^1\)
g. That the working days in a year would be 280, after allowing for festivals, religious activities, some community work, bad weather and illness. Today in the First World countries, after allowing for weekends, public holidays, and vacations, people work about 235 days per year in the United States, and 221 days in Europe.

In this section the building sequence and the time needed to build each vessel are summarized, with the more extensive details and minutiae of construction on which the times are based in Appendix P.

3.2. A Note on Felling Trees, and on Shaping and Finishing Timber

In Appendix P the times for the various activities involved in building a boat are set out and the methods used to establish these times are detailed. In this paragraph a summary of this information is given.

\(^1\) For work involving sustained heavy manual labour, such as shipbuilding in antiquity, human physiology places limits on the productive hours that can be worked. For a day or two workers doing heavy work may put in a double shift of 16 hours, but their productivity drops off markedly after 10 to 12 hours. From personal observation as a manager in heavy industry, if long hours are worked regularly, the useful output drifts down to that from a normal 8 hour shift. With long hours, people work more slowly and take longer rest periods.
a. Times for felling trees of various sizes: see Appendix P, Table App.P.5
b. That the time for clearing the undergrowth, felling a tree, snedding (branch removal), de-barking and making the bucking cut to remove the crown would be about 2.5 times the direct felling time.
c. The time to split an oak log depends on its diameter and length, and can vary from a few minutes to several hours (Appendix P, section 4).
d. One square metre (1 m²) of the surfaces of timbers and planks can be shaped and smoothed with axe and adze in an hour (Appendix P section 4)
e. Drilling holes for nails and wooden pegs with a Roman spoon bit: the graph, Fig. App.P.4, gives times for various diameters and depths of holes.
f. Driving and clenching nails: the graph Fig. App.P.5 gives the time for driving nails. The total time for the nailing crew (2 men) to position themselves and drive and clench the nail is estimated to be three times the driving time (Appendix P, section 6).
g. Sawing logs or squared baulks into planks: about 4 m² can be sawn in an 8 hour day. With a Roman frame saw a tree trunk 0.5 m diameter by 8 m long could be sawn in half in a day by two men, one man working at each end of the saw (Appendix P, section 7).

3.3. A 5 m Long River Barge (see Appendix N for drawing and detail)
(Dimensions: 5 m long x 1.25 m beam x 0.40 m deep: cargo capacity about 1.2 tonnes.)
This is a small ‘home-made’ barge, and it has been assumed that the builder/owner would not have a large frame saw, would split the planks tangentially from a log, and would use axe and adze to shape and smooth all the frames and planks. This was the practice in the Iron Age before the advent of the Romans, and in the Scandinavian tradition of ship building continued until at least the tenth century A.D. (Crumlin-Pedersen 1997:93; McGrail 1977:10)

<table>
<thead>
<tr>
<th>Timber required</th>
<th>Surface area to be shaped and smoothed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 side planks, 0.2 m wide by 5 m long, finished both sides</td>
<td>8.0 m²</td>
</tr>
<tr>
<td>4 bottom planks, 0.35 m wide by 4.5 m long, finished both sides</td>
<td>12.6 m²</td>
</tr>
<tr>
<td>8 end planks, 0.45 m wide by 0.57 m long</td>
<td>4.1 m²</td>
</tr>
<tr>
<td>2 ile or chine logs, quarter round, 5m long from 0.20 m diameter tree</td>
<td></td>
</tr>
<tr>
<td>All planks split to about 0.04 m thick, finished with axe and adze to about 0.025 m</td>
<td></td>
</tr>
<tr>
<td>The timber can be cut from one 0.70 m diameter and one 0.20 m diameter log, each about 6 m long. Weight of timber about 2.15 tonnes.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time, man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planking</td>
<td></td>
</tr>
<tr>
<td>Locate suitable timber for felling</td>
<td>16</td>
</tr>
<tr>
<td>Felling, bucking cut to remove head, de-barking and de-branching</td>
<td>9</td>
</tr>
<tr>
<td>Splitting into planks</td>
<td>16</td>
</tr>
<tr>
<td>Hewing surfaces of planks to finished size with axe and adze</td>
<td>24.7</td>
</tr>
<tr>
<td>(24.7 m² @ 1 m² per hour)</td>
<td></td>
</tr>
<tr>
<td>Chine logs</td>
<td></td>
</tr>
<tr>
<td>Felling, bucking cut to remove head, de-barking and de-branching</td>
<td>1</td>
</tr>
</tbody>
</table>
### Splitting into quarters
- Hollowing with adze: 10
- Hauling planks and chine logs to building site, two loads: 16

### Frames
- Finding 22 frame pieces from boughs and crooks, felling: 16
- Shaping to fit at 4 hours each: 88

### Building stocks/slipway
- Felling 55 m of 0.2 diameter poles, trim, cut to length: 6
- Haul to site, 1.5 tonnes, two loads: 12
- Build stocks: 16

### Assembly
- Position planks and frames, temporary clamping in position: 8
- Drilling 528 1 cm holes for nails 8.5 cm long @ 4.6 mins: 40.5
- Driving and clenching 528 nails 20.5 cm @ 3 mins each nail, with 2 men: 52.8
- Collecting moss and resin for caulking and applying it: 16
- Making one punt pole and two paddles: 16

#### Total hours: 368.0
#### Total man-days: 46.0

#### Contingency allowance of 20% to allow for inclement weather, errors, logs not splitting as planned, etc.: 9.2
#### Total man-days with contingency allowance: 55.2

Even allowing for some rest days, one man, with an extra hand for the nailing, could build this small barge in about two months, or two men (or a BEU of a man with family help), in about a month. The finished weight of the boat is about half a tonne, and he would probably haul the timber needed with his own yoke of oxen and cart. It has been assumed that he would buy the iron nails from a blacksmith with a significant part of his surplus produce. An alternative would be to fasten the barge entirely with wooden treenails. He and his family could fashion treenails a few at a time until they had sufficient to build the barge, and at the same time could carve a couple of paddles and a punt pole. On the assumption that nails are available for purchase, a small farmer or one man business needing small scale water transport, could build this simple boat without impinging significantly on his principal occupation. Agriculturists have traditionally used the winter months for making and repairing farm equipment and facilities. When working outdoors in the period from November to the end of February in Britain, the effective working day would be limited to about eight hours. Most farmers and small scale craftsmen probably built their own dwellings, barns, workshops and stock enclosures, and would be quite competent in working with axe and adze. Using a spoon bit to drill holes, although very
hard work, does not require a high level of skill. The operating costs would be minimal as the owner-builder or his family would operate it as needed. On slow flowing inland rivers, as most in southern Britain are, a vessel of this sort could be propelled and managed quite safely by one man or youth. Maintenance costs would also be low, and repairs for minor damage fairly easily effected. The working life would be ten to fifteen years or longer, as long as the vessel was not left on land to dry out, or in contact with damp soil, which would promote rot.

3.4. A 10 m Long River Barge (see Appendix N for drawing and detail)

This is a commercial vessel, significantly larger, with a cargo capacity of about 12.3 tonnes, and would require a regular crew of two to three people. It could be owned and operated by a self-employed bargee who would contract with customers requiring his services. Alternatively it could be owned by a large manufacturing or extractive industry, such as a tilery or quarry and operated by slaves or paid hands. It might also be the property of a larger town, and manned by their slaves or workmen.

Dimensions: 10 m long x 2.5 m beam x 0.80 m deep.

**Timber required**  
**Surface area to be shaped and smoothed**

<table>
<thead>
<tr>
<th>Material</th>
<th>Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 side planks 0.40 m wide x 10 m long, finished both sides</td>
<td>32 m²</td>
</tr>
<tr>
<td>8 bottom planks 0.32 m wide x 8.4 m long</td>
<td>43 m²</td>
</tr>
<tr>
<td>8 end planks 0.28 m wide x 2.5 m long</td>
<td>11.2 m²</td>
</tr>
<tr>
<td>2 ile or chine logs, quarter round, 10 m long</td>
<td></td>
</tr>
</tbody>
</table>

All planks split to about 0.08 m thick, finished with axe and adze to about 0.05 m thick. The timber can be cut from one 0.70 diameter tree, four 0.50 diameter trees, and one 0.40 diameter tree for the chine logs. Weight of timber about 11 tonnes.

An alternative for this barge would be the use of sawn planks.

**Activity**  
**Time, man-hours**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time, man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locate suitable timber for felling</td>
<td>16</td>
</tr>
<tr>
<td>Felling, bucking cut to remove head, de-barking and de-branching</td>
<td>9</td>
</tr>
<tr>
<td>One 0.70 diameter tree</td>
<td></td>
</tr>
<tr>
<td>Four 0.50 diameter trees</td>
<td>13</td>
</tr>
<tr>
<td>Splitting into planks</td>
<td>40</td>
</tr>
<tr>
<td>Hewing surfaces of planks to finished size with axe and adze</td>
<td>86.2 (86.2 m² @ 1 m² per hour)</td>
</tr>
<tr>
<td>(or sawing into planks, about 50 m² of saw cuts, 100 man-hours, plus about 12.8 m² of shaping and finishing plank edges with an adze, 13 hours, a total of 114 hours, compared</td>
<td></td>
</tr>
</tbody>
</table>

2 Until at least the early 1950s, on canals in Holland and northern France, owner-operated barges were still common. In Britain in the 19th. century barges and inland water-craft were often owner-operated.

3 A piece of timber with a quarter circle cross-section shaped from splitting a log into quarters. It formed the junction between the side and bottom in some flat-bottomed barges, see Fig. II.9.3.1a.
with 126.2 hours for splitting and finishing using just axe and adze. For these simple planks there appears to be little difference in the time needed)

**Chine logs**
- Felling, bucking cut to remove head, de-barking and de-branching: 4
- Splitting into quarters: 4
- Hollowing with adze: 24
- Hauling planks and chine logs to building site, 11 loads: 88

**Frames**
- Finding 42 frame pieces from boughs and crooks, felling: 21
- Shaping to fit at 6 hours each: 252
- Hauling frames to building site, c. 1 tonne: 8

**Building stocks/slipway**
- Felling 20 0.2 m diameter trees, 6 m long, trim, cut to length: 20
- Haul to site, about 3.2 tonnes, three loads: 24
- Build stocks: 32

**Assembly**
- Position planks and frames, temporary clamping in position: 32
- Drilling 1680 1 cm holes 12.6 cm deep for nails 21.6 cm long @ 5.3 mins. each: 149
- Driving and clenching 1680 nails @ 3.2 min. each, 2 men: 180
- Collecting moss and resin for caulking and applying it: 64
- Make four paddles and 2 punt poles: 56

**Total hours**: 1122.2

**Total man-days**: 140.3

Contingency allowance of 20% to allow for inclement weather, errors, logs not splitting as planned, etc. 28.1

**Total man-days with contingency allowance**: 168.4

Converting man-days to BEUs 0.601

BEUs to produce nails from Appendix P, page 299, Table 4 2.812

**Total BEUs**: 3.413

This is a much more massive vessel than the first barge, and the component parts are much heavier. One side plank would weigh about 240 kg, and would need a minimum of four sturdy adult men to move it around. The natural crook for an L Shaped frame would weigh seventy or eighty kg before being worked to its final form. At times a construction crew of at least five woodworkers, of whom at least one would have to be at least a semi-skilled shipwright, would be needed. Depending on the stage of the construction the daily crew strength could vary between three and five men, with an average of perhaps about four. This suggests a construction period of one and a half to two months. Unless the nails were purchased from a smithing industry, a blacksmith and helper for making nails and tool repairs would also be needed. Forging the nails would use about 0.292 BEUs, see Appendix P, Table 3, or 40 man-days with 2 men. If working full time on the site, the
blacksmith and helper could keep abreast of the construction requirement for nails, and have some time for making, repairing and sharpening tools.

3.5. The Barland’s Farm Boat (see Figs. II.6.9.2a, II.6.9.2b, II.6.9.3, II.6.9.4)

This vessel, although still an open boat, is a vastly more complex piece of shipwrighting than the slab sided box-like two barges described above. It has a defined plank keel, stem and stern posts, with the strakes of the planking curving into the posts from the beam amidships. The planks, other than the two keel planks, are sinuous and twisting, see Figs. II.6.4.1 and II.6.4.2 for examples of the type of shapes developed in the planking. Each one would have to be bent and forced into position, the edge marked off to mate up exactly with the adjacent plank, and carefully worked with axe, adze, plane and chisel for a perfect fit. It is likely that more than one fitting up to the neighbouring plank would be needed before an adequate fit was obtained. The plank edges would then be covered with the moss and resin or pitch caulking material, and the plank nailed to the floors and frames, and to the stem and stern posts. The garboard strake, the plank next to the keel would be installed first, and then the garboard strake on the opposite side would be fitted and fastened. Planking would then continue up, alternating between the two sides, otherwise the hull is pulled out of shape.

In line with the practice for the Blackfriars Ship 1 and the St. Peter Port Ship, it is assumed that the stem and stern posts and the floors and frames were hewn to shape with axe and adze. The planking was definitely sawn (McGrail and Roberts 99:136).  

---

4 A strake runs from stem post to stern post, but may be made up of more than one length of plank, especially in large vessels, see Maritime Glossary.

5 The width of a strake varies along its length in all vessels except those with a completely box-like shape, generally being narrower at the ends, although some may be wider at the ends. In modern practice with skeleton-first construction, the garboard strake is usually fitted first. The sheer strake at the top edge of the hull comes next, its position being adjusted to give a pleasing sheer line. The remainder of the planking is fitted in between, being adjusted as far as possible to avoid excessively narrow plank ends at the stem and stern, or excessively wide planks. With a hull that is rounded or trapezoidal in cross-section terminating in stem and stern posts at the ends, the cross-sectional perimeter to be covered by the planking is greater amidships. The planks forming the strakes must initially be wide enough to accommodate both the width at the widest point and the sinuosity.

6 The Barland’s Farm had sawn planking, not planks split tangentially from the log. Finishing the wide surfaces with axe and adze would not be necessary, except for minor trimming to fit against the frames. Because the planks in round bottomed hulls have a sinuous shape, see Figs. II.6.4.1 and II.6.4.2, the narrow edges would have to be shaped with axe and adze to the proper curvature. In general when planking up a round bottomed hull, the shipwright starts with a pile of planks of varying width with unfinished edges. His skill lies in selecting the unworked planks to plank the hull with minimum wastage.
**Timber required**

2 keel planks cut from one tree, 8 m long x 0.27 m wide x 0.05 m thick.
2 bottom strakes 10 m long x 0.40 m wide x 0.035 m thick.
10 side strakes 10 to 12 m long x 0.35 to 0.40 m wide x 0.035 m thick.

The keel planks were cut from one tree, about 0.40 m diameter with about 8 m length of clear trunk. The tree diameter has to be somewhat larger than the plank width to allow for removal of bark, sapwood and minor irregularities in the trunk. The other planking can be cut from two trees of about 0.60 m diameter with something over 12 m of clear trunk. The fourteen floor timbers needed, together with the twenty-two short side frames, could be cut from a tree of about 0.90 m diameter with about 11 m of clear trunk, and the surplus timber from the planking oaks.

In addition the ten half frames (five sets of pairs) would have to be fashioned from naturally curved branches or crooks, about 2 m long x 0.13 m wide x 0.09 m thick in finished cross-section. The stem and stern posts would also have shaped from natural crooks about 2.5 m long x 0.22 m x 0.18 m in finished cross-section. In their raw state when extracted from the forest, the crooks for the half frames and posts would be substantially larger than the finished cross-section, in order to allow for shaping to the exact curve of the hull while trying to maintain the natural grain of the wood along the length of the piece.

**Activity**

**Planking, Floors and Side Frames**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time, man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locate suitable timber for felling</td>
<td>16</td>
</tr>
<tr>
<td>Felling, bucking cut to remove head, de-barking and de-branching</td>
<td>32</td>
</tr>
<tr>
<td>Set up for sawing into planks, saw pit or trestle⁷</td>
<td>16</td>
</tr>
<tr>
<td>Sawing into planks, 190 m² of sawing @ 0.5 m² per hour with 2 men</td>
<td>760</td>
</tr>
<tr>
<td>Sawing 8 planks into floors and side frames, 56 m², 2 men</td>
<td>224</td>
</tr>
<tr>
<td>Hauling sawn planks to construction site, c. 10 tonnes, 10 loads</td>
<td>80</td>
</tr>
<tr>
<td>Gathering macerated wood shavings and tar or resin for caulking, nailed</td>
<td>16</td>
</tr>
<tr>
<td>to the edge of planks before fastening into position</td>
<td></td>
</tr>
</tbody>
</table>

**Stem and stern post and ten half frames**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time, man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locate suitable timber and cut</td>
<td>24</td>
</tr>
<tr>
<td>Hauling to construction site, 1 load</td>
<td>8</td>
</tr>
</tbody>
</table>

**Sub-total for procuring material**

1176

---

⁷ The largest trunk would weigh over six tonnes, and would require rollers to move it and a very sturdy trestle, if a trestle were used. The most likely and economic scenario would be to set up the trunk on rollers over a relatively short saw pit, and move the log forward on the rollers as sawing proceeded.
Building Stocks/slipway
Felling and trimming
3 trees 0.30 m diameter for longitudinal members  2
20 trees 0.20 m diameter for posts and cross-pieces  8
Hauling to construction site, c. 6 tonnes, 6 loads  48
Setting up stocks at construction site  40

Sub-total for stocks  98

Assembly (This lists the operations required, not the sequence of building)\(^8\)
Shape and locate two keel planks and secure  16
Shape and position stem and stern posts, with temporary supports  48
Shape 14 floor timbers with axe and adze @ 16 hours each  224
Shape 22 side frames with axe and adze @ 6 hours each  132
Shape 10 half frames with axe and adze @ 12 hours each  120
Shape mast step and three cross beams  20
Shape and fit two bottom planks, P1 and S1 @ 16 hours each  32
Spile, fashion and fit 10 side strakes @ 24 hours each\(^9\)  240
Make 650 treenails, 14 mm diameter x 20 cm long @ 10 per hour\(^10\)  65
Position and nail 168 m of macerated wood and resin caulking along plank seams @ 5 m per hour  34
Drill 650 treenail holes 14 mm diameter by 0.13 m long @ 5.8 mins. each  63
Drill 650 nail holes through the treenails 8 mm diameter by 0.13 m long @ 5.6 mins each  61
Drive and clinch 650 nails 1 cm dia. x 25 cm long @ 3.8 mins., with 2 men  82

---

\(^8\) McGrail and Roberts suggest the following sequence as one possibility:
The two planks of the keel are forced together, and held by nailing floors F6 and F13 in position.
Stem and stern post and two floors that hold them, F4 and F 17, are fastened to the keel.
Five pairs of half frames and remaining five floors are fastened to the plank keel.
Two bottom strakes fastened in position.
The five pairs of side strakes are fastened in the sequence, P5 and S5, P7 and S7, P6 and S6, P3 and S3, P4 and S4, being supported by side frames inserted as needed.
Remaining bow and stern frames are fashioned by spiling from the planking and fastened in position.
(McGrail and Roberts 1999:141)

\(^9\) Marking out the curved edge of a plank, usually with dividers, to fit tightly against the adjacent plank, or the keel, stem or stern rabbets.

\(^10\) It is assumed that a simple lathe would be used. These were known and used in the Roman world
(Liversidge 1976:162). Making them by hand would have been both tedious and inaccurate.
Make mast, yard, 4 oars and steering oar
Sub-total for assembly

Total hours

Total man-days
Contingency allowance of 20% to allow for inclement weather, errors, logs not splitting as planned, etc.

Total man-days with contingency allowance

Converting man-days to BEUs

BEUs to produce nails from Appendix P, Table App.P.4
Allowance for cordage and sail

Total BEUs

Allowing for some rest days a team of four to five men could build the hull of a vessel of this type in about three months. Additional time, labour and expense would be needed to buy or make the iron nails, the propulsion equipment, mast, rigging, sail, oars and steering oar, and the ground tackle, an anchor and anchor line or chain.

3.6. The Blackfriars 1 Ship (see Figs. II.6.8.1a to II.6.8.4c)

This ship is the most complex and largest of the craft, the construction of which has been described and discussed previously. Ships of this type may have been the ‘standard’ Romano-British seagoing vessels for voyages across the Channel and over to the Rhine, as well as for coastal voyages with the larger cargoes around Britain. In the Mediterranean by the first century A.D., ships of 100 to 200 tonnes cargo capacity were probably the ‘standard’ freighter for much of the trade, with a number of considerably larger vessels used on particular routes, such as the grain trade from Egypt to Rome. Around the coasts of Britain and north-west Europe larger vessels would have two problems. They would not be able to penetrate the numerous small creeks and inlets, and the amount of cargo from any one place would not justify large ships. Even for the movement of grain, discussed in Section III.5 below, pick-up of the cargo would be from dozens to hundreds of small shipping points scattered along the south and east coasts of Britain. This contrasts with the Roman Mediterranean grain trade, in which a high proportion of the ships loaded at Alexandria and discharged at Ostia.

In the building of the Blackfriars Ship 1, from the evidence of tool marks, all the floors and frames were hewn to shape with axe and adze. For the planking the evidence is uncertain. It could have been either sawn into planks or formed by splitting logs

---

11 Marsden from a study of the depth of water at high tide alongside the berthing facilities at London notes that this water depth “probably indicates that Blackfriars Ship1 was one of the larger seagoing merchant ships of that region.” (Marsden 1994:90).
tangentially and then finishing them with axe and adze. The St. Peter Port Ship and the Barland’s Farm Boat both had sawn planking. They are more than one hundred years later, but on balance it seems quite likely that large frame saws could have been available in Britain by the first quarter of the second century A.D., as a Roman technological introduction. In this study it has been assumed that the planking was sawn.12

Timber required (all timber is forest grown oak, Quercus sp.)
22 strakes cut from five trees 1 m diameter and with 11 m of clear trunk
24 floors cut from twelve trees 0.6 m diameter with 11 m of clear trunk
30 side frames formed from natural crooks, 3m long by 0.25 diameter.
Stem and stern posts formed from one large natural crook, 5 m long by 0.35 m diameter.
2 mast shelves cut from one tree 0.5 m diameter with 9 m clear trunk.
2 mast partners cut from one tree 0.4 m diameter by 7 m long
24 deck beams cut from two trees 0.5 m diameter by 12 m clear trunk
1 hold coaming cut from one tree 0.5 m diameter by 9 m long
20 deck planks cut from four trees 0.5 m diameter by 11 m long
26 ceiling planks cut from three 0.4 diameter trees by 8 m long
1 mast formed from a tree 0.3 m diameter by 13 m long
2 rudders cut from tree 0.4 m diameter by 7 m long
2 oars shaped from two trees 0.2 m diameter by 4 m long

Activity at the felling site

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time, man-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locate suitable timber for felling for planking and floors</td>
<td>32</td>
</tr>
<tr>
<td>Planking (5 trees 1.0 m diameter by 11 m long)</td>
<td></td>
</tr>
<tr>
<td>Felling, bucking to remove head, remove bark and branches</td>
<td>131</td>
</tr>
</tbody>
</table>

12 This question of when sawn planking started to be used, or became normal, in Romano-British ships, for at least the larger vessel, remains unclear. Pre-Roman water craft in Britain certainly used hewn planks and other components as found in the Bronze Age Dover Boat and the Brigg Raft. To date no planked vessels from Iron Age Britain have been found, but in the south vessels similar to those of the Veneti may well have existed. In the post-Roman period the various invading groups from North Germany and Scandinavia built their boats with radially split hewn oak clinker planking fastened with iron nails clenched over iron roves (a rove is a metal washer placed over the end of the nail before clenching, and the end of the nail is then rivetted over the rove). This method of construction lasted through the ‘Dark Ages’ and on into the medieval period, with ships like the Anglo-Saxon Sutton Hoo ship from Suffolk and the Skuldelev ships from Roskilde in Denmark. In Britain the eleventh century Magor Pill boat from the shores of the Bristol Channel in South Wales has been dated by dendrochronology to A.D. 1239-40 (Nayling 1998:119). “Saws appear to have been hardly used at all, there being only one possible set of saw marks on the aft end of the stem post scarf (inboard). Most of the working of the timbers was undoubtedly done with axes although only those involved in the finishing of the timbers have left traces.” (Brunning 1998:102). Sawn planking has been assumed here for the Blackfriars Ship, but it is not a certainty.
Set up for sawing into planks, 4 trees

Sawing into 22 planks + 3 extras, 0.06 to 0.075 m thick, (5 trees, 6 saw cuts per tree each 1.0 wide by 11 m long) 330 m$^2$ @ 0.5 m$^3$ per hour with two men

Floors (12 trees 0.6 m diameter by 11 m long)
Felling, bucking to remove head, remove bark and branches
Rough hew to shape @ 42 man-hours per log

Side frames
Locate 30 natural crooks 3 m long 0.25 m diameter
Fell 30 crooks and trim
Rough hew to 0.2 m wide

Stem and stern posts
Locate natural crook 5 m long 0.35 m diameter
Fell and trim
Split
Rough hew both halves to shape

Locate trees for:
beam shelves, mast partners, deck beams, hold coaming and ceiling planks

4 Beam shelves, 0.075 m thick (1 tree 0.5 m diameter by 9 m long)
Felling, bucking to remove head, remove bark and branches

13 The felled trunks would weigh about 7½ tonnes, and would have to be manoeuvred over a saw pit using rollers, levers and manpower. It would need six to eight men to lift one end with a lever with a five to one advantage, and another two to slide rollers into position. It would probably take about four hours to position ten rollers, or about forty man-hours to set up each tree.

14 This could best be done by squaring the log roughly by tangentially splitting off a sector shaped piece from each side using wedges, ending with a baulk about 0.45 m square. Each baulk could then be sawn in half using a frame saw designed for cross-cutting (each log makes two floors). Each roughly squared baulk 5.5 m long would then be axed and adzed to about 0.35 m square, and the centre two thirds trimmed down to about 0.22 m thick by notching with an axe and then splitting off between the notches. The time for these operations would be:
Splitting off four sector shaped pieces
Cross-cutting each baulk into two pieces
Axe and adze the two halves to 0.35 m square
Thin centre 3 m of the two halves down to 0.22 m thick
Total to process one log 42

15 Thickness can only be hewn when fitting to curve of hull.
Set up for sawing into planks
Sawing into 4 planks 0.075 m thick 22.5 m$^2$ (5 cuts 0.5 x 9 m)
@ 0.5 m$^2$ per hour with 2 men
Saw edges of 4 planks 5.4 m$^2$ (8 cuts .075 x 9 m)
@ 0.5 m$^2$ per hour with 2 men

2 Mast Partners, 0.075 m thick (1 tree 0.4 m diameter by 7 m long)
Felling, bucking to remove head, remove bark and branches
Set up for sawing into planks: use setup for beam shelf
Sawing into planks 8.4 m$^2$ (3 cuts x 0.4 x 7)
@ 0.5 m$^2$ per hour with 2 men
Saw edges of 2 planks 2.1 m$^2$ (4 cuts x 0.075 x 7)
@ 0.5 m$^2$ per hour with 2 men

24 Deck beams, 0.075 m thick (2 trees 0.6 m diameter by 13 m long)
(Each 13 m tree is cut into 6 planks, which are then halved to 6.5 m)
Felling, bucking to remove head, remove bark and branches
Set up for sawing into planks
Sawing into planks 110 m$^2$ (2 x 7 cuts, 0.6 x 13 m)
@ 0.5 m$^2$ per hour with 2 men
Saw edges of 24 planks 23.4 m$^2$ (2 x24 x 6.5 x .075 m)
@ 0.5 m$^2$ per hour with 2 men

48 Hanging knees for deck beams and 4 lodging knees for the mast partners
Locate 52 suitable natural crooks @ 0.5 hours each
Fell, debark
Square sides and jough out shape with axe and adze

Hold coaming, 0.075 m thick (1 tree 0.5m diameter by 8 m long)
Felling, bucking to remove head, remove bark and branches
Set up for sawing into planks
Sawing into 3 planks 16 m$^2$ (3 x 4 cuts x 0.5 x 8m)
@ 0.5 m$^2$ per hour with 2 men
Saw edges of 3 planks 3.6m$^2$ (6 cuts 0.075 x 8 m)
@ 0.5 m$^2$ per hour with 2 men

20 Decking planks, 0.05 m thick (4 trees 0.6 m diameter by 11 m long)
Felling, bucking to remove head, remove bark and branches
Set up for sawing into planks
Sawing into planks 158.4 m$^2$ (4 x 6 cuts 0.6 x 11 m)
@ 0.5 m$^2$ per hour with 2 men
Saw edges of 20 planks 22 m$^2$ (2 x 20 cuts 0.05 x 11 m)
At this stage the squared lumber, the beam shelves, the mast partners, the deck beams, the hold coaming, the decking and ceiling planks are ready for any finishing or smoothing cuts with axe or adze, for cutting to final length, and for fitting into the hull, with some work on shaping the ends for a snug fit in their final position. The mast, yard, rudders and oars have been shaped to their final form. Some work is still needed to fit the mast into its step, hang the rudders and fit the tillers. The hull planking, stem and stern posts, floors and side frames still need extensive work to develop their final shape and fit each piece tightly into place, with caulking between the planks and at the stem and stern posts. The decking planks will also need shaping to fit along the curved sides of the hull, around side frames and around the opening for the hold.

The next two steps are to transport the roughed out timbers to the building site, and construct a slipway or base for the assembly of the vessel. The total weight of the roughed
out timbers is about 42 tonnes, compared with about 100 tonnes for the felled and trimmed tree trunks from which they were formed. This suggests that it would be easier and cheaper to move the roughed out timbers than the whole logs. The larger logs weigh about 7½ tonnes each after felling and trimming, while the heaviest roughed out pieces only weigh about 0.7 tonnes, a much more practicable load for a wagon. Only if the trees were felled near water and could be barged or rafted to the building site, could it be attractive to do the sawing up and roughing out work at the building site. In this study it will be assumed that the timber would be felled and roughed out in a forest within 5 to 10 km of the building site, and hauled thence in one tonne wagon loads. The total weight of ship timber to be hauled would be the 42 tonnes noted above.

A vessel of this size, with an estimated hull and deck weight of 25.23 tonnes (Marsden 1994:89), could be built in a cradle on a slipway sited on a firm and gently sloping bank, preferably at the high tide line in a tidal inlet or estuary. A slipway and launching cradle could be built out of 0.2 m diameter de-barked tree trunks. This would have the advantage of raising the hull high enough above ground level to give easy access for the driving of the long iron nails from underneath the hull through the keel planks and floors. The 33 trees needed, 29 trunks 12 m long and 4 trunks 18 m long, with a diameter of 0.2 m, would each weigh respectively 0.324 tonnes and 0.486 tonnes. They could easily be moved by wagon. The total weight of slipway and cradle timber would be about 11 tonnes.

Felling, de-barking and trimming slipway timber
Fell 29 trees, 0.2 m diameter by 12 m long and cut in half 15
Fell 4 trees, 0.2 m diameter by 18 m long 3
Sub-total 18

Hauling timber to the Building Site
Hauling 42 tonnes of ship construction timber @ 8 hours/load 336
Hauling 11 tonnes of slipway timber @ 8 hours/load 88
Total hours for haulage 424

Construction of the slipway and cradle
Clear and level ground area 7 m x 20 m, 140 m², 7 men 1 day 56
Lay out 19 sleepers in shallow troughs, level across and longitudinally 40
Notch sleepers at both ends to accept 18 m longitudinal members 6
Lay in and spike 2 longitudinal logs 13
Notch next level of cross members on top and bottom position 12
and spike or treenail to longitudinal members 6
Lay in cradle longitudinal members (not spiked) 2
Notch top cross members of cradle on one side only 6
Spike to cradle longitudinal members 6
Sub-total for slipway construction 147
Construction of the ship
Final shaping of keel planks P1 and S1, put on cradle and
fasten together temporarily, caulking
Shape and fit a central floor timber
Shape and fit stem and stern posts, caulking
Shape and fit floor timbers 3 and 24 to secure stem
and stern posts, caulking
Spile, shape and fit remaining 21 floor timbers
Spile, shape and fit strakes P2 and S2, caulking
Spile, shape and fit strakes P3, S3, P4, S4, caulking
Shape, erect and temporarily support 30 side frames
Spile, shape and fit strakes P5 to P11 and S5 to S11, caulking
Make 1500 treenails, 19 mm diameter @ 10 per hour
Drill 700 holes 19 mm dia. by 0.4 m deep through floor timbers
Drill 800 holes 19 mm dia. by 0.20 m deep through side frames
Drive in and trim 1500 treenails @ 10 minutes each
Drill 700 holes 15 mm dia. by 0.40 m through treenails
Drill 800 holes 15 mm dia. by 0.20 m through treenails
Drive, caulk under head and clench 700 x 0.60 m nails, 2 men @ 9 mins./nail
Drive, caulk under head and clench 800 x 0.35 m nails, 2 men @ 4.8 mins./nail
Cut and fit two beam shelves
Make 144 treenails for deck beam shelves @ 10 per hour
Drill 144 19 mm holes by 0.225 m long @ 11.4 mins. each
Drive and trim treenails @ 10 mins. each
Drill 144 holes 15mm dia. by 0.225 m long through treenails
@ 10.6 mins. each
Drive and clench 144 deck shelf nails 0.45 m long, 2 men @ 6.6 min./nail
Notch shelves for 24 deck beams and 2 mast partners
52 notches 0.3 m long x 0.075 wide by 0.075 m deep @ ½ hour each
Cut and fit 24 deck beams and 2 mast partners
Drive 104 beam and partner nails 0.25 m long, 1 man @ 3.9 mins./nail
Finish shape and fit 48 hanging knees and 4 lodging knees
Drill 204 holes 15mm dia by 0.20 m long for knees @ 9.4 mins each
Drive and clench 204 by 0.3 m long nails, 2 men @ 3.75 mins. each

For caulking between plank edges and similar joints a figure of 5 m of plank edge per hour has been used for applying the hot pine resin and postioning the wood shavings. For caulking under the nail heads with hazel slivers and pine resin an extra minute has been added to the driving and clenching time for each nail.

Nails for the deck planking, some parts of the deck structure, and for the hold ceiling would not normally be clenched, but just driven into the supporting timbers. On the Blackfriars ship the surviving ceiling nails were not clenched.
Cut and fit hold coamings, caulking 9
Drill 120 nail holes 0.15 m long @ 6.5 mins. each 13
Drive and clench 120 nails 0.2 m long, 2 men @ 2.5 mins each 10
Cut and fit 20 deck planks, caulking 170
Drill 1020 by 15 mm dia. starter holes for deck plank
nails (no treenails) @ 4.8 mins. each 82
Drive and caulk 1020 0.28 m long nails, 1 man @ 4.5 mins 77
Cut and fit 26 ceiling planks 18
Nail into place using short 0.15 m long iron nails with no
pre-drilling, 40 nails per plank, 1040 total @ 1.5 mins. each 26
Sub-total for assembly 3970

Total Man-Hours for building hull
Felling site work 2897
Felling slipway timber 18
Hauling timber to construction site 424
Constructing slipway 147
Assembly of hull 3970

Total hours 7456

Total man-days 932
Contingency allowance of 20% to allow for inclement weather,
timber not splitting as planned, errors and reworking 187
Total man-days with contingency allowance 1119
Converting man-days to BEUs 3.995
BEUs to produce 638 kg of nails for hull 4.203
Estimated BEUs to produce 595 kg of nails for upper works 3.912
Allowance for sails, cordage and miscellaneous fittings 0.5
Total value in BEUs 12.610

Building the Blackfriars Ship 1 would require at least one, and preferably two or
three skilled shipwrights, as well as at least three of four other workmen. Even after felling
and rough shaping the larger strakes and floors would weigh 600 to 700 kg and even in their
finished state 200 to 350 kg. Holding up long planks against the floors and frames for
marking off, and bending them around the frames would need seven or eight men as a
minimum. The use of an A frame or gin pole with blocks and tackle would seem very
probable for components of this weight. Launching should not be too much of a problem.
Temporarily extending the slipway into the river or inlet at low water, and applying tallow,
a singularly slippery substance, liberally between the slipway and the cradle should ensure a
prompt launch\textsuperscript{18}. With a work force of eight to ten men and a blacksmith the ship could be built in about six months. The amount of ironwork would justify a blacksmith on site.

3.7. Discussion and Conclusions

This section is has a rather large number of assumptions and hypothetical figures. Are they justified? The hard facts are the remains of the Barland's Farm boat and the Blackfriars Ship 1. The concept of the two barges is based on the remains of the well preserved barges from Zwammerdam. For the Barlands Farm boat and the barges the remains were sufficiently well preserved that a reliable reconstruction could be made. For the Blackfriars Ship 1 half of the hull was preserved up to the ninth strake from the keel, and the extant floors and half frames were in good condition. The two topmost strakes and all the deck structure are conjectural, but based on comparison with other known vessels, quite logical. In general the reconstructions appear acceptable. For the tools used, there are many Roman tools of the type needed for ship building in British museums, except for the large frame saws. However, from the saw marks on the St. Peter Port ship, large frame saws can be inferred, at least by the later third century. The times used in this section for the felling and working of timber are derived from a very small, indeed minute data-base of experimental work, and it would be very desirable to confirm them with a more extensive programme using copies of Roman period tools to carry out the various operations of felling, cutting notches, drilling holes and finishing surfaces with axe and adze. The times for sawing have been compared with those used by DeLaine for the Baths of Caracalla and Shirley for the fortress at Inchtuthill. The time taken for sawing is the most debatable point. They use times from nineteenth century handbooks. I am doubtful about comparing recent steel saws with machine cut teeth with Roman saws, see Appendix P, Section 7 for a full discussion of the derivation of the times for sawing.

The value calculated for the iron blooms is based entirely on Cleere's work on the production of iron in the Weald in the first to second century A.D. This is in the right general area for the value of iron in BEUs, but like the experimental work noted above, it uses a very small-data base. I am confident of the times worked out for forging blooms into nails, based on personal knowledge of blacksmithing. The basic technology of hand forging iron has changed very little in the last two thousand years.

If the information used to derive the cost of building the four vessels is reasonably correct, the most interesting point is the high percentage of the cost committed to the nails. Table III.3.1 below lists the cost of nails for each vessel as a percentage of the total cost.

\textsuperscript{18} In the late 1940s, while working in a small shipyard handling vessels up to 100 tonnes deadweight, two of us routinely hauled out and launched both wooden and steel hulled vessels on wooden cradles and wooden tallowed slipways with a small winch and some snatch blocks.
Table III.3.1: Nail costs as percentage of total cost

<table>
<thead>
<tr>
<th>Vessel Costs &gt; in BEUs</th>
<th>Total cost</th>
<th>Cost of nails</th>
<th>All other costs</th>
<th>%age cost of nails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>0.787</td>
<td>0.590</td>
<td>0.197</td>
<td>75%</td>
</tr>
<tr>
<td>Barge 3</td>
<td>3.413</td>
<td>2.812</td>
<td>0.601</td>
<td>82.4% (Note 1)</td>
</tr>
<tr>
<td>Barland’s Farm</td>
<td>2.421</td>
<td>0.680</td>
<td>1.741</td>
<td>28%</td>
</tr>
<tr>
<td>Blackfriars Ship</td>
<td>12.610</td>
<td>Hull 4.199</td>
<td>Deck 3.916</td>
<td>All Nails 8.115</td>
</tr>
</tbody>
</table>

Note 1:- In designing this hypothetical barge I may have been overgenerous with the nails. If nail numbers and costs were reduced by a third, the percentage of total cost would fall to 77%, close to that of barge 5. The Barland’s Farm boat is of much lighter construction than the others, which could largely account for the lower percentage for nail costs.

The capital cost per tonne of cargo carried declines sharply with the increasing size of the vessel. Table III.3.2 below shows this effect.

Table III.3.2: Capital cost per tonne of cargo carrying capacity

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Cost in BEUs</th>
<th>Maximum cargo, tonnes</th>
<th>BEUs per tonne capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>0.787</td>
<td>1.2</td>
<td>0.656</td>
</tr>
<tr>
<td>Barge 3</td>
<td>3.413</td>
<td>12.26</td>
<td>0.278</td>
</tr>
<tr>
<td>Barland’s Farm boat</td>
<td>2.421</td>
<td>6.5</td>
<td>0.372</td>
</tr>
<tr>
<td>Blackfriars Ship 1</td>
<td>12.610</td>
<td>50.0</td>
<td>0.252</td>
</tr>
</tbody>
</table>

This is what would be expected, as the volume for cargo is proportional to the cube of the linear dimensions, while the area of planking is proportional to the square of the dimensions. These relative costs suggest that the Blackfriars Ship, as well as being the only vessel suitable for cross-Channel passages and serious sea going, would be more economical than the Barland’s Farm type for coastal passages, as long as the trading activity would allow it to pick up fairly full cargoes. The barge types, in any size, are only suitable for inland waters, or very sheltered estuaries.
Section III.4: The Cost of Operating and Maintaining Four Representative Vessels, and their Useful Working Life

4.1. Introduction

Of the four types of vessel discussed in this thesis only three would have a specific cost for its operation. These three are the inland waters commercial Barge 3, the Barland’s Farm Boat, a small coasting craft, and the sea-going, cross-channel and coasting ship, the Blackfriars Ship 1. For the Barge 5 type, owned and operated by the modest peasant farmer and his family or small craftsman or manufacturer, the operating cost would be minimal. For the owner-operator it was a part-time activity, included in his regular schedule of work. He and his family would be providing for their subsistence, purchase of needed goods and taxation from their main occupation, farming or small-scale manufacturing. The vessel is small enough to be propelled by one male or female adult, or a reasonably sturdy teenager, by either paddling or punting. The maintenance and repairs would be modest, and would probably be done along with routine repairs to their dwelling, farm buildings and structures, and workshops, at quiet times in their principal occupation. The specialized skills of cargo handling and stowage, seamanship and navigation would not arise on the slow flowing inland rivers on which this type of vessel would be used.

The three large vessels require specialized skills, not only in their construction and repair, but above all in the three critical operating skills noted above. The proper stowage and securing of cargo is essential for the safety of the ship. Two key requirements are that the cargo should not be able to shift when the vessel is under way, and that it should be stowed in such a manner that the vessel is neither unstable nor excessively stiff. Seamanship, the skills needed for operating and manoeuvring the ship in all conditions of wind, sea state and tidal currents, are also vital. Navigation has two aspects. One is the avoidance of danger such as rocks, sandbanks and shoals, and the second is the need to take the ship from its starting point to its destination in the shortest practicable time. A voyage unnecessarily prolonged by poor navigation reduces or eliminates the profit for the shipowner or master. This requirement for a set of specialized skills implies the use of a full-time crew of professional sailors, for whom this was their principal occupation. Even watermen managing large barges in tidal estuaries such as the Tyne, Humber and Thames require skills in loading and discharging cargoes, and in safely working their craft up, down and across the often choppy and swirling tidal streams. The Blackfriars Ship 1 was apparently sunk in a collision on the Thames at London (Marsden 1994:91)! The crews for these professionally manned vessels have to be paid and fed, probably year round. Some ongoing costs for wear and tear and minor maintenance, such as periodic scrubbing of the bottom, replacing worn ropes and cordage and sail repairs, can also be

---

1 If the weight of the cargo is carried too high in the ship, she will be unstable, and liable to capsize. If concentrated too low it will result in excessive ‘stiffness’, giving the ship a very rapid and jerky rolling motion in a seaway. This can lead to loss of mast and spars and possibly structural damage.
considered as part of the operating costs, as opposed to hull and other major repairs. These are, one hopes, less frequent, and would only occur after some mishap on only a few occasions during the ship’s working life. The total operating cost should also include an allowance for replacing the vessel at the end of its useful life.

4.2. The Cost of Operating the Vessels

The ‘wages’ of the crew, whether in cash or kind, would be the major operating expense. Barge 3 might have a permanent crew of two men. For the Barland’s Farm coastal trader a minimum crew of two men might manage on rivers and short coastal voyages, but three would be needed on long distance coastal passages (McGrail and Roberts 1999:142). For a coastal voyage lasting more than the daylight hours of one day, three men would be needed to keep the craft moving overnight. For the Blackfriars Ship 1 a crew of at least three is certain. For the St. Peter Port Ship, a slightly larger vessel of the same type, “A crew of three is suggested by the amount of pottery recovered. This fits with estimates for other ships of the period....” (Rule and Monaghan 1993:129).

In Appendix B, it is demonstrated that the peasant farmer and his family generate two BEUs in a year, one for subsistence and one for outside purchases and taxation. The male head of the household produces one BEU (= one man-year of output), while the combined output of his wife and children produce a second. Assuming that the level of income and output was fairly level across banausic occupations, the crew of three would need to make as much, or possibly somewhat more per man than the peasant farmer. Some of the crew members might be married with families, but not necessarily all. A possible combination could be two experienced married men as skipper and mate, with a younger third hand who would in time progress to the positions of mate and skipper, and the married

---

2 All water-borne vessels and static installations such as wharves and jetties acquire ‘fouling’, a build up of barnacles, mussels and other forms of marine life as well as various forms of plant life commonly referred to as ‘weed’. These add enormously to the frictional drag on a ship’s hull, leading to a continuing and increasingly significant loss of speed. They have to be scraped and scrubbed off regularly. On ancient vessels lacking effective anti-fouling protection in the form of special paints or copper sheathing, the bottom might need to be scraped and scrubbed every two to three months. The vessel would need to be beached at a sheltered site towards high tide, while the crew worked around the vessel as the tide dropped, scraping and scrubbing. For a vessel the size of the Blackfriars Ship 1 this might take the crew two days. Thus something between 24 and 36 man-days could be taken up with this activity. An ameliorating factor arises if the vessel spends some time alternately in seawater and fresh water. Lack of salt water kills off the marine organisms, while salt water kills the fresh water life forms. This is not a complete solution, as the calcareous shells of organisms such as barnacles remain firmly attached, leaving a rough bottom with a higher frictional resistance.

3 If the vessel can average say 2 knots in 24 hours, it will make good 48 nautical miles as opposed to only 20 if it moves in only 10 daylight hours. One inherent advantage of seagoing water transport is that it can keep going 24 hours a day, and a major part of its economics lies in this facility for continuous operation.
status. Depending on the income and social status of the crew, their wives and families might have to work. For example, if the skipper were also the owner, it would imply that he had had enough capital to build the ship, either from his own resources, or by borrowing. With this capital investment he might have a social status and income that did not require that his wife and family work. If the skipper were an employee, the owner would be concerned to pay the lowest wage possible, consistent with getting a competent person. Several scenarios are possible. Two extremes are:
a. The skipper, mate and third hand are all married with working wives and families: the cost of the crew would be three BEUs per year.
b. The whole crew is married, without working wives and families: the cost of the crew would be six BEUs per year.

A possible scenario, in line with the situation in the 19th century coasting trade, is for a married skipper whose wife and family do not work, paid two BEUs, a married mate whose wife works part time, paid one and a half BEUs, and an unmarried third hand paid one BEU, for a total crew cost of four and a half BEUs. This is the figure that will be used here for the Blackfriars Ship 1. For the Barland’s Farm boat, making predominantly short coastal voyages, the skipper would be a full-time professional, paid two BEUs, but the other two crew members could be young unmarried men, or a man and a boy. Their pay would be no more than one BEU each, giving a total for the boat of four BEUs. If the skipper were also the owner, he would presumably strive to maximise his profit from the freight rates he charged, and might earn more than the equivalent of two BEUs per year. This does not affect the basic cost of running the ship, although it increases the amount paid by the shipper, and therefore the portion of the gross domestic production which would be absorbed by water-borne transport costs. For Barge 5, run by its owner-operator and his family unit, there is no incremental labour cost to operate their small barge. For Barge 3, its two man crew would probably have a working wife and family, and the operating cost would be two BEUs.

In addition to the running costs of paying the crew, a capital replacement fund would be needed to replace the ship at the end of its useful life. All ships have a finite life. The maximum for a well cared for and maintained wooden ship at that time might be as much as fifty years, and at the other end of the scale less than a year in the case of accident. The average, allowing for less than perfect maintenance and marine casualties would probably be less than half the maximum. Of thirty Porthmadog wooden sailing schooners built between 1891 and 1913, one built in 1900 was finally broken up in 1950. Two others were wrecked or lost at sea within a year of being built. The average life of the whole group was 16.7 years and the median 13.1 years. Apart from the one broken up at fifty years old, eleven were wrecked, nine lost at sea, two lost in collisions, and seven sunk by enemy action in the Great War of 1914-1918. If the seven lost by enemy action are excluded, although this could be equated to losses from piracy, the average life of the remainder was 17.4 years and the median still about 13 years. These schooners were larger

---

4 The difference between the average and the median shows that losses were relatively higher in the early lives of the vessels. This could be due to some vessels being less well constructed, although in this case all
than the Roman vessels under discussion, averaging about 100 tons cargo capacity, but they sailed in the same areas around the British Isles, across to Spain, France and the Low Countries, and sometimes even farther afield. They carried the same sort of cargoes, stone, cereals, coal and mixed merchandise. A modern study by Couper has made a number of points:

"Weather conditions still account for most ship losses under 100grt."5 Collisions and strandings tend to be concentrated around narrow channels and headlands. Problems are "...compounded by reduced visibility, strong tidal currents, ...and above all by human error." (Couper 1983:162). Weather and reduced visibility affect all British coastal areas during the course of a year, while strong tidal currents are ever present.

For the purposes of this thesis an average useful working life for the coastal and seagoing vessels of 18 years has been used.6 The river barges faced fewer natural hazards than the seagoing ships, and their working life would generally be ended by deterioration of the structure to a point where they were broken up or abandoned. The New Guy’s House Boat, a London river barge, appears to have been abandoned after a working life of about 25 years (Marsden 1994:102-104), and this figure is used for the probable working life of Barge 3.

The annual depreciation allowance per year for each vessel, the original capital cost divided by the average life, would be as shown in Table III.4.1 below.

Table III.4.1 Annual depreciation allowance per year

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Barge 5: (see note below)</th>
<th>Barge 3</th>
<th>Barland’s Farm Boat</th>
<th>Blackfriars Ship 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost, BEUs</td>
<td>0.590</td>
<td>3.413</td>
<td>2.421</td>
<td>12.610</td>
</tr>
<tr>
<td>Life, years</td>
<td>25</td>
<td>25</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Annual Replacement Allowance</td>
<td>0.024 BEUs</td>
<td>0.137 BEUs</td>
<td>0.135 BEUs</td>
<td>0.701 BEUs</td>
</tr>
</tbody>
</table>

were built by the same builder, or more likely reflects varying competence of the masters and crew. The information on the life span and cause of loss has been calculated from information in Greenhill (1988:285).

5 grt is gross register tonnage, the useable internal volume of the ship divided by 100. It gives a good indication of how big the ship is.

6 Of the St. Peter Port Ship, Rule and Monaghan say "...the ship was not new, but there is no evidence that it was of great age." (Rule and Monaghan 1993:129). The Blackfriars Ship 1 was possibly 20 to 25 years old when lost, but could be somewhat younger. The County Hall Ship was apparently only a few years old when abandoned. At the other extreme the Kyrenia ship from the Mediterranean is thought to have been about 80 years old when lost off Cyprus.
Note: For Barge 5 only the cost of the iron fastenings is counted. The labour to fashion and build the wooden parts of the hull are provided from the owner-operator’s ‘spare’ time.

4.3. The Cost of Maintaining the Vessels

The cost of annual maintenance would not normally be very high, as much of the periodic minor repairs and servicing of the hull, mast, sail, oars, rudders and standing and running rigging would be done by the crew. The exception would be if the vessel had sustained significant damage from a marine accident, such as stranding or collision, or if rot or marine borers had damaged the hull to the extent that major replacements of frames and planking were necessary. Equipment such as sails and cordage would need periodic replacement as well as regular repair. The cost of maintaining the vessels is made up of three components, materials, specialized hired craftsmen, and the crew’s own labour. The crew’s own contribution is not included here, as the entire cost of the crew is included under operating costs, for example when scrubbing the bottom. If they work alongside other labour during repairs, their cost has already been accounted for. In the life of the hull it has been assumed that, apart from the costs of any maritime accidents, the cost of maintenance in the first few years would be minimal. One or two minor repairs using a shipwright or blacksmith taking perhaps four or five days might cost 0.025 BEUs. After four to six years some rot, damage from marine borers, or cumulative damage from a number of minor collisions or strandings, would probably have occurred. This could require the replacement of a few planks or frames, and a number of the iron fastenings. For the barges with their lower exposure to marine hazards, it has been assumed that they might need major overhauls about every six years in their life span of twenty-five years, in years six, twelve and eighteen. In year twenty-four to twenty-five they would be scrapped. For the two seagoing vessels, the Barland’s Farm Boat and the Blackfriars Ship 1, a major overhaul every four years seems reasonable, which would mean three overhauls in their shorter life of eighteen years. In the major overhauls it has been assumed that about five percent of the iron nails might be replaced, and that about four percent of the timber would be replaced at each overhaul, or a total of twelve percent over the life of the vessel. Table III.4.2 below summarizes the maintenance costs.
Table III.4.2: Total annual and major overhaul costs in BEUs

<table>
<thead>
<tr>
<th>Activity &amp; costs</th>
<th>Barge 5</th>
<th>Barge 3</th>
<th>Barland’s Farm Boat</th>
<th>Blackfriars Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of annual rep.</td>
<td>25</td>
<td>25</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Cost of Each</td>
<td>0</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Total life cost</td>
<td>0</td>
<td>0.5</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>Major overhauls</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Nail costs</td>
<td>0.029</td>
<td>0.140</td>
<td>0.036</td>
<td>0.40</td>
</tr>
<tr>
<td>Timber repairs</td>
<td>0</td>
<td>0.021</td>
<td>0.050</td>
<td>0.1612</td>
</tr>
<tr>
<td>Total life cost</td>
<td>0.087</td>
<td>0.483</td>
<td>0.258</td>
<td>1.6836</td>
</tr>
<tr>
<td>All repairs, total</td>
<td>0.087</td>
<td>0.983</td>
<td>0.618</td>
<td>2.0436</td>
</tr>
<tr>
<td>Average cost/year</td>
<td>0.0035</td>
<td>0.0393</td>
<td>0.0343</td>
<td>0.1135</td>
</tr>
</tbody>
</table>

4.4. Summary of the Annual Costs of Operating and Maintenance

The total annual cost of operating each type of vessel is shown in the table below. The dominant cost is that of the crew, followed by the depreciation or capital replacement cost. These can be considered fixed annual costs. The cost of maintenance and repairs is the smallest component of the total. It consists of a small annual charge and periodic higher costs every few years for major repairs and overhauls.

Table III.4.3: Annual operating, replacement and maintenance costs

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Barge 5</th>
<th>Barge 3</th>
<th>Barland’s Farm Bt.</th>
<th>Blackfriars Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating costs</td>
<td>0.0</td>
<td>2.0</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Replacement cost</td>
<td>0.023</td>
<td>0.133</td>
<td>0.127</td>
<td>0.7005</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>0.0038</td>
<td>0.0393</td>
<td>0.0343</td>
<td>0.1135</td>
</tr>
<tr>
<td>Total Costs</td>
<td>0.0268</td>
<td>2.1723</td>
<td>4.1613</td>
<td>5.314</td>
</tr>
</tbody>
</table>
If the carrying capacity is compared with the total annual cost for each vessel, the results show that setting aside the part-time owner operated Barge 5, the Blackfriars Ship 1 is easily the most economic carrier of the four craft considered, see Table III.4.4. below.

Table III.4.4: Annual costs per tonne of cargo capacity

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Barge 5</th>
<th>Barge 3</th>
<th>Barland’s Farm</th>
<th>Blackfriars Ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual cost</td>
<td>0.0268 BEUs</td>
<td>2.1723 BEUs</td>
<td>4.1613 BEUs</td>
<td>5.3106 BEUs</td>
</tr>
<tr>
<td>Capacity, tonnes</td>
<td>1.2</td>
<td>12.2</td>
<td>6.5</td>
<td>50.0</td>
</tr>
<tr>
<td>Cost per tonne</td>
<td>0.0223</td>
<td>0.1781</td>
<td>0.6402</td>
<td>0.1062</td>
</tr>
</tbody>
</table>

The reason for this is that, with the costs of the crew making up a major part of the total annual costs for the three commercial vessels, the Blackfriars Ship 1 can operate with a crew larger by only one man, despite the fact that its cargo capacity is several times larger. In Table III.4.3 above the small Barge 5 shows no operating cost because of the assumption that it is operated by the owner-operator and his family in their ‘spare time’.
Section III.5: The Volume of Goods to be Transported, and the Number of Vessels Needed for Sea and Coastal Voyages, and Inland River Movements

5.1. Introduction

For the purpose of this section the period from c. A.D. 130 to 150 will be examined.\(^1\) This period has been selected as one where the internal and external settlement and trading patterns have temporarily stabilized. With the building of Hadrian’s Wall and its forward forts the northern frontier was defined, and all of Britain south of the Tyne-Solway isthmus, including Wales, had been pacified. The advanced positions in Scotland reached by Agricola by A.D. 84 had been abandoned by about A.D. 87. The three permanent legionary bases at York (Legio VI \textit{Victrix}), Chester (Legio XX \textit{Valeria Victrix}) and Caerleon (Legio II \textit{Augusta}) had been established. The needs of the army and the civilian population for the movement of goods would be somewhat different, and both are examined in the following sections.

5.2. The Goods Requiring Transport

As noted in Section III.2 above, the food and materials to be moved over medium to long distances include: grain in large quantities; wine; olive oil; olives; \textit{garum}; pottery of all sorts; metals, both as ingots and finished products; glassware; fine marbles; salt; coal; tiles and brick; and quarry-run stone in large quantities for buildings and city walls. In addition, many items produced and sold locally, vegetables, fish and shellfish, timber, charcoal, livestock, and the output of small craftsmen such as blacksmiths, carpenters, weavers, and small scale potters, might use river-borne transport to move these items to local markets in the twenty-one towns and fifty-three small towns and settlements in Britain. The distances covered in these local movements could vary from four or five km up to ten to fifteen km.

The goods to be moved fall into two broad categories. One is goods that would normally make up the principal or only cargo for a ship or barge. These would include grain; quarry-run stone; tiles and brick; timber; amphorae of wine and olive oil; some pottery; and some metal ingots. The other category is goods such as lamps; fine pottery; small finished metal objects; glassware; and small amounts of marble and other exotic stone. Although lamps and similar small objects might be moved in large consignments of several thousands, in terms of weight or volume occupied in the ship’s hold, they would not

\(^1\) Although by Trajan’s reign a northern ‘frontier’ line had been established along the line of the Stanegate, backed by a number of forts such as Vindolanda, parts of the North appear to have remained restless. Hadrian’s Wall was probably intended to stabilize the frontier and consolidate the province. The frontier was pushed forward to the Forth-Clyde line with the construction of the Antonine Wall in the 140s. This was abandoned by the 160s A.D. and Hadrian’s Wall became the permanent frontier.
make up a full shipload. These would be shipped as a consignment to fill vacant capacity in ships carrying bulk material, or as part of a general mixed cargo.

Livestock could be a full or part cargo in barges on inland waterway systems, or for short coastal journeys. Using a vessel such as the Barland’s Farm Boat about fifty sheep or eight cattle could be carried. Generally livestock was raised in many areas of Britain and there would be little call for long distance movements by sea. In special circumstances, as for example, in crossing the larger tidal rivers, such as the Thames, Humber or Tyne, or interior rivers too deep to ford, there could be a requirement to move sheep, goats and cattle by water. For example, to move sheep from the Somerset levels to forts in South Wales, it would be quicker to ship them the ten to fifteen km across the Bristol Channel than to herd them seventy to eighty km up the east side and a similar distance down the west side. It would be both quicker and much less tiring for the sheep.

In this paper an attempt will be made to quantify the amount of grain, wine, olive oil, quarried stone, metal ingots and some pottery moved by sea, and the shipping needed to move these materials calculated. For other products, such as marble veneers and similar luxury items, a few ship loads per year would probably have met the demand. Imported pottery, lamps, small metal products and other low volume items would be part cargoes, and would be fitted in with the bulk cargoes. Material, such as coal from the north of Britain, would probably be transported as a return cargo in grain ships from the south, which would otherwise return empty or in ballast. For the estuary and inland river barge traffic, an estimate of the number of craft needed will be made, based principally on the number of villas, towns and small towns, and their daily and periodic local needs. Some products, such as grain, would move as coastal traffic around Britain, but as an export overseas.

5.3. Grain

a. Grain for the Army and its dependants

Frere has estimated the garrison of Britain in the Hadrianic period to be about 41,010, made up as follows (Frere 1987:143-4):

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garrisons on the northern frontier</td>
<td>15350</td>
</tr>
<tr>
<td>Garrisons in other parts of the north</td>
<td>11060</td>
</tr>
<tr>
<td>Total in the north</td>
<td>26410</td>
</tr>
<tr>
<td>Garrisons in Wales and its borders</td>
<td>9500</td>
</tr>
<tr>
<td>Military in other posts</td>
<td>5100</td>
</tr>
</tbody>
</table>

Millett has estimated that the army and its dependants numbered about 125,000 by the fourth century (Millett 1990: 185, Table 8.5; and Appendix B, page 186). The numerical strength of the army was less in the fourth century due to the reduction in the size of legions, but the number of dependants would have increased somewhat after some

---

2 One thousand lamps would weigh about 200 kg, 5,000 one tonne.
concessions on ‘wives’ by Septimius Severus, and Caracalla’s granting of citizenship to all free people in the empire. This step allowed serving soldiers to marry legally. Millett has estimated about four dependants, see Appendix B, section 2. The evidence from Housesteads suggests a more ‘domesticated’ garrison in late antiquity, with some subsistence farming, and possibly families living inside the fort (Frere 1987:343-5). For our period, fifty to seventy years earlier than the Severan changes, two to three dependants seems more likely. This would include slaves, women and children. The army in the Hadrianic period was still based on the Augustan model. For the Hadrianic to Antonine period in Britain an estimate of 2.5 dependants per soldier, made up of a mix of slaves, servants, concubines and children, seems probable. The legions all had fixed bases by this time, and the auxiliary units manning the frontier forts appear to have remained in the same post for quite long periods.

Much grain would be produced and consumed locally, but supplies for the army’s granaries, particularly in the north would have to be shipped from the major grain producing areas in the south and east. Marsden has estimated that the Blackfriars Ship 1 could carry about 18.36 tonnes of grain. In discussing the Blackfriars Ship 1 he also comments that based on the depth of water alongside the Roman wharves in London at high tide, 0.5 to 1.5 m, this depth “...probably indicates that Blackfriars Ship 1 was one of the larger seagoing merchant ships of that region.” (Marsden 1994:89-90). For the purposes of this study, it will be assumed that the Blackfriars Ship 1 was typical of the Romano-British seagoing vessels, and its cargo capacity will be used in calculating the number of ships needed to support the movement of grain and goods by sea.

From Appendix B, section 3.b, the daily ration of grain for a soldier in the Roman army was about 1.3 kg, or 474.5 kg per year. With a strength of 15,350, the army on the northern frontier would need 7,284 tonnes per year, or allowing for a twenty percent loss in transit and storage, about 8,740 tonnes. Using ships of the Blackfriars type, this translates into 476 shiploads. The 11,060 men in other northern forts would need 6298 tonnes, or 343 shiploads. Assuming that the 2.5 dependants were two adults and one juvenile, as a group they would need 2.5 kg per day, or 24,100 tonnes per year. About half of this might have been provided by the dependants cultivating crops and raising small livestock in the vicinity of the forts, leaving 12,050 tonnes to be imported from the south. To summarize, the shipping requirement for the army and its dependants in the north would be 15,038 tonnes of grain for soldiers plus 14,459 tonnes for dependants, a total of 29,497 tonnes, equivalent to 1,607 ship loads. For the 9,500 troops in South Wales and the borders and their dependants, the army would need 5409 tonnes per year and the dependants another 5201 tonnes, for a total of 10,610 tonnes. In a year Wales would need 578 ship loads.

---

3 The amount a ship or boat can carry depends on the specific gravity of the cargo. The ship has to maintain both stability and a safe freeboard. For example, the Blackfriars Ship 1 could carry a maximum cargo of fifty tonnes of high specific gravity such as metal ingots at minimum safe freeboard, but the ingots would only fill a small part of the volume of the hold. For grain, a cargo of 18.36 tonnes completely fills the hold, with adequate stability and ample freeboard.
(i) Grain for the North

Looking at the distribution of the auxiliary garrison along the northern frontier and in the hinterland, and with one legion at York and one at Chester, it would appear logical to ship half the quantity needed up the east coast, and the other half along the south and up the west coast to Chester and Carlisle. For the west coast it would seem reasonable to ship about half to Chester and half to Carlisle. The main grain-growing areas with a surplus were in the east and south. For the east coast, possibly a third of the total was shipped from the south-east, a third from the Wash area, and the remaining third from the area around the Humber. The navigable distance from the Thames to the Tyne is 280 nautical miles, from the Wash 156 nautical miles and from the Humber 135 nautical miles (Watts 1965:668-69). Although the Blackfriars Ship could make 7 knots under ideal conditions, the average speed made good was probably between 1 and 2 knots from slipping to berthing at the destination. Voyaging up and down the east coast of Britain the winds would be mostly adverse or abeam. Casson quotes speeds with unfavourable winds in the Mediterranean in the range 1.5 to 2.6 knots (Casson 1995:289), but these would have been with much larger ships. The average speed made good in coasting voyages in the late nineteenth century was in the range 1.0 to 1.5 knots (McGrail and Roberts 1999:145). This suggests that the Blackfriars ship could probably average about 1.25 knots with adverse winds, but about 5 to 6 knots with a force 4 to 5 following wind, or allowing for variable winds average about 3 knots with favourable winds. For the east coast conditions it is reasonable to assume an average speed made good of 1.25 knots on both the outward and return voyages. For voyages along the south and west coasts, westbound down the Channel with the prevailing south-westerlies an average speed of 1.25 knots has been used and for eastbound voyages 3.0 knots. Sailing along the west coast of Britain, north bound vessels would frequently have a favourable wind, giving an average speed of 3.0 knots, but coming south they would have headwinds and would only make about 1.25 knots. Two days have been allocated at each end of the voyage to loading and discharging cargo. Tables III.5.1 and III.5.2 below summarize the number of ships needed for the east and west coast trade, assuming a nine month sailing season.

---

4 The maximum possible speed of a displacement vessel is $2.43 \times \sqrt{\text{waterline length in metres}}$. Thus a Mediterranean ship of 200 tonnes cargo capacity with a waterline length of about 30 m would have a maximum speed about 1.3 times that of the Blackfriars Ship.

5 There are periods of prolonged bad weather in the winter, and less frequently in the summer when sailing would not be possible. In addition there is the time expended on annual maintenance, scrubbing the bottom, and periodic ‘make and mend’ days for the crew and ship. In all the calculations in the following sections the number of voyages in a year has been based on a nine month or 270 day sailing season. In short periods of settled weather in winter coastal voyages could be made quite safely, provided shelter was available close by. Conversely during a summer gale, navigation could be held up for a week or more.
Table III.5.1: Number of Ships Needed to Move Grain to the North-East

<table>
<thead>
<tr>
<th>Voyage &amp; distance</th>
<th>Round trip time</th>
<th>Tonnes of grain</th>
<th>Voyages per year</th>
<th>No. of Ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thames/ Tyne 280</td>
<td>23 days</td>
<td>4916 = 268 cargoes</td>
<td>12</td>
<td>22.3</td>
</tr>
<tr>
<td>Wash to Tyne 156</td>
<td>14.4 days</td>
<td>4916 = 268 cargoes</td>
<td>19</td>
<td>14.1</td>
</tr>
<tr>
<td>Humber/ Tyne 135</td>
<td>13.0 days</td>
<td>4916 = 268 cargoes</td>
<td>21</td>
<td>12.8</td>
</tr>
</tbody>
</table>

The total number of ships needed for the east coast would be about 50.

For the west coast voyages, as noted previously, there is a mixture of unfavourable and favourable winds. Two destinations seem likely, Chester for the Legio VI *Victrix* and Carlisle to service the west half of Hadrian's Wall. It has been assumed that about half the grain would come from East Anglia, and a half from southern Britain. Table III.5.2 below shows the number of ships needed for the west coast routes.

Table III.5.2: Number of Ships Needed to Move Grain to the West Coast Ports

<table>
<thead>
<tr>
<th>Voyage &amp; distance</th>
<th>Round trip time</th>
<th>Tonnes of grain</th>
<th>Voyages per year</th>
<th>No. of Ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Anglia to Chester 1,390 n.m. 695 @1.25 knots 695 @ 3.0 knots</td>
<td>37 days</td>
<td>3687 = 200 cargoes</td>
<td>7.3</td>
<td>27.4</td>
</tr>
<tr>
<td>Southampton to Chester 1,098 n.m. 484 @ 1.25 knots 484 @ 3.0 knots</td>
<td>28 days</td>
<td>3687 = 200 cargoes</td>
<td>9.6</td>
<td>20.8</td>
</tr>
<tr>
<td>East Anglia to Carlisle 1,560 n.m. 780 @ 1.25 knots 780 @ 3.0 knots</td>
<td>37 days</td>
<td>3687 = 200 cargoes</td>
<td>7.3</td>
<td>27.4</td>
</tr>
<tr>
<td>Southampton to Carlisle 1,138 n.m. 569 @ 1.25 knots 569 @ 3.0 knots</td>
<td>31 days</td>
<td>3687 = 200 cargoes</td>
<td>8.7</td>
<td>23</td>
</tr>
</tbody>
</table>

The total number of ships needed for the west coast route would be 99, which with the 50 for the east coast route gives a total of 149.

The garrisons in Wales and its borders would also need supply by sea. As for the supply to the west coast it has been assumed that half the supply came from East Anglia and half from southern Britain. Table III.5.3 below shows the number of ships needed for the South Wales route.
Table III.5.3: Number of Ships Needed to Move Grain to South Wales

<table>
<thead>
<tr>
<th>Voyage &amp; distance</th>
<th>Round trip time</th>
<th>Tonnes of grain</th>
<th>Voyages per year</th>
<th>No. of Ships</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Anglia to South Wales 928 n.m. 464 @ 1.25 &amp; 464 @ 3.0 knots</td>
<td>26 days</td>
<td>5305 = 289 cargoes</td>
<td>10.4</td>
<td>27.8</td>
</tr>
<tr>
<td>Southampton to South Wales 600 n.m. 300 @ 1.25 &amp; 300 @ 3.0 knots</td>
<td>18.2 days</td>
<td>5305 = 289 cargoes</td>
<td>14.8</td>
<td>19.5</td>
</tr>
</tbody>
</table>

The total number of ships needed for the South Wales supply is about 48, giving a total for the military grain supply of 197 Blackfriars Ship 1 types.

For the 5,100 remaining military personnel scattered over the more settled parts of Britain, including London, it has been assumed that they would find their grain requirements locally, and would only need local inland river or road transport.

b. Civilian and Export Grain Shipments

To calculate the amount of grain that could be available for export it is necessary to estimate the difference between the total production in Britain and the amount consumed within the province. From Appendix B, page 182, the civilian population of Roman Britain has been estimated at:

- Urban population: 240,000
- Rural population: 3,300,000

The rural population engaged in agriculture and pastoralism has to produce enough food to support itself, plus enough to feed the military and urban population. If there is a surplus, it can be exported in exchange for wine, olive oil, fine pottery and other imports. In Appendix B it was calculated that the agriculturalist could reliably grow a grain crop that would feed himself and his family, and produce a surplus of the same amount to support all the non-agricultural population. The 3,300,000 rural population equates to between 550,000 and 660,000 rural families with an average family size of five or six persons.

Possibly about two thirds of the population was engaged primarily in agriculture with some stock raising for their own consumption, while the remaining third was primarily concerned with stock raising, but probably produced enough agricultural products to meet at least some of their needs for grain. If a rural population of 600,000 family units is assumed, then 400,000 primarily agricultural family units would produce enough grain to supply their needs and a surplus. The grain surplus from these units would have to supply the needs of the army and its dependants, the urban population, and part of the needs of the pastoral rural population. The 400,000 agricultural units could each produce a surplus of about 1.6 tonnes of grain per year, or 640,000 tonnes per year in total. This surplus would be expended as follows:
Northern military and dependants & 29,497  
Wales and borders military and dependants & 10,610  
Other military posts & 4,747  
Urban, 50,000 families @ 1.57 tonnes each per year & 78,500  
Pastoral population, 50% of grain needs \(^6\) & 160,000  
Beer, animal feed, and miscellaneous & 40,000  
Total domestic consumption & 323,354  
Total production & 640,000  
Surplus for export & 316,646  

Assuming losses in storage and during movement to the overseas shipping point of 20%, the net amount for export would be about 253,000 tonnes, or 13,780 shiploads. About half would probably go in foreign bottoms either as return cargoes in continental ships bringing in imports, or in foreign vessels coming over specifically to pick up grain cargoes, leaving about 6,890 loads to go in British ships.\(^7\) Most shipments of grain probably went from the east coast ports to the Rhine delta for the armies in Germany. The navigable distance from the middle of East Anglia to the Rhine Delta is 105 nautical miles. At 1.25 knots this gives a seagoing time of 7 days. With 2 days at each end for loading and discharging, the round trip time is 11 days, or 25 round trips per year. This needs a fleet of 276 ships, based on a nine month sailing season.

c. Summary on the Cost of Shipping Grain

The coastal movement of grain around Britain required 198 ships, with a further 276 for the export trade, a total of 474 vessels. With an average life expectancy of 18 years (see Section III.4), this would need about 26.33 new replacement vessels each year, at a cost of 12.610 BEUs each, for a total cost of 332.06 BEUs. The 26.33 vessels would need a total of 32.46 tonnes of iron nails for the hull, decking and upperworks, or about 4.6% of the iron production from the Weald. The cost of operating the 465 vessels for a year at 5.3106 BEUs each would be 2,469.4 BEUs, including the replacement costs. This is less than 0.4% of the total annual output of ‘surplus’ BEUs. The cost of operating the coastal and seagoing grain fleet was no significant drain on the resources of the province, particularly in light of the essential services it provided.

\(^6\) It is difficult to estimate the coastal shipping required to move grain to the pastoral population, who mostly lived in the south-west, Wales and the north-west. In the north-west they could probably meet their needs without coastal imports. Wales and the south-west could be supplied from southern Britain, and this is discussed in Section 5 below.

\(^7\) For continental ships bringing over wine in amphorae or barrels, olive oil, pottery and other imports, grain would make a convenient return cargo. In reverse, British ships taking grain to the continent would also look for return cargoes.
5.4. The Shipping of Olive Oil, Wine, Metals, and Pottery

No other product would require shipping, either as an import or export, on the scale of the grain shipments. Olive oil and wine would be imports, metals would be primarily exports, and pottery was both imported and exported. Imported pottery would be moved in larger quantities than exported pottery. There are scatters of British pottery along the nearer continental coasts. For example South-East Dorset Black Burnished Category I wares occur in coastal areas of northern Gaul, and as far as Texel beyond the Rhine delta, with the highest concentrations in Brittany and Normandy, the areas closest to the production sites. It seems probable that British pottery exports were opportunistic, perhaps using ships returning to the continent empty, or with only a part cargo.

For imports from the Mediterranean intended for Britain the recognized shipping routes were five. One was from Narbonne via the rivers Aude and Garonne to Bordeaux, and thence by sea to Britain. The others started up the Rhône, with four possible routes onwards: to the Loire and St. Nazaire; to the Seine via Plateau de Langres; to the Rhine via Saône and Doubs; and to the Rhine via Saône and Moselle. From the Rhine, Seine and Loire there were fairly short sea passages to Britain.

Olive oil and wine would be imported to meet the needs of the military, to supply the requirements of the civilian Roman officials in Britain, and to satisfy the demands of the romanized local British élite. Fine pottery would be imported primarily to supply the élite, although some would be acquired by families in the banausic occupations. Samian wares from Gaul were imported in large quantities from southern and later central Gaul. Glass was imported, although it would not have been a significant item in terms of shipping space required. Textiles, silverware, some jewellery and similar luxury items were imported, but are an insignificant part of total imports in terms of tonnage.

a. Olive Oil

Olive oil had two principal uses, one as a part of the diet, and the second as a fuel for lamps. Based on sherd counts of amphorae from excavations, it appears that more olive oil was imported than wine. In excavations at Canterbury counts of amphorae sherds gave the following figures:

<table>
<thead>
<tr>
<th>Amphora Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressel 20 (olive oil from the Guadalquivir region of Spain)</td>
<td>68%</td>
</tr>
<tr>
<td>Dressel 7-11 (fish sauce from Spain)</td>
<td>4.5%</td>
</tr>
<tr>
<td>Pelichet 47 (wine)</td>
<td>6.5%</td>
</tr>
</tbody>
</table>

The remaining Dressel 20 type of amphorae at Canterbury occurred on average at about 1% or less (Arthur 1986:245)

In a more recent study Williams and Carreras comment on the Dressel 20 olive oil

\[8\] From southern Gaul the route to Bordeaux has the shortest distance, but the worst rivers and longest sea passage, well over 500 nautical miles to Dover, compared with 120 from the Seine or 90 from the Rhine. The sea passage is across the Bay of Biscay, on the edge of the continental shelf, an area notorious for bad weather (Peacock 1978:49)
amphorae: "...indeed it is also the most commonly found of any amphora type in Britain, normally averaging between at least 50-70 per cent in weight and count of amphora assemblages from any type of site." (Williams and Carreras 1995:232).

The question from the shipping point of view is how much olive oil was imported into Britain? Along with salt it was one of the smaller components of the military rations. Goldsworthy notes that the daily ration of oil was 5 cl in the Byzantine army in the sixth century A.D. (Goldsworthy 1996:291). Using this figure for the 41,010 military personnel in Britain gives a daily requirement of 2050.50 litres per day or about 689 tonnes per year. Of the 250,000 urban residents, perhaps 50,000 might be users of olive oil for cooking and lighting on a somewhat more liberal scale than the army ration, particularly for lighting. If the civilian users also consumed an average of 5 cl per day, it would add about 832 tonnes to the annual requirement, bringing the demand up to about 1521 tonnes. It is assumed that most of the rural population and the banausic workers in the towns would continue to eat a diet similar to that in the pre-Roman period, and for lighting would continue to rely on firelight, or crude tallow lamps. Adding in an allowance for the lighting needs of the military and elite households might bring the total needed up to about 3,000 tonnes per year. Because oil in amphorae has a higher specific gravity than grain, the Blackfriars Ship 1 could carry about 18.61 tonnes of oil in amphorae, which would weigh a further 9.15 tonnes for a total cargo weight of 27.76 tonnes. This would require about 161 voyages per year to meet the annual need. Assuming that about half was shipped from the Seine, with a navigable distance of 120 nautical miles to Dover plus a further 91 to London via the Wantsum Channel, and half from the Rhine delta with a navigable distance of 139 miles to London, the round voyage times would be 23.4 and 13.2 days respectively. The number of voyages needed for the annual trade could be carried in 5.19 ships for the Seine route and 2.9 ships for the Rhine route, say 8 ships in total, with the ships operating year round in this service.

b. Wine

Although it seems rather surprising, based on the amphora sherd counts, the amount of wine imported in amphora could be less than the amount of olive oil. This could be offset to some extent if a large part of the wine imports were in barrels. From the archaeological, epigraphic and iconographic evidence we know that barrels were used in Gaul and Germany, and were imported into Britain. The consumption of good wine was probably limited to the officer class in the army, the British elite, including wealthy merchants, and the Roman civilian administrators. Wine or sour wine was part of the

---

9 Olive oil has a specific gravity of about 0.92. The Dressel 20 amphorae on average held 62.83 litres, and the empty amphora weighed 28.42 kg, a litres/kg ratio of 2.21 (Peacock and Williams 1986:52.)

10 It is possible that in Britain olive oil was partly or largely replaced by animal fats for cooking and lighting, both in the army and in the civilian population, particularly in late antiquity. In the mid-second century A.D. it seems likely that the army could still be issuing olive oil. The civilian Roman administrators and the British elite would have preferred olive oil, especially for lamps. The peak level of imports of oil from Spain was "...during the mid-second century A.D." (Williams and Carreras 1995:232).
soldier's ration, but by the second century in Britain it may have been replaced by local celtic beer. Including headquarters staff, for every 600 soldiers there would be about 10 officers of the rank of centurion or higher. For an army of 41010 total strength this gives 685 officers. The civilian administration might be twice this number, say about 1400 men. Of the 240,000 urban dwellers perhaps 20% or 48,000 might be sufficiently high up the social scale to be regular drinkers of wine. This gives a total of 50,085 wine drinkers. If on average they all drank half a litre per day or 183 litres per year, this gives an annual consumption of about 9,141 tonnes per year. Peacock has suggested that wine originating in southern Gaul was imported from the Rhine area as a surplus from the large quantities sent to the Rhine garrisons and population (Peacock 1978:51). Wine from southern Spain would probably take the Rhône-Seine route. Using the same shipping figures as for olive oil 8.2 ships would be needed for the Rhine route, and 14.5 for the Seine route. Twenty-three ships could carry the entire trade.

The discrepancy between the sherd counts for oil and wine amphorae, and the estimated quantities of each imported, 3,000 tonnes of oil and 9,141 tonnes of wine has several possible explanations. One is that a some part of the wine came in barrels, and some in amphorae. Other possibilities are that olive oil imports have been seriously underestimated, or the wine imports overestimated. Wine amphorae could have been recycled. If the olive oil imports have been underestimated, and in fact about 9,000 tonnes was imported annually, it would add only another sixteen ships to the merchant fleet, a small percentage of the total.

c. Metals

In terms of tonnage the principal metals exported from Britain were lead, iron, silver, gold and small amounts of copper and tin. The iron output of the Weald in the second century has been estimated at 750 tonnes, see Appendix D. If about half were exported, nine voyages with the Blackfriars ship at 40 tonnes per voyage would take the entire amount. The most likely destination was the Rhine, and from the port at Rye the

---

11 The Vindolanda tablets contain accounts referring to beer and wine, but the quantities of beer are larger than the quantities of wine (Bowman 1983:32). Another reports that the beer supplies are running low, "To Flavius Cerialis, prefect, from Masculus, decurion..... My fellow soldiers have no beer. Please order some to be sent." (Birley 1999:45). Tab. Vindol.11 182 refers to "...Atrectus the brewer..." (Bowman 1994:110). Many of the auxiliary units came from beer drinking areas, and they may well have preferred to have their alcohol issue in the form of beer rather than wine. Reynolds and Langley, after field trials, have suggested that the "corn driers" found at many Romano-British villas and other rural sites simply do not work as driers, but are very effective malting floors. The floor temperatures in the structures "...are ideal for the malting process." (Reynolds and Langley 1979:41). Some barley seeds found with a drier at Barton Court Farm had sprouted to the point where the starch had been converted to sugar, a starting point for fermentation to produce alcohol.

12 Some of the elite would be children, probably not serious wine drinkers, but this allows the adults to consume a litre or more per diem.
round voyage time would be 13 days. The entire amount could be carried over by one ship in six months.

The quantity of lead mined, smelted and exported is very difficult to estimate. The Roman mines and smelting facilities have been largely obliterated by medieval and later workings. From the distribution of lead pig finds in Britain and Europe, it is fairly certain that the Mendip mines exported through the Southampton area to Gaul, and the mines in the Midlands through the Humber, probably to the Rhine. It is probable that more lead than iron was exported. If a figure of 2,000 tonnes per year were exported from Southampton to the Seine it would use about two ships to carry the annual trade. Thus even if the annual export of lead were several times greater than 2,000 tonnes, it would still use relatively few ships.

For every tonne of lead mined only about 0.3 kg of silver was recovered, or to produce one tonne of silver, 3,333 tonnes of lead would have to be mined and smelted. The tonnage of silver and gold to be shipped to continental Europe each year would not make one ship load. Its movement could be a security problem, but in shipping terms it is insignificant. The quantities of tin and copper were also probably trifling in terms of overseas shipping.

d. Pottery

Counting each soldier and his dependants as one household, which gives 41,000 military households, taking the 240,000 urban population as 48,000 households, and the rural population of 3,300,000 as 660,000 households, produces a total of 751,000 households. It seems probable from the archaeological evidence that the banausic rural population largely used pottery from local sources. The exceptions would be specialized items such as mortaria. Fine imported pottery would be purchased by the elite in both the military and civilian spheres. The number of households using fine imported pottery would be those of 685 military officers, 1400 civilian administrators and 48,000 city and town dwellers. (See the figures for elite numbers from page 168 above). The typical combined weight of a platter, mid-sized bowl and drinking vessel is about 1.4 kg. Assuming that the average military officer’s household had eight sets, the civilian administrator’s had ten sets and the urban household four sets, the total weight of fine pottery in use is 75,277 kg, or about 76 tonnes. Assuming 20% gets broken every year, this needs 15 tonnes per year of new imported fine pottery. Pottery is a high specific gravity cargo, and the Blackfriars Ship I could carry 40 tonnes comfortably. This would require less than one voyage per year. It seems likely that imported pottery would travel as a part cargo with other goods.

e. All Other Imports

At the worst, a few ships should be able to handle the miscellaneous and minor items traded, even if they were not carried as part cargoes with the major traded products. In compiling the summary table below, twelve ships have been assigned to miscellaneous

13 Depending on their status, urban households could have had many sets or none. Four sets seems a possible average.
Table III.5.4: Number of Blackfriars Ship1 types for overseas and coastal cargoes

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>Number of Ships Needed</th>
<th>Annual Cost in BEUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain from the south to the R. Tyne</td>
<td>50</td>
<td>265.7</td>
</tr>
<tr>
<td>Grain from the south to Chester</td>
<td>48.2</td>
<td>256.1</td>
</tr>
<tr>
<td>Grain from south to Carlisle</td>
<td>50.4</td>
<td>267.8</td>
</tr>
<tr>
<td>Grain from the south to Wales</td>
<td>48</td>
<td>255.0</td>
</tr>
<tr>
<td>Grain exports to Europe</td>
<td>276</td>
<td>1466.7</td>
</tr>
<tr>
<td>Olive oil imports</td>
<td>8</td>
<td>42.5</td>
</tr>
<tr>
<td>Wine imports</td>
<td>23</td>
<td>122.2</td>
</tr>
<tr>
<td>Metal exports</td>
<td>3</td>
<td>15.9</td>
</tr>
<tr>
<td>Pottery</td>
<td>1</td>
<td>5.3</td>
</tr>
<tr>
<td>Miscellaneous cargo</td>
<td>12</td>
<td>63.8</td>
</tr>
<tr>
<td>Total</td>
<td>519.6</td>
<td>2761.0</td>
</tr>
</tbody>
</table>

The annual cost of the long distance coastal and overseas shipping trade is about 0.4% of the gross product of Roman Britain, about one seventh of the cost of the army. For the essential services it supplies, the shipping costs are relatively trifling.

5.5. Inland Waters and Short Coastal Shipments

The barge voyages on inland waters and short distance coastal shipping are concerned with two types of traffic, the onward movement of imports from overseas, and the internal distribution of food, raw materials and manufactured items within Britain.

a. Onward Movement of Imports

Of the two types, the onward movement of imports appears to be a minor part of the total traffic. The total tonnage of imports of olive oil, wine and pottery from Section III.5.4. above is about 12,217 tonnes annually. Much of the imported material would arrive at sites on the major river systems from the Exe in the west to the Tyne in the north-east and the Solway Firth in the north-west. After transhipment to inland water barges, or small coasting vessels like the Barland’s Farm Boat, the onward journey would be from a few kilometres to perhaps 50 km on inland waters. On coastal voyages the distance could be up to a maximum of 120 km, but the average was about 40 km. Nowhere in Britain is more than about 100 km from the coast or 50 km from a navigable waterway. In the lowland
areas navigable waterways are generally within a few kilometres. Incoming cargoes would generally be moving upstream against the current. With paddling, punting and occasional help from a simple sail barges would average one to two km per hour up stream. From a glance at the location of a number of inland towns of importance, York, Lincoln, Gloucester, Chester, Caister, Colchester, Canterbury, Chichester, Winchester, Dorchester, Exeter, Caerleon and Carmarthen, it is evident that all have river access and none are more than 40 to 50 km from the coast. If the average upstream journey is about 30 km, the upstream journey might take 30 hours or three days, after allowing rest and eating and sleeping time for the crews. Downstream with the current would take less than half the time. Including two days for loading and discharging the cargo, a round trip might take seven days. Traffic on inland waters could operate for most of the year, perhaps about 320 days after an allowance for floods, low water and repairs to the barge. About 46 round trips per year would be possible. Taking the hypothetical Barge 3 with a capacity of 12 tons as typical, it may be estimated that each barge could move about 550 tonnes per year. The imports could all be moved with about forty barges. There were twenty-three large towns in Britain, from London, the largest, to smaller centres like Wroxeter. Most had a viable and fairly short connection to the sea. In general their imports could be barged up the rivers from the points where the seagoing ships discharged their cargoes.

Of the fifty-four small towns, twenty-three had immediate access to a major inland river, and could accept river craft of the Barge 3 size. Of the remaining thirty-one, most had at least a local stream or river running through them capable of taking small barges or scows with a capacity of one to two tonnes (see Appendix L). A majority of the urban centres could receive their imports by water borne transport. From the urban centres, further distribution to minor settlements, villas and farmsteads by the minor river systems would be possible.

b. Internal Traffic

In the southern and eastern parts of the province with their surplus of grain, the movement of the surplus by river to shipping points, either for distribution to other parts of Britain or to ports for export, would be a major activity. In general, the movement for overseas shipment would be downstream, but the round trip time would still be in the range of five to seven days. Grain that was consumed within the local area would move by road or the small Barge 5 type of vessel. Grain making a short coastal trip would use a vessel of the Barland’s Farm type. As well as making coasting voyages, this could work its way up narrow and winding rivers and inlets too small for the seagoing vessels. Apart from grain, other inland cargoes would be quarry-run stone, timber, bricks, tiles, pottery, metal ingots, coal, charcoal, salt, livestock and possibly people. From the calculations on grain production and distribution (page 165) above, the movement of grain on inland waterways would be the dominating traffic. Taking the total of the exports and the supply of grain to the army in the north and Wales, about 360,000 tonnes of grain would need to be moved.

---

14 There could often be a return cargo of grain, livestock, timber, pottery, tile and other local products.
from collection points in the producing areas to loading points for the seagoing vessels. The average inland waters trip would be about 30 km downstream, with a return journey time of five days. In a year, as noted previously, navigation could take place for about 320 days. Each Barge 3 type could make about 64 return journeys in the year, and transport 768 tonnes of grain. To move the 360,000 tonnes, about 468 barges would be required.

The Barland’s Farm Boat dates to the late third century, 150 years later than the period studied in this thesis. By that time some imports were reduced, being replaced by local manufactures. The late third century would require more coastal shipping to move products such as pottery around Britain. In the Hadrianic period vessels of the Barland’s Farm type would have more use along the south coast and Bristol Channel area than on the east coast. The east coast is much better supplied with rivers, river estuaries and tidal inlets than most of the south coast, and once imports were unloaded, they could be distributed widely without the need for coastal voyages. On the south coast the Barland’s Farm boat would be useful for moving goods from the main landing points for imports, Dover, the River Rother, the area inside the Isle of Wight (the Solent, Southampton Water and Spithead), Poole Harbour, and the River Exe, to smaller points along the coast. The average journey would not be more than about 40 nautical miles, and on a round trip the boat could average about 2 knots. Allowing one day at each end for loading and discharging the 4.5 tonnes of cargo, the typical voyage would take four or five days. In a year the boat could make 54 round trips in a sailing season of 270 days, carrying cargoes of about 4.5 tonnes on each voyage. In a year it would move 243 tonnes. Assuming that about one third of imports, 6,300 tonnes, were landed for distribution along the south coast, including the Bristol Channel area, 30 boats of the Barland’s type could distribute the import trade. A further 30 could be needed for local traffic along the south coast, to supplement the return cargoes carried by boats distributing imports. It seems probable that another 30 could be used for local traffic in the Bristol Channel and Severn estuary. For goods moving from south west Britain to Wales and up the Severn, a relatively short journey across the Bristol Channel would be far cheaper than transport by land over a route many times longer. In total about 90 boats of the Barland’s Farm type could handle the local coastal traffic along the south coast and in the Bristol Channel.

For short distance local traffic the simple Barge 5 type would be used. It is a little difficult to find a basis for calculating how many might be in use. Only farmers, small manufacturers, or villas with river frontage access would own and operate this size of vessel. Adding up the inland navigable length of the rivers around Britain from the Tyne, down the east coast, along the south and up the west to the Solway Firth gives a figure of about 2100 km. Assuming that there was one small barge for every kilometre, this would give about one vessel for every 285 rural households. Not all the river frontage would be used for farming, and this would increase the density of the small barges on the farming frontage. If the 23 large and 54 small towns were each serviced by about ten small barges, this would require 770 barges. Small barges could be used within the countryside for moving materials and products made and used within a locality by the rural inhabitants. The basis for estimating the number of small barges is very tenuous, but until more evidence is available a figure of about 2,000 seems reasonable.
c. Cost of the Internal and Short Distance Coastal Traffic

This traffic was carried by three types of vessel, the coastal seagoing and river boats of the Barland’s Farm type, and the two inland river barges, Barge 3 and Barge 5. The Barland’s Farm boat is a real vessel, and her size and performance are reasonably certain. Building and sailing a replica could confirm the uncertainties that may exist about her. The barges are hypothetical for Britain, but are based on the real Zwammerdam barges from Holland. Five possible sizes were considered (see Appendix N), and the two sizes selected were chosen as having probably the most useful size. On some of the larger rivers with heavy traffic, some of the larger barge types may have been used, but if this were so, it is not likely to alter significantly the general conclusions reached. Table III.5.1 below summarizes the costs of the internal waterborne traffic.

Table III.5.5: Annual costs for internal and coastal shipping

<table>
<thead>
<tr>
<th>Type of Vessel</th>
<th>Number of Vessels</th>
<th>Annual cost per Vessel</th>
<th>Total Annual Cost BEUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barland’s Farm Boat</td>
<td>90</td>
<td>4.1613 BEUs</td>
<td>374.52</td>
</tr>
<tr>
<td>Barge 3</td>
<td>508</td>
<td>2.1723 BEUs</td>
<td>1,103.53</td>
</tr>
<tr>
<td>Barge 5</td>
<td>2,000</td>
<td>0.0268 BEUs</td>
<td>53.60</td>
</tr>
</tbody>
</table>

The total annual cost for the internal and short distance coastal shipping is 1,531.65 BEUs. The total annual cost of operating, maintaining and replacing all the shipping is 4,255.55 BEUs, which is about 0.65% of the surplus BEUs available for all purposes after the population has been fed. Shipping is not a significant cost in the Roman operation of the province.

Section III.6. Discussion and Conclusions on the Cargoes Carried, and on the Costs of Building and Operating the Vessels

6.1. Introduction

The material in this section is based on a number of solid pieces of evidence, for example the measurements and capacities of the various craft involved, the tides and weather patterns around the British Isles, and the types of materials imported. Other evidence, such as the population and numbers in the garrison have been well researched by others, and are almost certainly in the right order of magnitude. Other parts of the evidence, such as the annual output of grain, are based partly on robust evidence and partly on what are believed to be sound hypotheses. For example, Britain had to grow enough grain to feed the population and the Roman army and administration. A surplus was also grown: the classical literature has a number of references to exports of grain from Britain. The exact size of the surplus is a matter for hypothesis, based on what was possible and what was probable, see Appendix B for details. Similarly it is certain that wine and olive oil were
imported. The numerous amphora sherds from archaeological sites confirm this, but the amount imported has to be reconstructed indirectly from a hypothetical, but not unreasonable, position on who consumed them, and how much they consumed per diem. Having stated these various cautions and caveats, it is felt that in the conclusions reached the general order of magnitude is reasonable, based on what information there is available to us. The figure that gives the most concern, but which is also the most interesting is that for shipping grain exports. Approximately half of the grain which could be grown was needed to feed the native inhabitants and the Roman army and civilian administration. The shipping of grain by sea to supply the Roman garrisons in Britain is estimated to have needed 197 ships of the Blackfriars Ship 1 type. A further 276 ships were needed for exporting the surplus, for a total of 473 ships tied up in the movement of grain by sea. Only 40 ships were needed for the import of all other goods.

Even if the number of grain ships is over-estimated, and the number for all imports is under-estimated by 100%, grain is still the dominant cargo. We know from the classical literature that Roman Britain exported grain at least up to the time of the Emperor Julian (A.D. 360-3). While restoring the Rhine frontier before becoming emperor, he is said to have taken steps to restore the grain trade from Britain to the Rhine, after pirates had destroyed the previous grain fleet and largely cut off the supply (Libanius. *Oration* xviii.83), and Zosimus comments: “Julian had timber gathered from the forests around the river and 800 boats larger than galleys built. These he sent to Britain and had them convey grain.” (Zos. III.5.2).

The number of ships needed to carry the annual imports of wine and olive oil is quite small, thirty-one altogether. This number is entirely dependent on the estimated consumption of these interesting liquids. Even if the consumption were two or three times the amount estimated, it would still not require a large number of vessels, compared with those involved in carrying grain.

A question which remains unanswered is the nature of the commodities that the grain ships brought back as return cargoes. Some probably sailed back in ballast. One possibility is that all the imports came in foreign bottoms, and then returned loaded with grain, but this would only reduce the British fleet by forty ships. The Romano-British ships carrying grain cargoes to the northern frontier and south Wales would have the same problem. On the east coast some certainly returned with cargoes of coal, pottery, and possibly with timber and stone. Many must have returned in ballast. Ballast in the form of quarry-run stone or gravel could have had a modest and low-priced market in areas like East Anglia which lacked convenient sources for this type of material.

6.2. The Cost of Building, Operating and Maintaining the Vessels

Based on the information collected for this thesis, the most striking feature of the costs is the large portion of the total building costs expended on purchasing and fabricating the iron nails. It has been assumed that at that time in Roman Britain, the timber was “free”, in the sense that one did not have to buy a tree in the naturally forested areas. This was probably the state of affairs in the LPRIA, when timber construction for dwellings, farm buildings, enclosures and trackways was the norm. There appears to be no information
on this subject for Britain. Certainly in Italy forests could be privately or state owned, and there would be a cost in acquiring trees. In Britain, if a town dweller wanted firewood, dressed lumber for construction or charcoal, there would be a price for it, but the price may well have involved only the labour for felling, reducing the tree to the final form needed and delivery to the customer. The cost of the iron blooms, from which the nails were made, is based on Cleere’s work on Roman iron production in the Weald (see Appendix D). If that is erroneous, then the cost of the iron nails could be different, either higher or lower. Unless the cost of iron can be shown to have been much lower, it would still be the major cost in building a ship.

The relative costs of the four vessels analysed in this thesis should be of the correct order of magnitude, as common information was used for all four cost estimates made. The estimates also correlate with the size and complexity of the different vessels. The Barland’s Farm Boat and Blackfriars Ship 1 are much more complex forms, requiring more labour than the two rather crude barges.

Another point of interest is that the annual depreciation or replacement cost allowance is small compared with the operating costs for the crew. This is of course governed by the hypothetical working life span of eighteen years for the Blackfriars Ship and Barland’s Farm Boat, and twenty-five years for the barges. If the working life were much less, then replacement cost would make up a larger portion of the total. However, even if the working life is reduced to three years, an unlikely figure, the annual operating cost is still the largest component of the annual costs. Overall it is believed that the costs are of the right order of magnitude, both absolutely and relatively. The total cost of building and operating the waterborne transport vessels is a small part, less than 0.7% of the surplus available after providing for the population’s basic needs.

6.3. The Cost of Wharves and Jetties

The only port with evidence for substantial wharves or quays is London. The wharves there were extended and rebuilt periodically. By the second century they seem to have had a life of about fifty years. Using the figures in Appendix P for working with timber, and the same assumptions as in Section III on the costs of building vessels, the cost per metre of the London quays would be about 0.0112 BEUs, or about 2 BEUs for those known on the north shore. The quays known from other major centres are much less extensive than those in London. In general the annual cost of building quays, perhaps 0.08 BEUs is insignificant compared with the annual cost of operating the ships, and this cost has not been considered further.
SECTION IV: SUMMARY AND OVERALL CONCLUSIONS
SECTION IV: SUMMARY AND OVERALL CONCLUSIONS

Section IV.1. The Technology of Romano-British Ships

The technology of the Romano-British merchant shipping was determined by the tidal conditions around Britain, by the configuration of the coastline and by the topography of the sea bottom in north-west Europe. The tidal range was large, and the tidal currents strong. The coastline on the east and south coasts, and in the Bristol Channel had numerous rivers, estuaries and tidal inlets, most of which were shallow, and many of which dried out to mud flats or sand and shingle banks at low tide. The topography of the sea bottom is very varied. In the approaches to the English Channel the sea bottom rises abruptly to the edge of the continental shelf, giving short steep waves. The Channel narrows rapidly along its length, giving rise to dangerous offshore tidal races around most of the headlands. At its narrowest point before it opens out into the North Sea it is encumbered by the dangerous Goodwin Sands. The southern North Sea between East Anglia and the mouths of the Rhine is cluttered with a complex of dangerous sandbanks, as is the Thames estuary. Moving north up the east coast the spacing between safe havens lengthens, and much of the time winds from north through east make it a lee shore.

This collection of natural phenomena and features determined the technology of the ships. They had to be robustly built to withstand the wind and weather conditions. They had to be able to take the ground safely in the various inlets, rivers and anchorages, while waiting for the tide to rise sufficiently for them to make their way up to their unloading point. The tidal range largely precluded the building of harbours with wharves which would have deep water alongside at all states of the tide.

The technical solution was the building of ships with flat bottoms, the characteristic two wide “keel” planks, with massive floors, frames and robust planking, and the whole structure fastened together with large iron nails. The ships were carvel planked, with planks positioned edge to edge and a caulking of wood shaving and pine resin along the edges of the planks, and in other joints in the ship. With all the planks nailed with clenched iron nails to the massive floors and frames, there was no need for the Mediterranean mortise and tenon edge to edge fastening. These design features allowed the ships to sit comfortably and safely on the bottom, either while waiting for a tide, or at their destination where the cargo could be unloaded. They could also withstand a certain amount of “bumping” on the bottom when small waves bounced them up and down in the period between being completely afloat and firmly aground. The discharging of the cargo could be on to a wharf, which the ship could reach at high tide, and where it could then sit comfortably in the mud as the tide fell. This was the situation for at least some vessels on the Thames in London, where there are the remains of substantial wooden wharves. These wharves are robust but simple structures, made up of heavy timber baulks laid in a grid pattern, with notched joints holding the timbers together. No nails were used in the joints. The grid was filled with rubble and gravel, levelled on top to provide a working surface. Apart from the Thames at London, there is very little evidence for wharves or jetties elsewhere. The common method of discharging and loading cargo would be to let the ship
take the ground in a sheltered spot, either on a natural or man-made "hard". The sand and gravel hard, often laced with timber if man-made, would allow carts and people to come alongside to load or unload the ship.

The Romano-British type of ship used the available technology to build a ship ideally suited to the conditions around Britain, and for the similar conditions along the north coast of Gaul and the coast of Holland.

**Section IV.2. The Costs and Cargoes for Romano-British Shipping**

The examination of the costs and cargoes has brought out some interesting points. The costs of providing and operating the seagoing and inland rivers vessels is less than one percent of the surplus resources available to meet all the other civilian and military construction and administrative needs, and the demands of taxation. The merchant fleet supplied an essential service at a trifling cost. Other points of interest are the apparent dominance of grain as a cargo, the quite small number of ships needed for the import of wine and olive oil, two staples of the Roman lifestyle, and the problem of return cargoes, particularly for those vessels engaged in the grain trade. If the volume of grain exported has been correctly estimated, Britain appears to be the "Egypt" for the Rhine area, and possibly for parts of north-eastern Gaul.

It has been suggested by Marsden that the Blackfriars Ship 1, although much smaller than the Roman period merchant ships trading in the Mediterranean, was "...one of the larger seagoing merchant ships..." (Marsden 1994:90). His conclusion seems entirely reasonable for two reasons. One is that, apart from the grain trade, relatively few ships of the Blackfriars type were needed to carry all other cargo. A two to four hundred tonne Mediterranean size of ship would have been underemployed in moving olive oil or pottery across the Channel. The other reason is technical. A large ship would have encountered much greater navigational difficulties around the British Isles, and would have had difficulty in getting into many of the smaller "ports". In many areas they would not be able to take the ground safely. A confirmation for this point comes from more recent times. In 1949, the 154 Thames barges still voyaging predominantly under sail around the east and south coasts of Britain, and across to France and Holland, operated in exactly the same manner as the Roman period ships. They were almost all in the 50 to 80 tonnes of size range (Carr 1951:306-20). If larger they could not work the numerous small tidal ports, and would run the risk of breaking the ship's back if positioned awkwardly on a bar or sand bank.

**Section IV.3. Further Research**

This thesis has been an attempt to explore a number of aspects of Romano-British shipping in the early to mid second century A.D. It has used currently available sources of information, and supplemented these by hypotheses. Many of the hypotheses depend on the hypotheses or work of other people. For example, the concept of the BEU is based on Millett's estimate of the population of Britain, Reynolds' work on the Butser farm project, and Beveridge's study of early medieval cereal production. The amount of iron available
and its cost is based on Cleere’s experiments on smelting iron in a Roman type furnace. The provision and shaping of timber for building the ships uses a very small base of experiment by Darrah, supplemented by equally small trials by the author. Although my thesis is reasonably consistent internally, a major change in some of the variables, such as population numbers, could alter the conclusions appreciably.

For the technological side, some modest experimental work on unseasoned oak with Roman type tools could have an appreciable effect on the calculations for the building of ships. Similarly for the forging of 9 kg iron blooms into nails, some experimental blacksmithing with Roman period facilities would give a good data base. An extension of Cleere’s work on iron smelting in a Roman type furnace using a number of furnaces over two or more furnace life cycles would increase the confidence in his results. The most interesting and very expensive project would be to build a replica of the Blackfriars Ship 1, using only Roman tools and technology. I fear that this is unlikely in my lifetime!
APPENDIX A

Some Fundamental Mechanics and their Expression in the Basic and Derived Units in the Metric Système International d'Unité, or S.I.
APPENDIX A

Some Fundamental Mechanics and their Expression in the Basic and Derived Units in the Metric Système International d'Unité, or S.I.

1. UNITS

<table>
<thead>
<tr>
<th>Unit</th>
<th>Basic</th>
<th>Derived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>metre m</td>
<td>Kilometre km = 10^3 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>millimetre mm = 10^3 m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogramme kg</td>
<td>tonne 1 tonne = 1000 kg</td>
</tr>
<tr>
<td>Time</td>
<td>second s</td>
<td>kelvin K</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>square metre m^2</td>
<td>square kilometre = 10^6 m^2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hectare 1 ha = 10^4 m^3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>square centimetre 1 cm^2 = 10^4 m^2</td>
</tr>
<tr>
<td>Volume</td>
<td>cubic metre m^3</td>
<td>litre 1 l = 10^3 m^3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>millilitre 1 ml = 10^-6 m^2</td>
</tr>
</tbody>
</table>

Density
Density = mass per unit volume
1 cubic metre of water has a mass of 1 tonne
1 litre of water has a mass of 1 kilogramme

Density of some common materials: kg per litre

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>8.4 to 8.8</td>
</tr>
<tr>
<td>Brick and tile</td>
<td>1.6 to 2.4</td>
</tr>
<tr>
<td>Bronze</td>
<td>8.45 to 8.62</td>
</tr>
<tr>
<td>Concrete</td>
<td>ca. 2.4</td>
</tr>
<tr>
<td>Copper</td>
<td>8.95</td>
</tr>
<tr>
<td>Glass</td>
<td>2.5 to 2.75</td>
</tr>
<tr>
<td>Iron</td>
<td>7.74</td>
</tr>
<tr>
<td>Lead</td>
<td>11.3</td>
</tr>
<tr>
<td>Limestone</td>
<td>3.16</td>
</tr>
<tr>
<td>Steel</td>
<td>7.85</td>
</tr>
<tr>
<td>Tin</td>
<td>7.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>7.1</td>
</tr>
<tr>
<td>Timbers</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>0.71</td>
</tr>
<tr>
<td>Beech</td>
<td>0.73</td>
</tr>
<tr>
<td>Birch</td>
<td>0.67</td>
</tr>
<tr>
<td>Elm</td>
<td>0.56</td>
</tr>
<tr>
<td>Oak</td>
<td>0.77</td>
</tr>
<tr>
<td>Pine</td>
<td>0.55</td>
</tr>
</tbody>
</table>

2. Some Basic Mechanics

Force
Force = mass x acceleration or F = ma
SI unit of force is the newton (N). Note: gravity exerts a force of 9.8 newtons.
Weight is a force: the force with which a body is attracted by gravity to the centre of the earth, or in symbols W = mg
Example: a loaded cart at rest with a mass of 1000kg will exert a force of 1000 x 9.8 = 9800 newtons on a bridge or road surface.
Momentum
Linear momentum = mass of body (kg) x velocity (metres per second or m/s)

Work
Work done by a force = force x distance moved in direction of force.
Work = newtons x metres or Nm
Unit of work is the joule, 1 joule = 1 Nm

Energy
Energy is the ability to do work. When work is done on a body, energy is given to the body. Conversely when energy is released, work is done. For example an ox pulling a cart for 1 km will release energy stored in its muscles and cardio-vascular system, and transfer the energy to the cart. For a ship under sail, wind energy will be transferred to the sails and thence to the hull. The unit for energy is also the joule. Energy and work are mutually interchangeable in S.I. units.

Potential Energy
A body has potential energy by virtue of its position or state.
Examples:
Water behind a dam has potential energy by virtue of its position. It can be released to drive a water wheel or flush away material.
Humans and animals, unless totally exhausted, have potential energy by virtue of their state.
A drawn bow has potential energy, which is transferred to the arrow when the bowstring is released, converting it to the kinetic energy imparted to the arrow.

Kinetic Energy
Kinetic energy is energy possessed by a body by virtue of its velocity: $= \frac{1}{2}mv^2$
Measured in joules.

Power
Power is the rate of doing work or expending energy: $= \frac{\text{work done}}{\text{time}}$
Unit is the watt = 1 joule per second or 1 Nm per second.

Pressure or Stress
Stress is force per unit area, measured in newtons per square metre or N/m$^2$. The unit of stress or pressure is called the pascal, but it is too small for practical use. Practical units are kilonewtons, meganewtons or giganewtons per square metre. The bar, close to the value of standard atmospheric pressure, is also used.
APPENDIX B

The Basic Energy Unit (BEU)
APPENDIX B

The Basic Energy Unit (BEU)

1. The Concept

A fundamental difficulty standing in the way of any attempt to study the economics of transportation in Roman Britain, or the economics of any other activity for that matter, is that of establishing what units to employ in measuring economic activity. In the case of a modern economy it is common to employ current monetary values, adjusted for inflation if necessary. Other yardsticks are manhours, rates of unemployment, percentage of productive capacity in use, ratio of household debt to income and other sources of information collected and collated by the various departments of government. For LPRIA Britain a rudimentary monetary system was in use in the southern part of the country before the Roman conquest. The Romans brought their coinage to Britain, initially to pay the army and administrators. Later it probably came into more general use, but much of the economic activity at the local level would have continued to be based on payments in kind, both for state taxes and rents and on barter for local inter-personal transactions. Finds of low value coins, predominantly bronze asses, in the second and third centuries come mostly from towns, with few from villas and other rural sites. This suggests that coins were used in town markets, but at the local level barter and exchange were probably normal. For the monetary transactions that did take place, we have very little information on the cost of foodstuffs, materials, manufactured goods and services such as transportation. Diocletian's price edict of A.D. 301 came rather late in the day for Roman Britain, and in practice rapidly became a dead letter. A further problem is that after about AD 250 the whole Roman world was affected by serious inflation and debasement of the coinage. Working from information on papyri from Egypt, Duncan-Jones has concluded:

"...the basic rate of army pay was probably six times higher under Diocletian than at the end of the first century AD under Domitian;...and finally, that despite large payments of donative, the real value of military pay under Diocletian was seriously below that in earlier periods" (Duncan-Jones 1990:106).

Although the army pay is one guide to inflation, it may understate the actual devaluation of the currency, in that with time donatives and payments in kind made up more of the soldier's total emoluments (J.B.Campbell 1984:161-76; Duncan-Jones 1990:114-117; Watson 1969:89-114). Officers' pay, plus donatives at the same flat rate as the payments to the rank and file, were supplemented by payments in kind. “Later in the fourth century large-scale payments in kind had certainly become the main remuneration for officers.” (Duncan-Jones :116)

In view of the problems listed above it was decided to consider the possibility of devising an economic measurement that would be relatively stable over time. The concept is to base the economics on energy inputs, "calorie" intake in the form of food required to support a "basic economic unit" or BEU for short. This unit is defined as a peasant
agriculturist and his dependents, his wife and children. This calorie input would be a constant over time. Any surplus over the food required for the family unit would be available for other purposes. These would include purchases by the BEU for items such as iron tools, pottery, textiles and leather goods not made within the household. External demands on the surplus of the BEU would include taxes, the annona and the annona militaris, rents paid to a landlord, and payments for services such as transportation of the BEU's surplus to points of sale or payment. The other banausic occupations, blacksmith, potter, tanner, weaver, bronzesmith, stone mason, carpenter, wheelwright, boatbuilder, carter, sailor, boatman and so on, would also require a stable calorie input over time, which would be similar to that of the peasant agriculturist. It is assumed that for all the manual occupations the energy output would be about the same. If there were no significant changes in the technology or tools, it would take the same amount of human time and energy to plough, sow and reap a field, to make a pot, make a batch of nails or make a wheel, whether in AD 50 or AD 400.

The number of people who could be supported in banausic occupations by the peasant farmers' surplus, after paying taxes and rents to the government and upper classes, would probably remain fairly stable. Improvements in agricultural productivity, either through bringing more land under cultivation with better equipment, or through increased output per hectare with improved agricultural practices and higher yielding strains of plants, could lead to a modest increase in the numbers of craftsmen as a percentage of the total population. The military, the civil administration, the rentiers, the merchants and traders are all supported by taxes and other levies on the agriculturalists and banausic occupations. The merchants and traders make their living by buying low and selling high, the military and civil administration are 'salarymen,' and the rentiers and élite live off their investments in land or other property.

2. The Population: its Composition and Age Profile

Caesar in Caes. B. Gall. V.12 comments on the Britons: "The inland part of Britain is inhabited by tribes declared in their own tradition to be indigenous to the island, the maritime part by tribes that migrated at an earlier time from Belgium to seek booty by invasion. Nearly all these latter are called after the names of the states from which they sprang when they went to Britain; and after the invasion they abode there and began to till the fields. The population is innumerable; the farm buildings are found very close together, being very like those of the Gauls; and there is a great store of cattle." And continuing further (Caes. B. Gall. V.14) he notes: "Of the inlanders most do not sow corn, but live on milk and flesh and clothe themselves in skins." Strabo has a somewhat different view: "Most of the country is flat and thickly wooded (my emphasis, see also Appendix C), though many districts are hilly. It produces grain and cattle, gold, silver and iron. These are exported along with slaves and dogs bred specifically for hunting...some of them through their want of skill do not make cheese though they have no shortage of milk, and
are unskilled in horticulture and farming in general." (Strabo IV.5,2). These comments from the ancient literary sources are not supported by the archaeological evidence, see Appendix C. The current view is that most clearances of woodland for agriculture had already taken place by the LPRIA. Essex was about 50% farmland (Rackham 1980:105), and "Farming had long since ceased to be confined to easy terrain: it extended into the heavy soils of Sussex and Essex, deep into what were later to be great woods and even into the Fens. There can be little doubt that England was almost as agricultural as it is now." (Rackham 1990:40).

Millett, after examining nine projections of the population of Roman Britain made between 1929 and 1982 estimates the population in the first half of the third century A.D. to have been in the following ranges:

Roman military, 10,000 to 20,000 plus families and dependents: 50,000 to 200,000
Non-agricultural town dwellers and craftsmen: 184,000 to 290,000
Rural population: 3,185,500 to 4,637,500

In his summation the most likely size and divisions of the population in the fourth century are:

Army and dependents: 125,000 3.4%
Urban Population: 240,000 6.5%
Rural population: 3,300,000 90.0%

(Millett 1990: 185, Table 8.5).

He also notes that, based on the available evidence, the normal household unit was

As noted below, p.191, the BEU would need to cultivate about 3.5 to 4.0 ha to supply food for the BEU, but could cultivate twice that amount. As noted in Appendix C, p.5, about 65,000 km² or 6,500,000 ha² was farmland in the early Saxon period. This would support a population of 3,000,000 to 4,000,000, based on the probable yield per ha, see pp.8-16, and Fn.3.

<table>
<thead>
<tr>
<th>Authority</th>
<th>Method of Estimation/Source</th>
<th>Estimate (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collingwood 1929</td>
<td>Towns, village, villas, army</td>
<td>0.5</td>
</tr>
<tr>
<td>Wheeler 1929</td>
<td>Known sites plus food need</td>
<td>1.5</td>
</tr>
<tr>
<td>Collingwood and Myres 1937</td>
<td>Settlement pattern</td>
<td>1.0</td>
</tr>
<tr>
<td>Frere 1967, revised 1987</td>
<td>Known sites plus food need</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Smith C. 1977</td>
<td>Frere 1967 + new rural density</td>
<td>5-6</td>
</tr>
<tr>
<td>Cunliffe 1978</td>
<td>Frere 1967</td>
<td>2</td>
</tr>
<tr>
<td>Fowler 1978</td>
<td>Frere 1967 + new rural density</td>
<td>4</td>
</tr>
<tr>
<td>Salway 1981, 544</td>
<td>Extrapolation from survey, Smith 1977</td>
<td>4-6</td>
</tr>
<tr>
<td>Fulford 1984, 131</td>
<td>Comparison with Medieval</td>
<td>max. 2.8</td>
</tr>
</tbody>
</table>
the nuclear rather than the extended family², but kinship groups may have lived as extended families. The typical family size is estimated to be five to six persons. In the estimates for the total population he feels that the range is unlikely to change much, and the rural element in any future more refined estimates would still be predominant (Millett 1990:185).

The population in the period immediately after the conquest of A.D. 43 would be that of the LPRIA, minus a relatively trifling percentage of war casualties, but plus about 40,000 Roman soldiers in the four legions and auxiliaries brought over by Aulus Plautius.

During the Roman period there were certainly shifts in the distribution of the population. In the early centuries the populations of the towns built up, but later there appears to have been migration from the urban centres to villas, often closer to the perimeter of the civitas. A middle class or wealthy town dweller who relocated to a commodious country villa remained a non-producer of agricultural products and a consumer of basic and luxury goods. Similarly, the urban craftsman or small manufacturer who relocated his production to a rural area still needed to acquire his food from the agricultural base. In the later Roman period there was a transfer of activity from the core of the civitates to the periphery. The pattern of urban life, industrial production and rural settlement changed. There was an increase in the number of villas, and a change in their character. Nucleated settlements develop. There was also diversification and innovation in agricultural production (Millett 1990:181-86).

3. Requirements for Human Nutrition
(The principal reference for the material in this section is the Encyclopedia Britannica 1990, 15th ed., V.25, pp.54-71)

a. Units for Energy from Food

Until the late twentieth century the human food intake to provide the energy to sustain life and do useful work has been popularly quoted in "calories". These are not true calories but 'dietetic calories', which are equal to 1,000 scientific calorie, or one real kilocalorie. To further complicate matters, with the adoption of the modern metric system, the Système International d'Unités or S.I. system of metric units, the calorie is no longer the unit for measuring energy, but has been replaced by the joule. One scientific calorie is equal to 4.186 joules, and one dietetic calorie is equal to 4,186 joules. The joule is an inconveniently small unit and energy is measured in multiples of it, kilojoules (kJ), megajoules (MJ), or even larger multiples if necessary. For the sake of consistency, and in conformity with current scientific practice all the energy measurements will be in joules or multiples of joules.

b. Human Food Requirements

Human energy inputs come from three sources:

---
² Two or more family groups on one farm were also possible, either two generations of the same family, or related families (Cunliffe 1991:213-46; Smith 1997:264-77).
proteins: providing 23kJ per gm, of which 17kJ are available
fats: providing 39 kJ per gm, of which 38kJ are available
starches: providing 17 kJ per gm, all of which is available

As well as food energy the body requires small amounts of fourteen other organic compounds and eighteen inorganic elements. These are required for general health and body repair and maintenance, but do not contribute directly to the energy input.

For maintenance at rest the body requires about 5.23 kJ per minute for a 65 kg male and about 3.77 kJ per minute for a 55 kg female. This is the basal metabolic rate or BMR. In a seated position the BMR increases about 50%. After a meal the metabolic rate increases by about 30% to provide the energy for digestion.

Energy expenditure is increased by activity:

**Brisk walking:** 20.92 kJ per minute
**Light work, domestic activities, light craft work:** 7.54 to 15.08 kJ per minute
**Moderate craft work:** 31.40 kJ per minute
**Heavy work, mining, lumbering:** 32 to 62 kJ per minute.

Studies on non-mechanized farming in Africa and Asia classify the average work level over the year as moderate (31.40 kJ per min.), but with marked seasonal variations from heavy to light over the twelve months. While asleep for eight hours about 2510 kJ are needed for men, and 1810 kJ for women.

Energy Input Required for an Iron Age Family Agricultural Unit:

**Male Farmer:**
- 10 hours of moderate work: \(10 \times 60 \times 31.4 \text{ kJ} = 18840 \text{ kJ}\)
- 6 hours of light work \(6 \times 60 \times 15.8 \text{ kJ} = 5688 \text{ kJ}\)
- 8 hours of sleep \(8 \times 60 \times 5.23 \text{ kJ} = 2510 \text{ kJ}\)
- Total \(27038 \text{ kJ}\)

**Farmer's Wife:**
- 16 hours light work \(16 \times 60 \times 15.8 \text{ kJ} = 15168 \text{ kJ}\)
- 8 hours sleep \(8 \times 60 \times 3.77 \text{ kJ} = 1810 \text{ kJ}\)
- Total \(16978 \text{ kJ}\)

For young males 16 to 20 years old about 15907 kJ per day are needed and for children 10 to 15 years old about 10465 kJ are required.

Total for a Peasant Farming Family:
- Adult male \(27038 \text{ kJ}\)
- Adult female \(16978 \text{ kJ}\)
- Young male \(15907 \text{ kJ}\)
- Three children @ 10465 \(31395 \text{ kJ}\)
- Total for the BEU \(91318 \text{ kJ}\)

In modern poor and non-mechanized agricultural societies diet consists of:
- 10% protein
10% fat
80% carbohydrates
(Note in prosperous areas of Europe and North America the average diet is about 12% protein, 40% fat and 48% carbohydrate.

The diet of the civilian population of Roman Britain would almost certainly be closer to current non-mechanized farming in Asia and Africa than to modern North American or European diets. Cereals provide about 17,000 kJ per kg. Thus if the diet were all cereals, the family would require about 5.37 kg of carbohydrates per day, 1.59 kg for the male head, 1.00 kg for the wife and 2.78 kg for the children. This totals 5.37 kg per day or 1961 kg per year. If 80% were cereals, a more realistic assumption, these figures would be 4.3 kg per day or 1570 kg per year.

Another source for calculating the dietary requirements for men doing moderate to strenuous work is the information we have on Roman army rations. Roy Davies in Service in the Roman Army calculates a daily cereal issue of 1.36 kg, together with bacon, cheese, probably vegetables, together with salt, olive oil and sour wine. This would be augmented with extra food, including meat from sacrifices, on days of special celebration. Bread would be wholemeal and in Britain was normally part of the diet. The cereal issue would provide about 23,127 kJ per day, supplemented by the protein and vegetables. Animal bone evidence from Hadrian’s Wall indicates that domestic ox, sheep, some goat, pork, plus wild deer, boar and hare were eaten. Fish and shellfish, poultry, eggs, fruits, nuts, honey, beans, peas and cabbage were also consumed. He comments that "...the food the soldiers ate was remarkably similar to that of civilians." (Davies 1989:187-203). This military diet would provide an energy input of the same order of magnitude as that calculated above for an adult male farmer. Polybius for the second century B.C. gives a similar figure for the bread ration, 1.4 kg per day (Polyb. 6.39). Rivet suggests a grain ration of about eleven bushels per year, or about 0.9 kg per day (Rivet 1969:195-6). Parker says that the diet was simple, bread, soup, vegetables, lard and vinegar mixed with water. The cereal component was 60 modii of grain per year, equivalent to 1.2 kg per day (Parker 1954:220). In summary it seems that the energy requirements for the BEU calculated in this section are of the right order of magnitude. For a discussion on the amount of land under the plough to meet the needs of the population as a whole, both civilian and military, see Appendix C.

Using the Butser figures of 2.0 tonnes of emmer wheat per hectare suggests that an area of between two and two and a half hectares under cultivation would provide the family with cereals, after allowing about 30% for seed corn, 10% for waste and spoilage and an allowance for contingencies such as a below average harvest. If the cereals were 80% of the diet, the family or BEU would also need 0.69 kg of protein (meat or fish) and 0.3 kg of fats. Assuming that some livestock was kept and grazed on grassland or wood pasture to provide kJ in the form of fats and high grade protein, the cultivation of two to three hectares would appear to provide the energy input for the BEU, and a small surplus for exchanging for basic necessities such as pottery and iron tools. But are the Butser figures realistic for the first century A.D.?

Beveridge, using documentary evidence from the extant account rolls of the Bishopric of Winchester for the period from A.D. 1208 to 1453, has calculated the amount
of seed sown and the yield per acre for a number of manors spread over seven counties in southern England. The counties are Surrey; Hampshire; Wiltshire; Oxfordshire; Buckinghamshire; Berkshire; and Somerset. These seven counties include coastal and inland sites, and cover much of the country from east to west. A summary of the accounts for all the manors is tabulated below, showing the seed sown per hectare, and the yield in kg per hectare, together with the percentage of seed retained for sowing the following year. Figures are shown for the high and low yield years and the mean, together with the corresponding figures for England in the period A.D. 1895-1914 (Beveridge 1927:155-167).

Table App.B.1: Seed sown per hectare in kg. (averaged over 250 years)

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Wheat</th>
<th>Barley</th>
<th>Oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>High year</td>
<td>218</td>
<td>293</td>
<td>361</td>
</tr>
<tr>
<td>Low year</td>
<td>126</td>
<td>212</td>
<td>252</td>
</tr>
<tr>
<td>Mean</td>
<td>178</td>
<td>270</td>
<td>310</td>
</tr>
<tr>
<td>1895-1914</td>
<td>195</td>
<td>218</td>
<td>344</td>
</tr>
</tbody>
</table>

Table App.B.2: Yield in kg per hectare

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Wheat</th>
<th>Barley</th>
<th>Oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>High year</td>
<td>849</td>
<td>1171</td>
<td>878</td>
</tr>
<tr>
<td>Low year</td>
<td>510</td>
<td>769</td>
<td>528</td>
</tr>
<tr>
<td>Mean</td>
<td>671</td>
<td>1027</td>
<td>757</td>
</tr>
<tr>
<td>1895-1914</td>
<td>2249</td>
<td>2364</td>
<td>2921</td>
</tr>
</tbody>
</table>

Table App.B.3: % of seed retained for next planting

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Wheat</th>
<th>Barley</th>
<th>Oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>High year</td>
<td>26%</td>
<td>25%</td>
<td>41%</td>
</tr>
<tr>
<td>Low year</td>
<td>25%</td>
<td>28%</td>
<td>48%</td>
</tr>
<tr>
<td>Mean</td>
<td>26%</td>
<td>26%</td>
<td>41%</td>
</tr>
<tr>
<td>1895-1914</td>
<td>11.5%</td>
<td>9.2%</td>
<td>11.8%</td>
</tr>
</tbody>
</table>

It seems very probable that the Romano-British productivity figures would be closer to the average for the 250 medieval years, than to those for the Butser experiment. There was very little change in agricultural technology from the Roman period to medieval times, and the energy input in human and animal power would have been essentially the same. In very good years on the right site, a Romano-British farmer could probably achieve the Butser level of production, but not on a routine basis. For the purposes of this study the mean medieval figure for wheat will be used. With a mean production of 671 kg, the net after allowing 26% for seed and 10% for spoilage and loss in storage and use would be about 450 kg per ha.

With these medieval figures the hypothetical Romano-British peasant family,
needing about 1600 kg per year for subsistence, would need to cultivate about three and a half to four hectares to provide their cereal requirement, plus about the same amount for their other requirements and commitments, a total of about eight ha. Is this practicable? Columella says:

"From this summing up of the day’s labour required, it is concluded that two hundred iugera of land can be worked with two yoke of oxen, the same number of ploughmen, and six common labourers, provided it is free of trees:" (Columella *Rust. II.xii.7*)

Two hundred *iugera* equals 50.4 hectare; so the amount cultivated per man employed is 50.4 divided by 8, or 6.3 hectare per man. Columella’s figures include ploughing, harrowing, hoeing and weeding. If Columella’s figures are applied to Britain, then the British farming family could farm eight to nine hectares. They could produce about twice the food they would need for basic subsistence. This would leave the other half available to acquire food, goods and services not produced at the household level, and to pay rent, taxes and other state imposts.

### 4. Summary

The BEU is the food energy input to meet the nutritional needs of a family unit of two adults and three to four dependents. It is the same for all levels of society, although the wealthier members may supplement their food intake with a wide variety of more palatable, exotic or expensive food and drink.

The peasant agriculturalist or small farmer has to produce this BEU, plus a surplus to meet other requirements, such as the purchase of tools, agricultural implements, animal stock and household goods. He also needs a surplus to pay rents, taxes, and other local or central government levies or requisitions. In the LPRIA these outside demands may have been modest, but once the Roman administrative system was established and in regular operation, there would be pressure on the peasant farmer to increase and/or maximize his output. Both the demands of the government, new markets for his produce, and the new availability of consumer goods would induce him to produce more.

Non-agricultural banausic occupations such as blacksmith, potter, weaver, miner, smelter, carpenter, stonemason, shipwrights and urban day labourers, would need to buy or barter for their basic subsistence BEU from the food producers. They would also need to acquire a second BEU, or further BEUs, from their production or service activities to meet their own needs for goods and services, taxes and rents. The wealthier classes, if not landowners producing their own subsistence, for example a London merchant, would need to buy their BEU needs for themselves and their household and staff. Modest to wealthy

---

3 If Millett’s figures for the possible range of population of 3,185,500 to 4,637,500 are reasonable, and the average BEU has five to six members, then the area under the plough should be between about 46,000 km² and 67,000 km². Appendix C, p.5 notes that by Anglo-Saxon times about 65,000 km² was farmland. This tends to support Millett’s figures for population.
landowners would provide their food BEU needs either from their tenants, or from the agricultural activities of their servants, slaves or hired hands.

By the late first century A.D. in Roman Britain, when conditions in most of the country had settled down, it would appear possible for the peasant farmer to cultivate enough land to support about two BEUs, leaving about one BEU surplus, after meeting his basic subsistence needs. Assuming that he used half the surplus to satisfy his needs for goods and services from other banausic occupations, it would leave half a BEU for rents and taxes. These rents and taxes would support the Roman administration and army, and the buildings and lifestyle of the Romano-British elite.

In terms of ‘man-days’ or ‘man-hours’, a more conventional measurement of human work, the hypothetical peasant family of man, wife and three juveniles can probably produce about two man-days of output per calendar day. The male head produces one man-day, the wife about half a man-day after her domestic duties, and the juveniles about another half man-day. As noted in the previous paragraph the family unit can produce about two BEUs per year. Hence if working in man-days, one man-year is equivalent in output to one BEU, making conversion simple.
APPENDIX C

The Late Pre-Roman Iron Age and Romano-British Countryside and Environment
APPENDIX C

The Late Pre-Roman Iron Age and Romano-British Countryside and Environment

The purpose of this appendix is to try to estimate the amount of land available for agricultural purposes in the developed Roman economy in Britain.

1. The Countryside in the Roman Period

The countryside of Britain immediately prior to the Roman conquest in A.D. 43 was not, as was thought in the earlier part of the twentieth century, heavily wooded in the valleys and low lying areas, with occupation and agriculture only on the higher ground and lighter soils. The climax in the growth of wildwood occurred about 4500 B.C. (Rackham 1990:28). As early as the Mesolithic humans started the creation of heathland and small clearings. Clearing and destruction of wildwood continued through the Neolithic and Bronze Ages. Wood pasture for raising and feeding domestic animals by partial clearing and coppicing of woodland begins in the Neolithic (Rackham 1986:100). By the end of the Bronze Age c. 500 B.C., agriculture was still local and confined to light and unstable soils. Chalklands and some lowland river terraces were quite densely settled. The new wildwood free moorlands and lowland heaths were subject to less intensive farming. About one sixth of Britain was agricultural, with the remainder still largely wildwood. With the arrival of iron tools, both cheap and effective, and improved techniques in growing and storing crops, there was a rise in population, requiring the cultivation of more land. By the early Iron Age, c. 500 B.C., about half of England had ceased to be wildwood (Rackham 1990:34-5).

By the time of the Roman arrival, England was a land with a fully developed agriculture, with ploughed fields, pastures, meadows, heath, moors and managed woodland. Land belonged to individuals or groups. Farming had spread to the heavy soils of southern East Anglia, and into the Fens. Land not under the plough or pastured was mainly moorland. Rackham postulates two types of countryside in England during the Roman period. One is areas "....with a patchwork of woodland and farmland (e.g. Herts and Essex), and those with little or no woodland (the great river valleys and most of the chalklands)." (Rackham :41).

In Essex Drury and Rodwell note "In summary, it is now becoming clear that over extensive areas of central and northern Essex a system of land division originating in or by the late Iron Age continues to form the basis of the present landscape." (Drury and Rodwell 1980:62). Roman Britain was not a rugged frontier province of boundless wildwood, with the occasional small clearing with human occupation and activity. Even in supposedly backward Essex "....villa abutted on villa for mile after mile, and most of the gaps were filled by small towns and the lands of British farmsteads." (Rackham 1986:74), and Drury and Rodwell :57-75). Roman centuriation is not significant in Britain, probably because the Romans found the land already divided amongst various owners. The exception was most of the Fens of East Anglia, which only became available for division with a fall in sea level about the time of the Roman arrival and large scale drainage. The layout of the terrain looks haphazard, but was probably worked around high spots as they became cultivable (Rackham :383). In Norfolk at Holme-next-the-Sea a Roman semi-regular grid is aligned
on the Roman road, Peddar's Way. In West Cambridge the modern street grid appears to follow Iron Age field boundaries, while at Tadlow and Carm Field in Cambridge, and Saffron Walden in Essex, a semi-regular grid of Bronze Age or Iron Age fields/enclosures preserve traces of an Iron Age grid (Rackham:176).

Although the wildwood had almost disappeared by the LPRIA, trees could still occur in hedges. Columella gives instructions on hedging (Columella Rust. XI.iii.3-5), as does Palladius Rutilius (I.34). The plashing of hedges to form barriers was known to Caesar (Caes. B Gall. II.17).

The majority of Romano-British villages and villas are not found on the main paved roads of Roman Britain, but in the areas between. They were serviced by a network of local and lesser roads and lanes (Rackham:252).

Heathland was mostly formed on a large scale in the Neolithic and especially in the Bronze Age. Much of it existed by the Roman period and was well populated. Most heathland can be grazed, and its other products were exploited, furze, ling and bracken for fuel, while bracken was also used for litter for livestock and thatch (Rackham:287-95). Grassland was rare before civilization, but was well developed in England by the Bronze Age. Grassland on higher ground was used for pasturage, and meadows on the flood plains of rivers were exploited for hay production. "The scythe was the reaping tool par excellence of the Roman world...", and a number of examples have been recovered from archaeological sites (Manning 1985:49-50, Plate 21).

The developed Romano-British countryside of the second century A.D. was composed of a mosaic of large towns, small towns, such as Kelvedon in Essex (Rodwell and Rawley 1975), large villas farming 160 to 400ha or more (in Essex up to 1300ha, Drury and Rodwell 1975:59), smaller villas, and numerous villages, settlements and British farmsteads. Rivet in The Villas of Roman Britain lists 179 villas (Rivet 1969:265-79). The Ordnance Survey Map of Roman Britain (1994 edition) shows about 278 villas and about 285 other substantial buildings, for a total of 563. Scott in A Gazetter of Roman Villas in Britain lists about 2,500 definite and possible villas, with the publications on each site (Scott 1993). Scott's listing is still far from the total, because as she notes "Particularly active individuals and antiquarian societies in specific regions have a profound effect on our known distribution of Roman villas." (Scott 1993:6). For example in Leicestershire groups and individuals have been very active, recording one hundred villas. In Cambridgeshire one hundred and ninety five have been listed, and in Norfolk and Lincolnshire with active groups, two hundred and seventeen and one hundred and ninety three sites have been noted. If all areas of England were surveyed as intensively, the total number of discoverable sites would probably number 10,000 to 15,000. The area of England and Wales is 152,516 km$^2$ (58,887 square miles), suggesting a possible average density of one villa for every 15 km$^2$. Drury and Rodwell speculate that some large estates of 13 to 26 km$^2$ may have been transmuted into Domesday vills (Drury and Rodwell 1980:71). Norfolk with an area of

---

1 Plashing is the bending down and interweaving of branches and twigs to form a hedge. To make or renew a hedge.
5317 km\(^2\) has an average of one known villa for every 24.5 km\(^2\).

By the time of the Anglo-Saxon occupation of the cleared land in large parts of Britain, about forty percent or 65,000 km\(^2\) was already farmland. The Anglo-Saxons did not need to clear a significant amount of new land. Pollen evidence suggests that woodland clearance ceased at the end of the Roman period, except for continued clearance in northern England and southern Scotland into the fifth and sixth centuries A.D. The Roman proportions of wooded and non-wooded areas remained about the same for the next 800 years (Rackham 1980:131-33).

2. Agricultural Output and Land Available for Farming

Millett's figures for the population of Roman Britain in the early third century of 3,200,000 to 4,600,000 and an average family size of five persons, would give 640,000 to 920,000 family units. From Appendix B it appears that a peasant farming family could provide for its basic subsistence needs, and generate a surplus for obtaining goods and services from other banausic occupations, and for paying rent and taxes, from the harvest of about 7 to 8 ha.

Millett, summarizing the work of a number of scholars, has concluded that in the LPRIA there was significant agricultural intensification, probably related to an increasing population. More land was taken into cultivation, and in most of England mixed arable and pastoral farming was widespread. There were regional variations, and changes over time. For example, arable farming has been detected in Wales and north-east England, using seeds from the archaeological record, while in the south in the LPRIA sheep grazing increased on chalklands, while cattle rearing increased in the Thames valley. The land was also exploited more intensively, with an increase in output per hectare (Millett 1990:10-11). Although the Butser experimental Iron-Age Farm has shown that it is possible to produce an average of 2.0 tonnes of Emmer wheat per hectare (Reynolds 1979:61), it seems likely that historical actual average figures for a 250 year medieval period could be more realistic. Figures from early medieval England show an average yield per hectare over a 250 year period in the range 671 kg to 1027 kg for different cereals (see Appendix B: p.190). If each peasant family farming unit cultivated about 7 to 8 ha, this would require 4,600,000 ha to 6,700,000 ha of cleared arable and stock raising land, or 46,000 km\(^2\) to 67,000 km\(^2\). This correlates quite well with Rackham's estimate of 65,000 km\(^2\) of cleared land in the Saxon period.

3. Conclusion

In developed Roman Britain, with intensified production and the available cleared land, the agricultural and stock raising community could produce a surplus of food sufficient to support not only the army and wealthier classes, but also to support a substantial number of workers in banausic trades and occupations. The peasant agricultural family group could produce about twice its own needs in basic sustenance, leaving it with a surplus to acquire goods and services not available from within the family group, and pay taxes and rents. If as an initial hypothesis it is assumed that half the surplus was used to
meet the farmer's own needs, then the other half would be available for the Province's public purse for provincial and municipal expenditures, and for the luxury requirements of the wealthy in the way of villas, townhouses, interior decoration, and imported exotic foods and goods.

A surplus would also be available for export, as described by Strabo, Libanius and Zosimus (Strabo Geog. IV.5.2; Libanius. Or.XVIII.83; Zos.III.5.2).
APPENDIX D

Iron Production and Distribution in Roman Britain
APPENDIX D

Iron Production and Distribution in Roman Britain

The purpose of this appendix is to identify the iron mining and smelting sites in Roman Britain, to estimate the amount of iron produced, and to trace the distribution system and probable routes to the point of final use.

1. Iron Sources, Mining Sites and Production


Three main types of ore are found in Britain:

a. Carbonates, FeCO$_3$, the most common type: ore from the Weald, covering parts of the counties of Kent, East and West Sussex, Surrey and Hampshire, is of this type, and it also occurs in Northamptonshire, Lincolnshire, Oxfordshire, and the Cleveland Hills in North Yorkshire.

b. Haematite, Fe$_2$O$_3$: found in West Cumberland and The Furness area of Lancashire.

c. Limonite, Fe$_2$O$_3$.H$_2$O or FeO.OH (hydrated oxides containing varying amounts of water): found in the Forest of Dean in Gloucestershire; a deep underground Roman mine is known at Lydney, and at places along the edge of the South Wales coalfield.

Iron also occurs in association with other metals: at Alderley with copper; at Weardale and the Mendips with lead, and in the Leadhills area of Strathclyde. The two main production areas were the Weald from shortly after the conquest until the early third century A.D., and the Forest of Dean from the late first century A.D., after the conquest of the Silures, to the fourth century. In this paper the analysis will use principally the output from the Weald and the Forest of Dean. Although widespread, production from other sources was comparatively small, and was probably mostly distributed and used only locally. Two other materials were required for smelting, a nearby source of fuel and a source for a refractory type of clay for furnace construction. Fuel for the smelting process was principally charcoal, produced by 'charcoal burning' from wood.

Both the Weald and the Forest of Dean had useful wooded areas adjacent to the smelting sites (Cleere and Crossley 1985:37-8, Rackham 1980:107-9).

2. Output and Distribution from the Weald

Iron mining and smelting in the Weald were well established before the arrival of the Romans. "Thus, by the time the Romans arrived in Britain in AD 43 there was a vigorous and technologically well advanced ironmaking industry in existence in the fringes of a region that was rich in iron ore and woodland, the two essential raw materials for this industry that was recognized by the Romans as a key one in their economy" (Cleere and Crossley 1985:55). The Romans introduced new technology, the shaft furnace, and increased the scale of production dramatically. Working from the calculated and estimated
size of the slag dumps (3 tonnes of slag were smelted along with every tonne of iron), Cleere and Crossley have calculated Roman iron production in the Weald as shown in Table 1. below.

**Table App.D.1: Annual iron production in the Weald**

<table>
<thead>
<tr>
<th>Date</th>
<th>Tonnes per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>43-100</td>
<td>150</td>
</tr>
<tr>
<td>100-150</td>
<td>700</td>
</tr>
<tr>
<td>150-200</td>
<td>750</td>
</tr>
<tr>
<td>200-250</td>
<td>750</td>
</tr>
<tr>
<td>250-300</td>
<td>200</td>
</tr>
<tr>
<td>300-350</td>
<td>200</td>
</tr>
<tr>
<td>350-400</td>
<td>50</td>
</tr>
</tbody>
</table>

The ratio of non-metallic materials to iron was 6:1 in the ore as mined, and after cleaning before smelting. The amount of overburden or waste material that had to be excavated to reach the ore was in a ratio of about 3:1 (Cleere and Crossley:78). Thus to produce 100 tonnes of iron, 600 tonnes of ore was needed, and this involved moving about 1800 tonnes of overburden. To smelt the 100 tonnes of ore, about 8,400 tonnes of wood would need to be converted to charcoal (Cleere 1976:233-46). This would yield about 2,100 tonnes of charcoal.

From the evidence of layering in the slag and refuse piles Cleere and Crossley suggest that at least part of the industry, probably the smaller sites, had a seasonal cycle. In the winter and early spring the work force would cut wood and convert it to charcoal by heap type burning. In this process the stack of wood is partly covered with earth, set on fire, and the burning controlled to drive off volatiles and water. The residue, about twenty-five percent of the weight of the original wood, is largely impure carbon. This was screened to remove fines and small pieces of less than 5mm. For smelting the charcoal lumps need to be in the size range of 5mm to 50mm. In the early summer ore would be mined and transported to the furnace site, roasted to drive off carbon dioxide leaving an iron oxide for smelting. It would be screened to remove the fines, and then stocked to await smelting. Once sufficient ore had been accumulated, smelting would start and carry on through the summer, autumn and into the early winter, until all the roasted ore had been processed. The annual cycle would then be repeated (Cleere and Crossley : 50-1).

To summarize, the labour and transportation needs for 100 tonnes of iron blooms:-

(i) Cut 8,400 tonnes of wood and convert it to about 2,100 tonnes of charcoal at the woodland felling site. Transport the charcoal to the smelting site.

(ii) Remove 1800 tonnes of overburden and dump at mining site.

(iii) Move 600 tons of raw ore to the smelting site.
(iv) Mine about 250 tonnes of Wadhurst clay for building and repairing smelting furnaces and roasting hearths, and transport it to the smelting site.

(v) Build or repair the roasting hearths and roast the ore.

(vi) Smelt the ore to produce the bloom, a lump of iron still contaminated with excess slag.

(vii) In a smithing furnace rework the bloom by repeated re-heating and hammering to expel slag and impurities.

These steps would produce a worked bloom which could be sold and shipped to end users around the country, army workshops, and makers of iron tools, agricultural implements and building hardware such as nails, hinges, hooks, clamps and locks, and domestic equipment. (See Manning 1985 for the end use of iron in Britain). Cleere built a replica of a Roman shaft smelting furnace, and carried out several trial smelts with it. The best result was the production of 9.1 kg of iron from 91 kg of ore and using 120 kg of charcoal. With more practice by the team operating the furnace and further refinements of the experimental technique it was believed that 18.1 kg could be produced from one charge. The durability of the furnace appeared good. It was estimated that about twelve smelts could be achieved before the furnace would need rebuilding. If roasting and smelting were not attempted simultaneously, a crew of five to six could operate the furnace on a sustained basis (Cleere 1974:213-17). The number of identified iron smelting sites has increased from 36 in 1974 to 60 in the early 1980s (Cleere and Crossley:57), to over 200 from field walking surveys (Hodgkinson and Tebbut 1985:159-64). Cleere and Crossley estimate that a minimum of 600 direct production workers would be needed, and that this figure should be at least doubled to provide for administrative and transport workers (Cleere and Crossley 1985:79). In addition, there would be groups providing other goods and services. A total of about 2,000 family units in the industry seems likely. They would require 4,000 BEUs for their sustenance and other needs, which, for the 700 tonnes of annual production, would value a tonne of iron at 5.7, say 6.0 BEUs.

By the mid third century iron production in the Weald declined, and the major production site shifted to the Forest of Dean on the border of Wales and Gloucestershire. Unfortunately practically all traces of the Roman iron industry there have been obliterated by later iron working. The decline in the Weald has been attributed to both piracy in the Channel and to a shortage of fuel from destruction of the Weald forests. Piracy seems the more likely. Rackham has shown that by managed coppicing of 9,308 ha, the fuel requirements for an annual production of 550 tonnes could be met indefinitely (Rackham 1990:41). Hammersley makes a similar point for the iron industry in both the Weald and Forest of Dean from the sixteenth to eighteenth centuries AD, when iron production was higher than in the Roman period, "But it is abundantly clear that the British charcoal iron industry did not destroy its fuel, and that it did not suffer from exceptional fuel problems." (Hammersley 1973:600-601).
2. Transportation to Markets

There were two areas of iron production in the Weald, the coastal sites and sites in the High Weald, supplying different market areas but with some overlap. The coastal sites are concentrated in an area about 9.6 km by 16 km in East Sussex, between Hastings and Winchelsea and inland as far as Battle. The High Weald sites spread across 48 km in West Sussex and Surrey, between Horsham, Crawley, Crowborough and Haywards Heath. All sites are within 3.2 km of a major or minor Roman road. For transportation purposes it is more logical to consider an eastern and western group. Iron from the eastern sites was initially shipped from the Hastings area and the Brede estuary. Later local roads to both the Rother and Brede rivers were used to move iron to sea shipping points on the rivers, and by the second century most eastern iron probably moved to a port site near Bodiam on the river Rother, where limited Roman remains have been found, and thence by sea to Dover. From Dover the iron could move by sea up the east coast to York and South Shields, or westward to Wales, Chester and Maryport.\(^1\) Up until the first half of the second century AD there was a large military requirement for iron for military building and projects.\(^2\) After that there was probably a surplus which went from Dover to Boulogne (\textit{Gesoriacum}), and coastwise to the Rhine, and then up the Rhine by barge. From the western Weald iron producing sites, iron went by major north-south roads.\(^3\) to London, where it would be made into finished products, which were then sent out by road to East Anglia and the home counties. Some would go by water up the east coast to points further north, some would be shipped up the Thames valley, and some would be sent across the North Sea to the Rhine provinces. Chichester would be a secondary distribution centre, receiving iron by road, and forwarding it by road or sea to the south-west (Cleere and Crossley:84-5). There may have been a shift to more land transport in the third century as piracy in the Channel became a significant menace.

\(^1\) Cleere has identified a number of military port installations at various military bases, the legionary fortresses at Caerleon, Chester and York, and others at various forts such as Carmarthen, Segontium, South Shields and Maryport for example (Cleere 1978:36-40).

\(^2\) An example is the ten tonnes of nails, over 875,000 nails, found at the legionary fortress of Inchtuthil (Pitts and St. Joseph 1985:276). Iron ore suitable for smelting was available fairly close by in Fifeshire, and it has been thought that the nails were made from locally smelted iron (Angus, Brown and Cleere 1962:959). More recently Cleere has concluded that although tap slag shows the presence of an iron smelting furnace, the amount of slag is very small, and that the iron nails came from the Weald. He speculates that a small amount of iron may have been smelted on site to meet a temporary shortage or special need (Cleere 1985:300-1). Shirley in her major study on the construction of the fortress at Inchtuthill states “There is no evidence of local ore extraction or smelting.” (Shirley 2000:170).

\(^3\) The two major roads were Brighton to London or Lewes to London.
3. A Note on the Role of the Classis Britannica in the Roman Iron Industry in the Weald

There has been a considerable amount published on the possible connections between the classis Britannica and the iron industry in the Weald, based largely on the finds of large numbers of tiles (over 1,000 at Beauport Park site) and some bricks stamped CL BR at a number of iron smelting sites, as well as at various harbours and port installations along the south coast and in the area of Boulogne (Gesoriacum) on the coast of Gaul. It is generally considered that the British fleet was used principally in supporting and supplying army campaigns, and not as a naval fighting force. For this role it would need cargo carrying vessels rather than oared warships, and it may well have shipped iron for military use as part of its supply function (Cleere 1974:186, Cunliffe 1968:255-65, Frere 1987:210).
APPENDIX E

Non-Ferrous Metal Production and Distribution in Roman Britain
APPENDIX E

Non-Ferrous Metal Production and Distribution in Roman Britain

(See Figs. App.E.1 to App.E.5)

(Note: The principal references for this Appendix are Healy 1978:52-62; Jones and Mattingly 1990:179-192; and Tylecote 1986:10-80. To avoid cluttering up the text, specific text references are only given for direct quotations from these authors).

1. Introduction

The purpose of this appendix is to identify the mining and smelting sites in Roman Britain for non-ferrous metals, to estimate, if possible, the amount of each metal produced, and to identify the distribution system and routes to the points of final use. One problem in looking at the sources for the metal ores in the Roman period is that most Roman mines were extensively exploited in the medieval and later periods, effectively obliterating the evidence for Roman mining practices. This also makes it difficult to impossible to estimate Roman ore production from the size of the worked out pits and galleries, and other techniques are needed.

2. The Metals Exploited

Six non-ferrous metals were exploited in the Roman period. Copper, gold, lead and tin were mined directly. Silver in Britain was recovered from the argentiferous lead ores from the Mendips area by cupellation. Zinc occurred in association with copper at the Halkyn Mountain site in Clwyd, North Wales, close to the area of Pentre on the river Dee. Zinc was not mined and smelted to a pure metal by itself in the Roman period, and in fact the technology to do this was not achieved until the late eighteenth century (Tylecote: 38). To produce the zinc needed for alloying with copper to produce brass, zinc carbonate (ZnCO₃) was mixed with copper under reducing conditions (no free oxygen available) in a crucible or closed furnace. Zinc vapour was absorbed by the copper granules, producing a brass with about 20% zinc. Zwicker experimented with producing brass in small crucibles, in one case reacting zinc oxide with copper sheet, and in a second trial using a malachite copper ore and zinc carbonate. Brass could be made with a zinc content of about 20%, and in some cases with zinc as high as 40% (Zwicker et al 1985:107).

Copper-tin bronzes were made in Britain long before the Roman period, and bronze artefacts continued to be produced after the conquest. Iron had replaced bronze for a wide range of tools, weapons and many building fittings. As can be seen from the artefact finds listed in excavation reports and in museum collections, the bronzes from the Romano-British period are mainly small objects: brooches; pins; jewellery; lamps; surgical and cosmetic implements; and a variety of small votive or decorative figurines of deities, humans and animals. The great advantage of bronze and brass, and later pewter, is that they can be cast into complex and intricate shapes in a wide range of sizes. The casting of iron did not become a practicable technology until the late medieval period, and was not
developed on a large scale until the early eighteenth century, when it became the material of choice for ships’ cannon. Mercury, antimony and arsenic were not produced in Roman Britain. Antimony and arsenic can appear as minor components in some lead ores.

Tin had been mined in Cornwall as far back as the Bronze Age, but was not exploited by the Romans until the third century A.D.1 About AD 60–70 the Romans had tried mining tin in Cornwall, but could not compete with the more efficient Spanish mines. Spanish tin was cheaper, and it was not until the third and fourth centuries that active Roman tin mining resumed (Elkington 1976:196; Healy :61).

Copper was mined at Parys Mountain in Anglesey, and Great Orme Head in Wales. Later exploitation has largely destroyed the Roman workings. At Llannonyn (West Shropshire), a Roman period cave and gallery mine has survived (Jones and Mattingly :191-2).

Under the Empire Britain became one of the main sources of lead. Mines in the Mendips were in production before the advent of the Romans. Roman lead mining in the Mendips started by A.D. 49, and extraction of the ore continued until the end of Roman Britain. The Mendip mines were predominantly open pit operations, a much less costly process than underground mining. A number of smelting sites have been identified around Charterhouse. After c. A.D. 75 lead was mined around Shelve and Linley Hill in southwest Shropshire; in Lower Machen in Gwent, where there is an intact gallery at Draethen (Boon 1971:461); and in Derbyshire into the fourth century. Smaller deposits at Nidderdale and Pateley Bridge in North Yorkshire were mined for a time in the late first and early third centuries. Small workings are known at Alston Moor in Cumberland, and at a few sites along the Pennines. Silver was produced as a by-product of the argentiferous lead ores from the Mendips. For the cupellation process for separating silver from lead to be economic, the lead needed to contain more than 0.06% (600 ppm) of silver. At best, for every tonne of Mendip lead smelted, about 0.3kg of silver would be produced.

The main site for gold production was the mine at Dolaucothi in Dyfed. Initially gold was recovered from outcropping gold bearing quartz veins. Later ‘hushing’ (sluicing) and hydraulic mining were used to expose the mineral veins, utilizing two aqueducts, the 11 km Cothi aqueduct, and the 6 km Annell aqueduct. Later still, open pits and adits for underground mining were developed. Other small sites are known in Cornwall, Wales and Scotland, but these were not extensively worked. Strabo notes that Britain exported gold and silver (Strabo 4.5.2).

3. Uses of Non-Ferrous Metals

Gold and silver were used for coinage, jewellery and for high quality and costly domestic vessels such as cups, bowls and trays. Three notable hoards of silver vessels have been recovered from Chesterton, Mildenhall and Traprain Law, and a very fine silver lanx (tray) from the bank of the Tyne at Corbridge. Silver bowls, bracelets, brooches, earrings

---

1 The only source for tin in Britain was the south-west, Devon and Cornwall.
and finger rings are found almost every year from excavations throughout Britain. The Snettisham hoard, probably from a jeweller’s workshop, included 89 finger rings together with silver bars (Britannia 17:403). Silver ingots are of hide or double axe shape, and weigh about one Roman pound (327.45 gm). Twelve inscribed ingots are listed in RIB II, Fasc. 1, 2402.1 to 2402.12. Silver ingots can be seen at a number of museums, for example at the museum at Segedunum (Wallsend) on the Tyne. Gold jewellery is also frequently found. An unworked gold ingot was recovered in St Albans in 1999 (Britannia 31:409).

Copper in Britain was smelted into bun shaped ingots weighing between about 13 kg to 25 kg. All the inscribed ingots from the archaeological record come from north Wales, around the copper mining areas of Parys Mountain and Great Orme Head. Copper in a relatively pure form as produced by the smelting process had limited uses. It was soft and easily deformed. Its main use was as the principal metal in tin-bronze alloys, with tin at 12% to 15% as the other major constituent. Romano-British bronzes for casting have a lower tin content than bronze used for forging. Small amounts of lead and/or zinc, which improve the fluidity of the molten metal when pouring into moulds were added for casting quality bronzes. Forging quality bronze generally has a higher tin content. Bronze was used for a wide variety of small objects, as noted on page 205 above.

Lead was produced in far greater quantities than any other non-ferrous metal. It was used for the manufacture of a wide range of objects, mostly of a utilitarian nature. The largest amount was probably used for water systems. Lead pipes used in the siphons for aqueducts required very large amounts. The Beaunant siphon, near Lyon in Gaul, alone used 2,000 tonnes of lead pipes, and the total for all siphons in the area of Lyon has been estimated at 10,000 to 15,000 tonnes (Hodge 1992:156). Almost every bath house, whether on the grand scale of the various imperial baths in Rome, or a modest installation for a small villa used some lead pipe. The water main in Ostia, 0.15 m internal diameter used about 0.178 tonnes of lead for every metre. The castella and pipes used to distribute water from aqueducts to public fountains, baths and private homes used large quantities of lead. Other uses for lead were: coffins; weights; cisterns; roofing; lining baths; seals; and later as a component of pewter (20% to 50% in pewter alloys).

4. Production and Distribution of Non-Ferrous Metals

In terms of weight, gold and silver were only produced in modest amounts compared with lead and iron. Apart from security concerns the movement and distribution of small amounts of the precious metals would not be a major transportation problem. For distribution of small consignments inside Britain, movement was almost certainly by road. Exports might be assembled into a convenient size of consignment, and then moved by road, possibly with a military escort from the fort at Pumsaint in the Mendips, to a short and relatively safe sea crossing to the Continent. This could be from the Dover-Richborough area, from which the crossing to Gesoriacum in Gaul could be made in a few hours.

---

2 The Great Bath at Bath was lined with large sheets of lead.
It seems probable that most of the copper, and its derivative bronze, would be distributed widely around Britain in small parcels by land transport. It could go firstly to major centres, and from them be further distributed to minor towns and settlements. As noted in previously it was used primarily for small objects, and most settlements have left some evidence of bronze working on a small scale. It seems unlikely that bronze was exported on a large scale. In the pre-Roman era in Britain there seems to have been an import trade in bronze, see pages 33-4, and Gaul and Spain had many easily worked deposits of copper, and in the case of Spain tin could be produced more cheaply than in Britain.

Lead would be the main non-ferrous metal to be moved in large quantities, both for internal distribution in Britain and to ports for export to Gaul and Germany. Lead ingots/pigs from the Mendips and other sources can be identified by the inscriptions cast into them, and by the composition of the small amounts of other metals in the ores from different mining areas. *RIB II, Fasc. I* lists seventy-three inscribed pigs: twenty-four from the Mendips; three from South Wales; three from Shropshire and Powys; eight from Clwydd; twenty-three from Derbyshire; four from Yorkshire; and nine from uncertain sources. Tylecote has compiled a list of eighty-seven lead pigs, including those from *RIB II*. More recently three inscribed pigs have been recovered from under a Roman warehouse in London (Brigham and Watson 1996a:427-8), and part of a pig from Greta Bridge (Casey and Hoffman 1998:145).

A combined list of pigs is attached as an annex to this appendix, arranged by source. Most pigs discovered in Britain have come from beside rivers or roads. Probable transportation routes can be derived from this information.

**Annex to Appendix E**

**Source and Find Spot for Lead Pigs from the Archaeological Record**

<table>
<thead>
<tr>
<th>Source</th>
<th>Find Spot</th>
<th>Date Made</th>
<th>Weight kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Derbyshire</td>
<td>Hexgrove Park, Notts</td>
<td>2nd-3rd c</td>
<td>83.6</td>
</tr>
<tr>
<td>2 Derbyshire</td>
<td>South Cave, Brough</td>
<td>2nd-3rd c</td>
<td>61.4</td>
</tr>
<tr>
<td>3 Derbyshire</td>
<td>Brough-on-Humber</td>
<td>2nd-3rd c</td>
<td>86.6</td>
</tr>
<tr>
<td>4 Derbyshire</td>
<td>Brough-on-Humber</td>
<td>2nd-3rd c</td>
<td>86.9</td>
</tr>
<tr>
<td>5 Derbyshire</td>
<td>Brough-on-Humber</td>
<td>2nd-3rd c</td>
<td>89.3</td>
</tr>
<tr>
<td>6 Derbyshire</td>
<td>Brough-on-Humber</td>
<td>2nd-3rd c</td>
<td>87.9</td>
</tr>
<tr>
<td>7 Derbyshire</td>
<td>Brough-on-Humber</td>
<td>2nd-3rd c</td>
<td>36.4</td>
</tr>
<tr>
<td>8 Derbyshire</td>
<td>Pulborough, Sussex</td>
<td>117-138</td>
<td>83.6</td>
</tr>
<tr>
<td>9 Derbyshire</td>
<td>Pulborough, Sussex</td>
<td>117-138</td>
<td>no record</td>
</tr>
<tr>
<td>10 Derbyshire</td>
<td>Pulborough, Sussex</td>
<td>117-138</td>
<td>no record</td>
</tr>
<tr>
<td>11 Derbyshire</td>
<td>Pulborough, Sussex</td>
<td>117-138</td>
<td>no record</td>
</tr>
<tr>
<td>12 Derbyshire</td>
<td>Tansley Moor, Matloc</td>
<td>117-138</td>
<td>80.0</td>
</tr>
<tr>
<td>13 Derbyshire</td>
<td>Matlock Bank</td>
<td></td>
<td>37.7</td>
</tr>
<tr>
<td>14 Derbyshire</td>
<td>Cromford Moor, Wirksworth</td>
<td>117-138</td>
<td>57.7</td>
</tr>
<tr>
<td>15 Derbyshire</td>
<td>Rugby (Tripontium)</td>
<td>2nd-3rd c</td>
<td>79.0</td>
</tr>
<tr>
<td>No.</td>
<td>County</td>
<td>Location</td>
<td>Date Made</td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
<td>-----------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>16</td>
<td>Derbyshire</td>
<td>Matlock</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Derbyshire</td>
<td>Castleton, Derbyshire</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Derbyshire</td>
<td>Carsington, Derbyshire</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Derbyshire</td>
<td>Cheshunt, Derbyshire 117-138</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Derbyshire</td>
<td>Ellerker, Humberside</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Derbyshire</td>
<td>Bradwell, Derbyshire</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Derbyshire</td>
<td>Oker Hill, Darley, Derbys.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Find Spot</th>
<th>Date Made</th>
<th>Weight kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derbyshire</td>
<td>Brough</td>
<td></td>
<td>no record</td>
</tr>
<tr>
<td>Derbyshire</td>
<td>Yeavely, Derbyshire</td>
<td>1st c</td>
<td>59.42</td>
</tr>
<tr>
<td>Derbyshire</td>
<td>Yeavely, Derbyshire</td>
<td>1st c</td>
<td>62.14</td>
</tr>
<tr>
<td>Clwyd</td>
<td>Bossington, Stockbridge, Hants 60</td>
<td>76</td>
<td>69.1</td>
</tr>
<tr>
<td>Clwyd</td>
<td>Hints Common, Staffordshire</td>
<td>74</td>
<td>81</td>
</tr>
<tr>
<td>Clwyd</td>
<td>Broughton, Chester</td>
<td>74</td>
<td>86.3</td>
</tr>
<tr>
<td>Clwyd</td>
<td>Roodee, Chester</td>
<td>117-138</td>
<td>84-96 no record</td>
</tr>
</tbody>
</table>

A group of twenty pigs found about 1590 near Runcorn on the south bank of the river Mersey. Information reprinted from Camden.
<table>
<thead>
<tr>
<th>Source</th>
<th>Find Spot</th>
<th>Date Made</th>
<th>Weight kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>74 Somerset</td>
<td>Clausentum/Bitterne</td>
<td>68-79</td>
<td>81</td>
</tr>
<tr>
<td>75 Somerset</td>
<td>Clausentum/Bitterne</td>
<td>68-79</td>
<td>75.3</td>
</tr>
<tr>
<td>76 Somerset</td>
<td>Charterhouse</td>
<td>69-79</td>
<td>82.7</td>
</tr>
<tr>
<td>77 Somerset</td>
<td>Charterhouse</td>
<td>69-79</td>
<td>no record</td>
</tr>
<tr>
<td>78 Somerset</td>
<td>Wells</td>
<td>164-169</td>
<td>no record</td>
</tr>
<tr>
<td>79 Somerset</td>
<td>Charterhouse</td>
<td>164-169(1 pig?</td>
<td>no record</td>
</tr>
<tr>
<td>80 Somerset</td>
<td>Charterhouse</td>
<td>164-169</td>
<td>no record</td>
</tr>
<tr>
<td>81 Somerset</td>
<td>Richborough</td>
<td>96-169</td>
<td>no record</td>
</tr>
<tr>
<td>82 Somerset</td>
<td>Caerwent</td>
<td></td>
<td>16.8</td>
</tr>
<tr>
<td>83 Somerset</td>
<td>King William St., London</td>
<td>69-79</td>
<td>80.25</td>
</tr>
<tr>
<td>84 Somerset</td>
<td>King William St., London</td>
<td>69-79</td>
<td>79.0</td>
</tr>
<tr>
<td>85 Somerset</td>
<td>King William St., London</td>
<td>69-79</td>
<td>78.0</td>
</tr>
<tr>
<td>86 Somerset</td>
<td>Greta Bridge</td>
<td></td>
<td>11.36</td>
</tr>
<tr>
<td>87 Yorkshire</td>
<td>Heyshaw Moor, Nidderdale</td>
<td>81</td>
<td>70.5</td>
</tr>
<tr>
<td>88 Yorkshire</td>
<td>Heyshaw Moor, Nidderdale</td>
<td>81</td>
<td>70.9</td>
</tr>
<tr>
<td>89 Yorkshire</td>
<td>Hurst, Swaledale</td>
<td>117-138</td>
<td>77</td>
</tr>
<tr>
<td>90 Yorkshire</td>
<td>Grassington, N. Yorks.</td>
<td>98-117</td>
<td>38.5</td>
</tr>
<tr>
<td>91 Yorkshire</td>
<td>Belby, Howden</td>
<td></td>
<td>51</td>
</tr>
</tbody>
</table>
APPENDIX F

POTTERY PRODUCTION AND DISTRIBUTION
APPENDIX F

Pottery Production and Distribution
(See Figs. App.F.1 and F.2)

1. Introduction

This Appendix summarizes the place of manufacture for the principal types of both indigenous and imported pottery, and the point of sale or use. Unless destined for use in the immediate neighbourhood of manufacture, all pottery had to be moved either by land or by waterborne transportation systems. Pottery generally survives well in the archaeological context, and is usually reported in some detail as to typology and source. This makes it a useful marker for plotting out transportation routes and networks.

Coarse pottery vessels can be made on a very small scale domestically, to meet the needs of a family or small group of families. This would not require any significant transportation system beyond the family members gathering clay and fuel locally, and carrying the fired pots to the point of use. In this appendix industrial scale activities are examined from the small one or two craftsman groups working full-time as potters, to large operations with a number of workers, possibly with craft specialization within the group. For any commercial pottery four items are essential: a source of good clay and other materials for temper; an ample source of fuel for firing the kilns; a convenient and reliable water source; and an economic means of moving the finished products to market. Pottery making requires the expenditure of human energy in the gathering and utilization of raw materials, the fabrication of the pots, and in distribution of the finished product. It also requires the use of animal energy in hauling clay and fuel to the work site, and in distribution, and the use of heat energy from the combustion of the fuel to fire the kilns.

In the LPRIA there were established pottery making sites in Britain, and their output was augmented by modest imports from the continent. The imports from the Mediterranean world made their way to the Britanny peninsula, either via the Rhône-Saône-Seine, or the Narbonne-Toulouse-Bordeaux routes. From the north coast of Britanny vessels sailed to Britain carrying both amphorae of wine but also local coarse wares from Britanny. The early landing point in Britain was Hengistbury Head, but by later in the first century BC the trade shifted toward the south-east. By that time some sigillata was appearing in south-east Britain, followed shortly by the terra nigra and terra rubra fabrics from northern Gaul. Plates, flagons and jars from centres near Orleans also appear (Millar 1991:67-83, Tyers 1996:49-52). By the first century BC the indigenous LPRIA pottery in the south-east was being produced on a fast wheel and on an industrial scale. Although nine major style zones have been identified, there is a similarity in fabrics from the different zones. In the south central region, the counties south-west of the Thames valley, potters developed a local style,

---

1 For example the Fishbourne publication on finds has 158 pages on pottery, and 125 pages on all other finds (Cunliffe 1971)
the Atrebatic, which persisted into the Roman period (Tyers: 55-6, Cunliffe 1991:462). To date very little evidence has been found for LPRIA pottery kilns. Some of the local pottery may have been fired in open bonfires.

From the conquest in AD 43 to the end of Roman Britain in the early to mid fifth century AD, a number of pottery industries were established in Britain, with four surviving for the full period. The products of some potteries were widely distributed, while others served only a very local market. In examining the transportation problems, this study will concentrate on the types with a regional or country wide distribution. The Journal of Roman Pottery Studies in 1992 listed 279 pottery types or classes, but only the major centres are considered here. One consideration for Roman Britain is: 'was pottery production seasonal?' With the rather humid British climate, drying pots to the leather hard stage may have been difficult in the winter months (Tyers 1996:47).

2. Romano-British Made Fine Wares (Tyers 1996:166-179)

a. Colchester Colour-coated Wares
Production: from c. AD 120 until later third century.
Source: Colchester.
Distribution: East Anglia, London basin, and southern Britain. Some export to northern frontiers in Antonine period.

b. Hadham Red-slipped Wares
Production: from later first century, expanded output in later third century.
Source: Hadham area on Herts-Essex border
Distribution: initially local, but in third century expanded to East Anglia and the London basin, with a few outliers to the Midlands.

c. London-Essex Stamped Wares
Production: early second century.
Source: region of Little and Much Hadham on Herts-Essex border.
Distribution: lower Thames basin: a few outliers in south and west.

d. ‘London Ware’ Style
Production: early Flavian to mid second century.
Source: Upchurch (Kent), Oxford, Ardleigh (Essex), West Stow and Wattisfield (Suffolk), the Nene Valley and London.
Distribution: generally in south-east, but outliers in the Midlands, the west, Wales and Hadrian’s Wall.

e. New Forest Slipped Wares
Production: AD 240-370.
Source: New Forest area.
Distribution: widespread in central-southern England, with a few outliers farther north.
f. Nene Valley Colour-coated Wares
Production: from mid second century to end of fourth century.
Source: Lower Nene valley, centred on Water Newton.
Distribution: Bucks, Oxon, and Lower Thames basin, with a lighter spread over the rest of England. By the fourth century partly displaced by Oxfordshire wares.

g. Oxfordshire Red-Brown Slipped Ware
Production: commences from circa AD 240 until end of fourth century.
Source: Oxfordshire potteries.
Distribution: extensive across southern England from the Severn to the Wash.

h. South-east English Glazed Ware
Production: AD 70-120.
Source: possibly the Staines area.
Distribution: London basin and surrounding counties: a few outliers in west and north-west.


Because of their lower unit value, both per piece and per kg, one would expect coarse wares in general to have a more local and concentrated distribution than fine wares. Transportation costs would be a much larger portion of the final price at the point of sale if they had to move long distances to a market. Only four production centres out of a total of sixteen functioned throughout the Roman period, the Severn Valley group, South-east Dorset black-burnished I (BB1), Alice Holt/Farnham grey ware, and South Devon burnished ware. Savernake type grey ware, Verulamium-region white, and North Kent shell tempered wares all faded out by the mid second century. Black -burnished II, and Rossington Bridge BB1 were produced only in the second century. Derbyshire, Dales-type ware, Late Roman grog-tempered ware, Crambeck, Portchester fabric D and South Midlands shell-tempered wares started production between AD 150 and 270. Derbyshire and Dales-type ware ceased production by the mid third century, while Late Roman grey-tempered lasted until the end of the fourth century. Crambeck (Yorkshire), Portchester fabric D and South Midlands shell-tempered all had a life span from about AD 300-400.

a. Alice Holt-Farnham (regional distribution)
Production: most extensive mid first century to mid second century, and late third to late fourth century.
Source: Alice Holt/Farnham area on the Surrey-Hampshire border: about 80 kilns known in 2km x 3km area.

Production: derived from pre-Roman Durotrigian traditions. Production dates back to Middle Iron Age, and continues to fourth century AD. The forms change over time.
Source: Wareham-Poole Harbour region in Dorset.
Distribution: found in pre-Flavian, Flavian and Trajanic sites in the west and south Wales.
By about AD 120 spreads to northern Britain at time of construction of Hadrian’s Wall. At
this time it also appears in the south-east, and becomes a major part of assemblages in the
Midlands, south-east and north in the third century. Declines in north in fourth century,
being replaced by Yorkshire grey wares from Crambeck and other centres. South-east
Dorset BBI is one of the most widely distributed Romano-British wares.

c. Crambeck Wares (regional distribution)
Production: early fourth century to end of Roman period.
Source: Crambeck (Yorks)

d. Dale Ware and Dales-type Ware (regional distribution)
Production: about AD 250-340.
Source: several sites in Lincolnshire, Humberside and Yorkshire.
Distribution: abundant in Lincolnshire, Humberside and south Yorkshire: thin spread across
north to Hadrian’s Wall.

e. Derbyshire Ware (regional distribution)
Production: mid second century to third century.
Source: kiln sites in Holbrook/Hazelwood area of Derbyshire.
Distribution: abundant in Derbyshire, and thin spread to the north up to the Wall.

f. Late Roman Grog-tempered Ware (regional distribution)
Production: late third century to end of Roman period.
Source: Wessex and Kent, but no kiln sites known.
Distribution: Hampshire, Sussex, the London region and Kent.

g. South Midlands Shell-tempered Ware (regional distribution)
Production: early fourth century to the end of the Roman period.
Source: Harrold (Beds) and Lakenheath (Suffolk), possibly other sources.
Distribution: across southern Britain, south of the Severn-Humber line, and north of
Thames.

h. North Kent Shell-tempered Storage Jars (regional distribution)
Production: Neronian to mid to late second century.
Source: Kent shore of Thames estuary, probably near Cliffe.
Distribution: Thames estuary region and London, outliers up east coast as far as Cramond
on the Firth of Forth.

i. Portchester Fabric D (regional distribution)
Production: early fourth to end of century.
Source: Overwey kilns near Tilford, Surrey, but other sources likely.
j. Savernake-type Greywares (regional distribution)
Production: Claudian period to mid second century.
Source: north Wiltshire, including Savernake Forest, Pewsey and Oare
Distribution: Wiltshire and extending into bordering counties.

k. South Devon Burnished Ware (regional distribution)
Production: Neronian, but wide distribution in second to fourth century.
Source: South Devon.
Distribution: Devon, Cornwall and west Dorset.

l. Severn Valley Ware (regional distribution)
Production: Claudian to fourth century.
Source: Severn valley: Alkington, Ledbury, Malvern, Perry Bar to Wroxeter; Gloucester region.
Distribution: first century, sites in Severn valley near Gloucester, Wroxeter, Chester.
Abundant on sites in the lower Severn valley in both the second to third centuries. From about AD 120-200 small scale supply to north-west England and Hadrian’s Wall. In fourth century distribution contracts to Severn basin.

m. Verulamium Region White-ware (regional distribution)
Production: about AD 50 to mid second century.
Source: Watling Street between London and Verulamium, sites at Brackley Hill, Radlett, Little Munden and St. Albans.

n. Rossington Bridge BBI (regional distribution)
Production: Antonine period
Source: Rossington Bridge (Yorks), alongside mortarium workshops of Sarrius
Distribution: Antonine Wall, Scottish forts, Corbridge.

o. Black-burnished 2 (regional distribution)
Production: about AD 120 to Antonine period.
Source: uncertain, possibly south-east England.
Distribution: scattered from Thames estuary to Cramond in Scotland.

4. Discussion of British and Romano-British Pottery

Of the twenty-three manufacturing areas listed above, the products of only two, Nene Valley colour-coated wares (mid second century to end of fourth century) and South-
east Dorset BB1 (LPRIA to fourth century) are widely distributed over the whole country. Oxfordshire red/brown slipware (AD 240 to end of fourth century) is distributed widely below the Severn/Wash line, but rather sparingly above that. Of the remaining twenty types, seven are regional in the south-east, Colchester, Hadham, ‘London ware’, Alice Holt/ Farnham, Late Roman grog-tempered, Porchester D and Verulamium region white wares. One is regional in the south-central area, New Forest slipped wares. One is regional in the west from Devon up to the Antonine Wall, the Severn Valley wares, while BB2 from the south-east is concentrated in the Thames basin and in Scotland along Hadrian’s and the Antonine Walls. South Devon burnished ware is regional in the west, and Savernake-type grey wares are regional between the Severn and Southampton areas. Dalesware is regional in the north-east, South Midlands shell tempered wares in the east-centre area, and Derbyshire ware in the centre of England. Crambeck pottery is regional in northern England above the Humber river. Other pottery, London-Essex stamped ware, South-east English glazed ware, Rossington Bridge BB1 and North Kent shell-tempered wares have an essentially local distribution.

For the purpose of this thesis, the transportation of pottery with only a local distribution will not be considered. The movement would be simple, using pack animals, carts or simple river craft, and the products would be sold in local markets. For the pottery with a wider distribution, four groups will be studied, two fine wares and two coarse wares. For fine pottery the Nene Valley colour-coated wares with their province wide distribution, and the New Forest slipped wares with their regional distribution in the south-central area will be examined. For the coarse pottery with a country wide presence South-east Dorset BB1 with its widespread distribution from Cramond in the north to the south coast of England will be used. For coarse pottery with a regional distribution, Crambeck ware for a regional distribution in the north and Alice Holt/Farnham grey wares for a regional distribution in the south will be utilized. For each group possible transportation routes, modes of transportation and costs will be evaluated.

5. Mortaria

Both imported and Romano-British mortaria have been found. Romano-British mortaria occur in large numbers on a wide variety of sites. Some have a country wide distribution and some only a local or regional market. Many of the Romano-British potteries also produced mortaria, but some manufactures specialized in this genre. Imported mortaria would have entered Britain from the continent at the various ports on the south and east coasts. From the port of entry they would probably have used the established internal distribution system. Many appear to have been sold close to the port of entry. For example, North Gaulish mortaria from the Pas de Calais are concentrated in London, Colchester and Kent (Tyers 1996:126). On the whole, finds of imported mortaria are sparse and scattered. Mortaria are often stamped with the potter's name stamp. Some potters moved from one workshop to another, and their movements can be traced by the stamps. Imported mortaria from North Gaul, Eifel, Aosta, Rhône valley, Italy and Soller have been found. In Britain eleven major manufacturing sites are known, while local small-scale potters made a few mortaria for local consumption. Of the eleven Romano-British types,
four were manufactured for most of the Roman period, and had country wide or regional distributions. These are the ones selected for study here.

5.1. Imported Mortaria (Tyers 1996:116-35)

a. Aosta Type
   Imported: AD 50-85
   Source: Aosta
   Distribution: occasional in Britain

b. North Gaulish Types
   Imported: AD 55-100.
   Source: North Gaulish.
   Distribution: largest numbers in Colchester, London and Kent areas; otherwise a small number scattered widely.

c. Rhône Valley Types
   Imported: AD 50-100.
   Source: Rhône valley.
   Distribution: other than some in London, a sparse distribution.

d. Soller Types
   Imported: AD 50-220.
   Source: Soller, near Köln.
   Distribution: several examples from St. Magnus House, London deposits: otherwise widespread but thin distribution.

e. Eifel Types
   Imported: pre-Flavian.
   Source: Eifel, Germany.
   Distribution: occasional on pre-Flavian sites in the south.

5.2 Romano-British Mortaria (Tyers :116-35)

a. Colchester Mortaria
   Production: c. AD 50-55 to AD 230.
   Source: Colchester, but also East Anglia and possibly Kent.

b. Mancetter-Hartshill Mortaria
   Production: c. AD 100-400.
   Source: Mancetter and Hartshill on Warwickshire/Leicestershire border. Many kilns excavated and recorded.
   Distribution: Midlands and the North.
c. Nene Valley Mortaria
Production: c. AD 10 to fourth century.
Source: Castor-Stibbington area in lower Nene valley.
Distribution: eastern England from Thames basin to the northern frontier: also abundant in East Midlands.

d. Oxfordshire White-ware Mortaria
Production: c. AD 100 to late fourth century.
Source: Oxfordshire potteries.
Distribution: second century distribution largely Oxfordshire and surrounding counties. From early third century spread to London basin, Kent, and later to East Anglia and the south-west.

6. Imported Terra Sigillata (Tyers: 105-116)

Terra sigillata, or samian wares, the classic red-gloss wares of the early Roman period, appear in pre-conquest sites in Britain. The fabric originated at Arezzo (Etruria). Later workshops were set up at Lyon, La Graufesenque (southern Gaul), Lezoux, and Les Martres-de-Veyre in central Gaul, and at sites in the Rhine area. A small workshop produced red-gloss wares at Colchester in the Antonine period. Five imported wares are considered for the purposes of this paper, together with the Colchester output.

a. Italian Type Sigillata
Imported: from about 45 BC.
Source: Arezzo, Pisa, Puteoli, and provincial workshops in Spain and Gaul.
Distribution: central southern Britain and the south-east, particularly Essex and Herts (this suggests Camulodunum as the port of entry)

b. South Gaulish (La Graufesenque) Terra Sigillata
Imported: late Augustan to AD 100-200.
Source: La Graufesenque near Millau.
Distribution: fairly extensive distribution around England and southern Scotland.

c. South Gaulish (Montans) Terra Sigillata
Imported: Augustan to late Antonine period.
Source: Montans in Aquitaine.
Distribution: wide but thin distribution in Britain.

d. Central Gaulish Terra Sigillata
Imported: Augustan-Tiberian to later second century.
Source: Lezoux and Les Martres-de-Veyre.
Distribution: First century AD common along the Loire and in Brittany, and thence to Britain. At first more common in south and west, later abundant throughout Britain.
221. Appendix F

e. East Gaulish *Terra Sigillata*
Imported: significant export to Britain from c. AD 120-260
Source: Argonne Forest, Moselle and Rhine valley.
Distribution: throughout Britain, but less common in west: largest concentrations in the south-east.

f. Colchester *Terra Sigillata*
Production: AD 155-180.
Source: Colchester, kiln 21.
Distribution: rare at Colchester, restricted to East Anglia: one outlier at Newstead.


Apart from *terra sigillata*, amphorae and mortaria, two other types of pottery were imported, fine table wares, principally in the form of cups, beakers and plates, and coarse wares from many sources. In general the imported coarse wares form only a small part of assemblages, and may have come as ballast or to fill space in the hold of cross-channel trading vessels. From Mediterranean underwater sites, such as the Madrague de Giens wreck of a ship with a cargo of amphorae, it is known that it was quite usual to supplement the main cargo with crated fine and coarse wares (Parker 1992a:249-250, Tchernia et al 1978). Thirteen types were not imported after the late first century AD, and two types first appear in the fifth century and later. These are not considered in this thesis. They precede the establishment of stability and normal civilian life in Roman Britain.

Three types, North Gaulish grey ware, Lower Rhineland colour-coated wares, and North African red slip appear by the late first century AD, and in the case of the African red slip continue until the end of Roman Britain. Six other types from Gaul and Germany are found in Britain, but they are either rare, or have a very local distribution. These nine types are listed below.

a. *Argonne Ware*
Imported: late third century to at least AD 450.
Source: Argonne region east of Rhine.
Distribution: widespread but sparse in south, concentrated around estuaries of the Thames and Solent: occasional sherds in north and west.

b. *Central Gaulish Black-slipped Ware*
Imported: AD 150 to early third century.
Source: central Gaulish *sigillata* workshops, Lezoux.
Distribution: appears throughout Britain, but not apparently in large quantities.

c. *Trier Black-slipped Ware* (Moselkeramik)
Imported: AD 180-250.
Source: Trier workshops.
Distribution: widespread in Britain.
d. Céramique à l’éponge
Imported: fourth century.
Source: western France, near Civaux (Vienne).
Distribution: scattered distribution in southern Britain, odd sherds elsewhere.

e. Lower Rhineland Colour-Coated Ware
Imported: Flavian period on, concentrated on beakers.
Source: Köln, kilns are known.
Distribution: mostly in south-east, with outliers in south and west.

f. German Marbled Ware
Imported: early or mid third century to late fourth century.
Source: middle Rhine and Moselle valleys.
Distribution: Kent and London area.

g. Late Roman Mayen Ware
Imported: from c. AD 300-450.
Source: Mayen.
Distribution: Concentrated in the south-east, with c. 90% from Canterbury, Richborough, Colchester and London.

h. North African Red Slip Ware
Imported: second to fourth century in Britain.
Source: Tunisia.
Distribution: sparse in Britain.

i. North Gaulish Grey Wares
Imported: Flavian to third century.
Source: Nord and Pas de Calais regions.
Distribution: concentrated in the south-east and up the east coast: absent in southern, western and central England and Wales.

Of the nine fabrics listed above only Trier black-slipped ware appears to have a wide distribution in significant numbers. The three wares from Germany, Lower Rhineland, German Marbled and Late Roman Mayen are concentrated in the south-east, while North Gaulish grey wares appear mostly in the south-east, but also up the east coast to Hadrian’s Wall and beyond. Only the five wares listed in this paragraph will be used in this paper.

7. General Discussion of the Imported Pottery

Imported pottery could have arrived in Britain in different circumstances:
a. As a full ship load of pottery heading for a definite market, either as a speculative venture, or to fulfil an order from a merchant or middleman at the port of entry, or as part of
a military supply contract.

b. As part of a mixed general cargo, with the same possible customers as in a. above.

c. As additional ballast or to fill spaces in the hold to prevent the main cargo from shifting. The captain or shipper would hope to sell the pottery, but failure to obtain a satisfactory price would not necessarily make the voyage unprofitable.

d. As part of the personal possessions of military or government officials arriving in Britain to take up an official post, or the possessions of people from the wealthier classes relocating to Britain to set up a business or buy land. The odd sherd could even reflect the arrival of craftsmen or others from banausic occupations following their trade, for example a painter or mosaicist bringing the odd valued possession with him.

The *terra sigillata* imports appear to have used ports of entry both in the east, probably Camulodunum, London and in Kent, and in the south ports of entry from the Isle of Wight area to Poole Harbour. With these ports of entry the imports could then utilize the established distribution system used for Romano-British pottery. Other imported wares, apart from Trier black-slipped ware, cluster closely around the ports of entry in the south-east. From there they would have used the local distribution systems to reach the nearby points of sale.
APPENDIX G

Salt Production, Consumption and Distribution in Roman Britain
225. Appendix G

APPENDIX G

Salt Production, Consumption and Distribution in Roman Britain
(See Figs.App.G.1 and G.2)

1. Introduction

Salt Production in Roman Britain utilized two sources for raw material, sea-water, or brine springs or wells in the Cheshire area, where thick Triassic rock salt beds underlie large parts of the county. In South Cheshire the springs were the focus of a well established pre-Roman Iron Age industry (Penney and Shorter 1996:360-5). At many coastal areas Iron Age salt production preceded Roman production at the same sites. No place in England is more than 96 km from the sea, so that access to salt supplies did not necessarily require a long haul for the finished product.

2. Salt Consumption

Salt would be used as a condiment for vegetable based foods, and as a preservative for meat, fish, cheese and other foodstuffs. With the evidence available it is somewhat difficult to determine what percentage of the total production was used for each purpose. Meat and fish can be preserved with a small amount of salt combined with drying and smoking. In the medieval period butter and cheese were salted. On the estates of the Bishop of Winchester at Overton in AD 1305 1 lb of salt was used for every 10 lb of cheese or butter produced (Bridbury 1955:xv). The Romans also used salt in cheese making (Columella Rust.7.8.1-5), and according to Varro "....they sprinkle it with a little salt and lay it down for the winter." (Varro, Rust. 2.11.3-4). For preserving hams Cato describes the process and he specifies "....a half modius of Roman powdered salt for each ham." (Cato, Agr.162). Columella provides instructions for pickling herbs, preserving olives, vegetables, cheese and fruit. A half-modius is about 4.4 litres, and 1 litre of powdered rough salt weighs about 1.45kg, or a half-modius of salt is about 6.4kg. Production of garum needed one or two parts of salt to every eight parts of fish (Adshead 1992:34). It would appear that significant amounts of salt were used for preserving food, as well as in cooking and as a condiment. Cato on rations for farm workers says "One modius of salt per person per year is sufficient." (Cato, Agr. 56-59). One modius of salt weighs about 12.8 kg, which converts into 35 gm per person per day. In western society today adults consume up to 10 to 12 gm of salt per day, many times the amount needed for good health (Engel 1993:109). In both modern and traditional societies minimum consumption for health should be about 0.6 gm per day, or about 0.22 kg per year. Actual consumption is about 2.27 to 4.54 kg per year (Adshead 1992:7). These figures suggest that Cato’s allowance of salt included amounts required for use as a preservative, and possibly other non-food uses. Millett has estimated that the population of Britain in the early third century AD at about 3,665,000, which includes the army, and the urban and rural populations (see Appendix B, p.186). In antiquity salt was a valuable commodity, and was probably used on a less prodigal scale than in today’s western world. A large part of today’s excess salt consumption comes with fast, fried and snack foods. Taking the average salt requirement at
about 5.5 gm per day, or 2.0 kg per year (the mean of the modern western use), Britain would need to produce about 7,330 tonnes of salt per year for seasoning food. Using Cato’s figures of 12.8 kg for all purposes suggests that about 10.0 kg per person per year might be needed for other purposes. These could include both food preservation and some manufacturing or industrial purposes, for example in leather processing. This quantity is small compared with the weight of grain or stone moved, but even if it were all moved by sea, it would only need 15 ships of the size of the Blackfriars 1 trading ship. In practice much of the salt was probably distributed over distances of a few tens of km, using inland water transport and road vehicles or pack animals. One pack load per year could meet the requirements of a small community for a year. One ship could carry all the salt needed to certain areas in the north, such as Hadrian’s Wall and the Antonine Wall from a production area in Lincolnshire or Essex.

3. Salt Production

Salt remains in solution until a critical concentration is reached, and above this concentration solid crystals form. The wet crystals can then be scraped or raked out of the container. Extracting salt from sea-water or brine springs uses this phenomenon. The water content is reduced by natural evaporation, or by a combination step-wise process using natural evaporation followed by heating, or in the case of brine from springs by direct heating. In general it is easier to produce salt from natural brine than from sea-water. Brine has a natural salts concentration of about 26%, while in sea-water the salts make up only about 3%. A further advantage of brine is that it contains fewer undesirable components, containing mostly sodium chloride (common salt) and a very small amount of calcium sulphate. In sea-water, as well as these two salts, magnesium compounds that impart a bitter taste to the end product are present. Fortunately the various salts crystallize out of the solution at slightly different temperatures, and the undesirable ones can be minimized by careful control of the process (Bridbury :3-10).

4. Roman Salt Production Sites in Britain

An examination of the articles and indexes in the Journal of Roman Studies from 1923 to 1979 produced no information on salt-making sites. Articles and notes from Britannia 1970-2001 list forty-five places or areas with archaeological evidence for one or more Roman salt-working sites. A certain number of sites have been published more fully in site excavation reports, for example: Bell, Gurney and Healey 1999; Fawn, Evans, McMaster and Davies 1990; Gurney 1999; Hurst 1997; and Woodiwiss 1992. The

---

1 About 460 ships of the Blackfriars Ship 1 type were needed to carry grain, page 171. Thirteen ships of the same size could have moved all the salt, but in practice little would have been shipped by sea. Most would have moved by land or inland waters.

2 Salt has a specific gravity of 2.163. The Blackfriars Ship could carry about 37 tonnes.
excavation reports are often publications of the local archaeological and antiquarian societies, and in many cases have a limited circulation and are difficult to acquire. In time a number of the Britannia articles notes may appear as independent reports, but at this time the Britannia reports appear to be the most useful sources on the number of sites.

a. **Brine Sites** (The numbers in brackets after each site are the volume and page numbers in Britannia)

**Cheshire**
- Middlewich (1:282, 5:419, 6:242, 29:391) SO 91 63
- Nantwich (18:287-8) SJ 71 61
- Shavington (27:360-5) SJ 70 51

**Hereford and Worcestershire**
- Droitwich (7:331), (8:396), (9:439), (10:299), (15:363), (23:283) SO 90 63

b. **Sea-water Sites** (Map references are given after the Britannia reference)

The known sites are concentrated from Lincolnshire through East Anglia and around the south coast from Kent to Cornwall and Somerset. Salt may have been produced on a minor and domestic scale not only on the east and south coasts, but also on the much wetter and more humid west coasts of Wales and England. The climate and lack of salt marsh type features generally militate against large scale production on the rock-bound parts of the west coast. On the domestic scale one or more pottery pans or pots filled with sea-water could be kept in the dwelling near the hearth or cooking fire. The water would slowly evaporate, and if regularly topped up with sea water, salt would start to precipitate.

**Lincolnshire**
- Addlethorpe (30:343) TF 54 69
- Car Dyke (10:186-7) TF O2 to TFO4 west to east, and 00 to 05 north to south
- Ingoldmells (12:335-6) TF 56 69
- Market Deeping (23:283) TF 14 10
- Lincolnshire Fens (7:325) Survey between River Slea, TF 177497 and Bourne, TF 096 202, covering an area 25 km long and 3 km east to west, with large scale Roman salt recovery industry along eastern edge.
- South Lincoln Fens (19:447. 185 sites were identified in a field survey of 35750 hectare)
- Spalding (29:392) TF 25 21
- Wrangle (21:232) TF 45 52

**Cambridgeshire**
- Coldham (12:94) TF 43 02
- Norwood (12:106-11) TL 42 98
- Peterborough (6:253) TL 19 99
- Upwell (11:375) TF 51 02
Norfolk
Middleton (23:288) TF 56 01
Nordelph (24:301) TL 52 99
Walsoken and West Walkin (15:365. Eighteen sites identified) TF 48 11

Suffolk
Sudbourne (30:351) TM 42 54
Trimley St. Martin (30:352) 25 36

Essex
Maldon (4:205) (Maldon sea-salt is still produced today) TL 85 07
Peldon (5:442-4) TL 99 17, TM 00 15
Tollesbury (9:452) TL 9511

Kent
Scotney Court Pit (22:291-2) TR 24 37

West Sussex
Chidham (21:359), (23:27-44) SU 78 03

Dorset
Cleaval Point (11:390) SZ 00 86
Rope Lake (7:362) SY 93 77

Cornwall
Carnegoonbank (10:326) SW 69 13
Trebarveth (1:298) 79 19

Somerset
Bridgeworth (7:357) ST 39 39
East Huntspil (10:323-4) ST 44 34
Pawlett (29:421) 30 43

The total number of sites noted from Britannia in the thirty year period is about 240, with the sea-water sites being heavily concentrated in East Anglia and Lincolnshire. The brine sites are in Cheshire, Hereford and Worcestershire. This compares with the Domesday survey of AD 1086, which listed 1195 salinae along the coasts between Lincolnshire and Cornwall, with 619 in Lincolnshire and East Anglia, and 482 along the south coast from Kent to Cornwall (Bridbury 1955:19-20). The final processing of the sea-water salt production involved boiling, but to be economic it seems probable that some preliminary concentration would have taken place in large open ponds. Celia Fiennes noted this being done at Lymington on the Solent in the seventeenth century (Morris 1947:19), and it was still done in the late twentieth century at Guérande between the rivers Vilaine
and Loire on the Atlantic coast of France (Delbos and Jorion 1984:278-83). In the 1990s salt was still being harvested from lagoons at Alyki near Skala in Kolpos Kallonis, a narrow-mouthed but extensive bay on the south coast of the Greek island of Lesbos in the Aegean (personal observation). It is also reported from the lagoon at Motya, a large commercial enterprise north of Marsala in western Sicily. There is even a museum of the industry there (personal communication from Dr. James Russell).

The 240 identified salt producing sites can only be a part of the total number that existed. The Domesday figure, based on a fairly exact count of 1195 sites may be closer to the actual total in the Roman period. With 1195 sites, this would require an average output per site of 36.8 tonnes per annum, or about 100.8 kg per day. If alimentary salt at 7,330 tonnes per year were the principal product, this would need an output of 20 kg per site per day.

For a brine-based site this would require the processing of 100kg of brine per day. In 1996 an almost complete inscribed Roman lead salt pan was found, with dimensions of 100cm x 90cm x 14cm deep (Penney and Shotter 1996:360-5). When full, this would hold 126 litres of brine, and would be quite capable of producing 26 kg per day of salt.

For a sea-water site, primary concentration by evaporation would be essential for economy in fuel. Apart from increasing the concentration of salt in solution, in both the brine and sea-water industries, settling tanks or lagoons were needed to settle out particulate material. At Droitwich in the brine based industry, clay and timber lined settling tanks with a capacity of about 3,000 litres each have been excavated (Woodiwiss 1992:13-14). In Essex, in the sea-water based areas, clay lined settling tanks have been excavated at Leigh Beck (CA 2001, No. 174:244), Goldhanger and other sites (Fawn et al:1990:8). In Hampshire, at Chichester Harbour, similar features have been found (Bradley 1992:41).

For the final boiling of the concentrated salt solution at the coastal sites it appears that pottery troughs placed over long trench-like hearths were used. The largest examples found to date are from Ingoldmells in Lincolnshire, and are about 75 cm long by 25 cm wide (Swinnerton 1932:239-53). From an Iron Age site at Helpringham in Lincolnshire trough fragments were recovered among the briquetage from troughs about 30 cm long and 14 cm wide (Healey 1999:17, Fig.8). From a Romano-British site at Shell Bridge, Holbeach St. Johns in Lincolnshire fragments from troughs about 60 cm long, 20 cm wide and 7-8 cm deep were recovered (Gurney 1999:56, Fig. 40). The briquetage from troughs is thicker, at Chichester 10' to 16 mm thick, than sherds from other vessels which are 4 to 9 mm thick. The thinner sherds, which have also been found extensively on inland sites, were probably from transport containers as opposed to processing equipment (Bradley 1992:36-8, and 41-2).

It is possible that some at least of the sea-water sites for salt production were operated on an annual cycle, without the use of a final boiling. These would be difficult to identify in the archaeological record, as the standard marker for a salt-making site is the presence of large quantities of briquetage with signs of burning, for example the "Red Hills of Essex". On the Atlantic coast of France between the rivers Loire and Vilaine, an extensive and complex series of channels, shallow lagoons a few cm deep, and ponds 50 to 80 m square for final crystallization were worked into the twentieth century. The winter was used to clean out and re-furbish the system. In April to May sea-water was admitted to
the system, and using natural evaporation from wind and sun a harvest of salt was made in
the summer to early autumn depending on the weather patterns (Delbos and Jorion
1984:278-83).

5. Discussion and Conclusions

In general it would appear that both Late Iron Age and Roman Britain could meet
their requirements for salt from indigenous resources. Because of the widespread
occurrence of sea-water salt making sites in the east and south, much of the distribution
network would be local or within a small region. Central England could have been supplied
either from the Cheshire to Hereford brine sources, or from the Lincolnshire sites. The
north above the line from the rivers Humber to Mersey, could draw on either source, but
this would involve a more extensive transportation network using both water-borne and
road transport. The normal shipping container would appear to have been a coarse ware
pot. As noted above, from the Chidham site the thinner sherds from the final production
stage areas are of similar dimensions and fabric to those found at inland sites, where the salt
would have been consumed. Bradley also raises the point that some evidence suggests that
a number of coastal sites ceased production in the second century AD. With the growth of
Roman towns it may have been more attractive to make salt by more intensive methods at
fewer sites (Bradley 1992:42). For transportation, a certain amount to major areas of
consumption such as London and the northern military centres would move in coastal
shipping. Smaller centres and inland areas would have been served by a mix of land
transport and river borne cargoes. Consignments of salt in their coarse pottery containers
were probably carried as part of mixed cargoes. Because production at many sites,
particularly the inland brine sites, would be continuous, distribution would be on a frequent,
possibly daily basis. Unlike grain with one annual crop, there would be no need to store a
year’s supply of salt in the settled parts of the country. The exception would be the
northern military area, where weather in winter could disrupt sea supply for long periods,
and even land transport could be difficult to advanced forts and lines of defence. Salt in
these circumstances could be stored in a small dry building in bulk or in large pottery jars.
Storage is practiced at Motya, where the salt piles are protected by terracotta tiles (personal
communication from Dr. James Russell).
APPENDIX H

Masonry, Quarries and Gravel Pits
APPENDIX H

Masonry, Quarries and Gravel Pits

1. Introduction

Quarried stone in terms of weight and volume was one of the largest cargoes transported in Roman Britain, particularly in the second century AD when many towns started building defensive stone walls. As far as practicable local sources would have been used, because of the problems and cost of moving the immense quantities involved. For example, the stone and clay core material for Hadrian’s Wall, totaling 3,713,500 tonnes, was quarried from sites close to the wall, and would have been hauled in carts or wagons. It has been calculated that if the Wall took ten years to build, 1,500 load carrying vehicles would have been needed, plus 7,100 draught-animals (Kendal 1996:146-7). The earlier “Forts of the Saxon Shore”, probably dating to the late second or early third century A.D., also used imported as well as local stone. At Brancaster stone from the Weald was used for facing, and at Bradwell Lincolnshire limestone was used in both large and small blocks. At Reculver, greensand from either the Medway or Folkestone area was used (Allen and Fulford 1999:175-76). In London, in the third century riverside wall and an unidentified monumental building, Lincolnshire limestone fragments from earlier buildings were reused (Hill et al.1980:198-200; T. Williams 1993:88-91,100-1). These are just some examples.

As well as quarried and dressed stone the Romans used immense amounts of gravel for foundations and surfacing, and quantities of sand and limestone for making mortar. Graveled surfaces are mentioned in almost all excavation reports on forts, cities, towns and small towns, and roads. Much of the gravel was dug from local “borrow pits” close to the site under construction, see Annex 1. Gravel and sand can be dug out of pits, but it requires less human energy to extract it from the beds, banks or benches, which can be found along the course of many active or dried up river beds. As an example of the volumes used, at the fortress of Inchtuthill Shirley has estimated that 16,800 cubic metres of gravel were used for surfacing and other purposes (Shirley 2000:87). At Cirencester Wacher has estimated that 84,000 cubic metres of gravel or stone rubble were needed each time the streets were resurfaced (McWhirr 1982:23).

This Appendix records the results of a literature search for published work on quarries in Roman Britain. The immediate conclusion from this preliminary search confirms Blagg’s comments in his Britannia article:

1 There are three annexes to this appendix:
Annex 2. Notes on Quarries along Hadrian’s Wall
Annex 3. Notes on Roman Masonry in Britain

2 Allen and Fulford, commenting on the relatively local collection of some masonry for these forts, write “ships might have beached empty at low tide, then loaded and floated off at high tide.” (Allen and Fulford:178)
Blagg has commented:

The number of quarries which can be positively identified as having been worked in the Roman period in Britain is small. Handbridge, outside Chester is one, and the area of Hadrian's Wall has produced a well known series of quarry inscriptions (Blagg 1976:155).³

2. Quarries and Pits

Using the publications on Hadrian's Wall (Breeze and Dobson 1978, Bruce 12th ed. 1966, Daniels 1989, and Johnson 1989), about eighteen fairly certain Roman quarry sites have been identified. These are listed in Annex 2 to this appendix.

Two reasonably substantial quarries have been reported from Cirencester (McWhirr, Viner and Wells 1982:31) and from the fortress of Inchtuthill in Scotland (Pitts and St. Joseph 1985:42,61, 255-7). The quarry at Cirencester was backfilled while quarrying was in progress to gain access to new working faces. It has also been largely levelled and overlaid by later activities, including a Roman cemetery. The quarry at Inchtuthill has been identified. It lies about 3.2km northwest of the fortress, cut into the southeast face of the Hill of Gourdie. It is about 190m wide, about 43m to 64m from front to back, with a working face about 9m or more high. The estimated volume of stone quarried and used in the building of the fortress is 35,944 cubic metres. The largest amount was 25,000 cubic metres for the main bath house, followed by 6,850 for facing stones on the defensive wall. Lesser amounts were used for ovens, the small bath house, the senior officer's house and the latrines (Shirley 2000:72, Table 5.29). The quarry site is overgrown, and to date no excavation or other investigations have been reported. The Inchtuthill quarry may be the best preserved large Roman quarry in Britain. It is in a relatively isolated area, far from major urban centres, and there seems to be no sign of it having been worked in the post-Roman period. It may be well worth a survey, and possibly excavation. One problem may be (and this is a general difficulty with sandstone and other soft stone quarries with the faces left exposed to the weather) that time and erosion from rain and frost may have obliterated the tool marks and other evidence for quarrying techniques. At Cirencester the working faces were preserved only because the quarry was backfilled immediately after use.

From the annual summary of excavations in the Journal of Roman Studies 1923 to 1969 and Britannia from volumes 1 to 32, 1970 to 2001, seventy-one "quarry" sites have been noted. These are listed with brief notes in Annex 1 to this Appendix. A summary of the types of quarries reported is given in Table 1 below.

³ The Handbridge quarry is described by Thompson (Thompson 1965:52-53). Directions for locating the inscriptions along Hadrian's Wall are given by Helm (Helm 1975:78). Inscriptions are in RIB I: 998-1016.
### Table App.H.1: Types of quarry

<table>
<thead>
<tr>
<th>Type of Quarry</th>
<th>Number Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone quarries</td>
<td>13</td>
</tr>
<tr>
<td>Gravel quarries/pits</td>
<td>29</td>
</tr>
<tr>
<td>Clay quarries/pits</td>
<td>5</td>
</tr>
<tr>
<td>Brickearth quarries/pits</td>
<td>5</td>
</tr>
<tr>
<td>Unspecified material</td>
<td>19</td>
</tr>
</tbody>
</table>

Most of the quarries or pits where no material type was reported appear from the published context to be probable gravel pits. Of the seventy-one quarries reported in the past seventy-eight years, most were small. A few were designated "large" by the excavators, and the two for which dimensions were given were about 6m x 7m and 27m across respectively, not large by Mediterranean standards or even in comparison with Inchtuthill, Handbridge and Cirencester.

Stone types quarried were principally varieties of limestone or sandstone, with some dolerite along Hadrian's Wall. Much limestone would have been burnt for the production of quicklime for mortar. There is evidence for this from two limekilns at Richborough (Cunliffe 1968:48, 249), and at Inchtuthill lime for mortar was quarried from a site south of the Loch of Clunie, about 3.6km north of the fortress (Pitts and St. Joseph 1985:46).

Flint nodules set in mortar were commonly used in the southeast, and were probably collected from the surface rather than quarried (J.H. Williams 1971:170). Chalk was quarried in the southeast, but is not a very satisfactory building material. A large chalk quarry pit has been identified at Lakenheath (P. Cambridge A.S. 1963, 55-56:34ff), and another at Greenhithe with some worked chalk blocks (Arch. Cant. 1966, 81:142). In the north Magnesian limestone blocks, a little better as a building material than chalk, were used at Well, Yorkshire (Gilyard-Beer 1951:38). Chalk decorative and architectural elements were used at the Bignor villa in Sussex (Winbolt and Herbert 1934), and in the fourth century reconstruction at Park Street (O'Neill 1945:55). At Park Street the chalk blocks were used with other inferior materials for interior partition walls.

There are probably two principal reasons for the small number of reported Romano-British quarries. The first, as McWhirr has noted, is that it is highly probably that the Roman quarries with better material were worked in later periods for the medieval and renaissance building programmes in stone, thus obliterating the earlier workings (McWhirr 1982:24). The second reason would be a general tendency to exploit local sources to minimize transport costs, both for the construction of buildings and the building of the Roman road network. This would produce large numbers of small quarries or borrow pits, which have either been obliterated by time and subsequent activities, or which have not been recognized as Roman workings. A few examples of clusters of small gravel pits for road works have been found. At the Roman bridge and road site across the River Nene at Aldwincle, Northamptonshire, extensive gravel pits for road construction have survived and were noted (Britannia 7, 1976:40). On Dere Street, about 6.5 km north-west of Oxton in Borders and south of Soutra Aisle (NT 452581), where the road crosses the pass over
Soutra Hill, gravel pits used as a source for road construction have been noted, and are still quite visible.

3. Materials Quarried

Other than Purbeck marble and some of the Cotswold stones, there are no high quality decorative rocks in Britain suitable for elite or prestige buildings. Thus there would be no inducement to go farther than necessary to obtain adequate functional building materials, with satisfactory structural and durability qualities. Stone suitable for roofing tiles tended to be concentrated in limited areas, and was shipped rather more widely (McWhirr 1982:24.).

Timber was the principal building material used in early Roman Britain, and stone structures, as opposed to field stone foundations, did not become widespread in Britain until the second century AD (de la Bédoyère 1991:18). Stone for buildings was first employed for imperial, army and civic structures, with lime based mortars as the bonding agent. There are very few buildings in Britain using monumental sized pieces of stone. Exceptions are structures such as the Temple of Sulis Minerva and the second Great Bath building at Bath. From an examination of the remains of hundreds of Roman stone structures, whether military, civic or domestic, one gains the distinct impression that masons preferred modest sized blocks, easily handled by one or two persons. Where necessary or economical, courses of tile or brick would be used to bond the walls or lighten the structure. Barrel vaults of any size were rare and most large civic buildings, and practically all domestic ones, appear to have had pitched roofs, with terracotta or stone tiles, or slates as the covering. Some small built vaults were used. With these building techniques small stone blocks could be quarried locally from convenient outcrops or pits. Faulting and cracks would be of far less significance than in a quarry aiming to produce large monolithic blocks for en-lit columns, other large architectural members, sarcophagi or blocks for monumental statuary.

4. Discussion and Conclusions

The combination of a need principally for small cheap blocks, for minimum transportation costs and a lack of highly skilled quarry workers would tend to favour small local quarries, serving the local urban centre, or even just a single building such as a rural villa. Compared with quarrying techniques on the continent, and particularly in the Mediterranean basin, those in Britain appear simple, if not crude. There is solid evidence from a number of sites for the cutting of wedge slots in the bedrock for detaching blocks, and the cutting of louis/lewis holes for lifting purposes. The technique of cutting a trench around three sides and then breaking the block free from the bedrock with wedges does not

4 Stone bathhouses were an exception, in that they tended to have vaulted roofs over at least some of the structure.
appear to have been used in Britain. Saw marks are extremely rare on any Romano-British masonry, and saws were almost certainly not used in quarries (Blagg 1976:155).

For roads, as far as practicable, local borrow pits immediately beside or close to the line of the road would be worked to provide the gravel and stone for the foundations and surfacing. Similar considerations seem to have applied to the building of Hadrian's Wall, where very localized quarries were used to supply stone for the Wall, its turrets, milecastles and forts.

Reports of the excavations in the London area in the *Journal of Roman Studies* and *Britannia* note that a very large number of gravel pits were exploited in the first century AD, and then later backfilled and built on as the city grew.

In summary, it would appear that Roman quarrying activity in Britain was almost entirely limited to small or very small local quarries or pits to supply an immediate local need. Only a few types of stone, Kentish ragstone, Purbeck marble, Bath and Cotswold stones and roofing slates were quarried on a large scale and transported any distance. Many if not most of these workings, both large and small, have been obliterated by later human developments, or by simple weathering, erosion and silting up.

In more remote areas the small pits may still exist, but are difficult to pick out and identify unless associated with a known Roman building, road or feature, as at Aldwincle (see page 228), or with Romano-British artefacts.

Of the larger quarries, Handbridge and the Querns at Cirencester have been excavated and published. The quarry for the Inchtuthill fortress in Scotland at the Hill of Gourdie would appear to be worth a reconnaissance and preliminary survey. If the survey were to find a reasonable number of working faces in fair to good condition, then this quarry might justify a full survey and selective excavation.

From a transportation standpoint a substantial part of quarried materials would have used land transport, carts and wagons. Inland rivers could have been used where the distance was long enough to justify the double handling, from cart to boat at the point of shipment, and from boat to cart at the destination. For example, Cotswold stone could be shipped down the Thames in small shallow draft barges to London. Portland stone and Kentish ragstone would use coastal craft, such as the Blackfriars Ship 1, to supply customers outside the immediate area of the quarry. In the coasting trade some stone could have travelled as ballast or part cargo, along with foodstuffs or other low density perishables (Allen and Fulford 1999:178-9). In some cases, such as the supply of Kentish ragstone to build London's stone defences, quarried stone would have been the major cargo, carried in a large number of ships and voyages.
Annex 1 to Appendix H: A Note on Romano-British Quarries

Notes on Quarry Sites Reported in Britannia, 1970-2001

Quarries, Gravel and Clay Pits
Annex 1 to Appendix H: A Note on Romano-British Quarries


Notes:
1. There were no articles on quarries in the Journal of Roman Studies.
2. Under each volume of Britannia the sites are listed in alphabetical order. In the case of London, if more than one site was reported in an issue, the London sites are arranged under the heading "London". In a few cases London has been subdivided further.
3. For each site the modern name, and where known the Roman name, is given, together with the county for the lesser known sites. On the same line the type of material in the quarry is given, followed by the page number in Britannia. On the next line the map reference is given.
4. Entries in quotation marks are direct quotations from Britannia. Those without quotation marks are a précis of the text in the journal.
5. Volumes with no relevant material are not shown.

Britannia 2, 1971
Kelvedon (Canonium), (Essex) Brickearth 273 (TL 865190). Two quarry pits for brickearth with pre-Flavian Samian ware at the bottom.
Various sites Various stones
Large chalk quarry pit at Lakenheath. One at Greenhithe with tooled chalk blocks 170
Greensand, a much superior building material to chalk, quarried from local pits at Little Chart, Eccles, Bignor, Rapsley, Petersfield. 172
Ferruginous sandstone, probably from Aldersholt Heath, used for fourth century walls at Rockbourne villa. 174
Purbeck limestone from either Purbeck or Swanage used for roofing 'slates'. 178
For limestone the most important quarries were located at Portland, Bath and North Oxfordshire at Barnock, Ketton, Weldon and Clipsham. 180

Britannia 4, 1973
Chelmsford (Caesaromagus), (Essex) Unspecified 301 (TQ 944967). At Orchard Street, "late features included small quarries".
Cirencester (Corinium Dobunnorum) (SP 030016). Romano-British cemetery between the town and the amphitheatre on the site of an early Roman quarry.

Deanshanger Villa (Northants) (SP 770396). Gravel quarries, mid first to third century A.D.

Godmanchester (Huntingdon) (TL 246705). St. Ann's Farm: Ermine Street flanked by quarry pits, filled in in the later first century.

Heybridge (Essex) (TL 850082). Site at Crescent Road, "an area of early Roman gravel digging".

Sea Mills (Abonae), Bristol (ST 558137). Excavations in the grounds of Nazareth House revealed a series of quarry pits in use in the early to mid second century.

Wakerley (Northants) (SP 940983). "Evidence of Roman quarrying" at an ironstone quarry.

Weston Wold Villa (Yorkshire) (SE 974279). A chalk quarry found. Villa in use from second half second century to fifth century A.D.

Britannia 5, 1974
Ancaster (Lincolnshire) (SK 983437). "A small scale gravel working area, perhaps associated with a nearby first century fort."

Chesterholm (Vindolanda) (NY 769663). Buff sandstone building stone, 0.29 x 0.22 x 0.15m from field wall enclosing vicus. Lower right hand marked XVI. Probably marked a batch at a quarry.

Hetha Burn (Northumberland) (NT 881275). Internal Phase III (late Roman) quarry associated with local settlement houses.

Britannia 6, 1975
Bishop Rigg (NW of Corstopitum) (NY 978652). Roman gravel digging. "Bishop Rigg is the only convenient source of gravel for Corstopitum and nearby lengths of Dere Street and the Stanegate, and there were numerous Roman gravel pits both large and small."

Manless Town (Gloucestershire) (SO 928116). 1.5km south-west of Brimsfield: "a Roman stone quarry was found at the site of a deserted medieval village....The rock here is a flaggy limestone suitable for use in making roof tiles and known as Througham Tilestone."
Aldwincle (Northants) Gravel 40
(SP 999801). A Roman road bridge across the River Nene was excavated and extensive Roman gravel quarrying was observed on both sides of the road west of the bridge.

Bidford-on-Avon (Warwickshire) Gravel/Sand 332
(SP 099519). "A large filled in sand and gravel quarry 27m wide and associated with second century pottery."

Odell (Bedfordshire) Gravel/Sand 336
(SP 956568). Several sand and gravel pits up to 6 x 7m, dating to the first century A.D.

Purbrook (Hants) Clay 366
(SU 686074). Crookhorn Farm, Roman clay pit dating to second and third centuries.

Various Sites Various Stones

Blagg, T.F.C.
The number of positively identified Roman quarries in Britain is small. There are a number along Hadrian's Wall. One has been identified outside Chester.

Cirencester (Corinium Dobunnorum) Unspecified 413
(SP 021015). "At Phoenix Way ....An early quarry was filled with massive deposits of silt before the mid third century."

Colchester (Camulodunum) Gravel 407
(TL 992248). At Butt Road gravel quarrying was noted below a later fourth century cemetery.

Leicester (Ratae Coritanorum) Gravel 392
(SK 579042). At Great Holme Street gravel pits lay under late first century industrial activity, pottery kilns.

London (Londinium), Southwark Gravel 410
(TQ 325799). In Borough High Street, two quarry pits of the mid to late first century.

---

1 They have been listed in:
Williams, J.H.

2 Noted in:
Thompson, F.H.
<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towcester (Lactodorum)</td>
<td>Clay</td>
<td>Appendix H, 399</td>
</tr>
<tr>
<td>London (Londinium), Tower Hamlets</td>
<td>Gravel</td>
<td>Appendix H, 408f</td>
</tr>
<tr>
<td>Spitalfields</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Britannia 9, 1978</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meldon Bridge (Peeblesshire)</td>
<td>Gravel</td>
<td>Appendix H, 418</td>
</tr>
<tr>
<td>Staines (Pontes)</td>
<td>Gravel</td>
<td>Appendix H, 468</td>
</tr>
<tr>
<td>Britannia 10, 1979</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cirencester (Corinium Dubonnorum)</td>
<td>Limestone</td>
<td>Appendix H, 319</td>
</tr>
<tr>
<td>Great Oakley (Northants)</td>
<td>Ironstone</td>
<td>Appendix H, 302</td>
</tr>
<tr>
<td>Little Houghton (Northants)</td>
<td>Clay</td>
<td>Appendix H, 302</td>
</tr>
<tr>
<td>Britannia 11, 1980</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kingscote (Gloucestershire)</td>
<td>Limestone</td>
<td>Appendix H, 385</td>
</tr>
<tr>
<td>London (Londinium) City Newgate Street</td>
<td>Brickearth</td>
<td>Appendix H, 380</td>
</tr>
<tr>
<td>Southwark</td>
<td>Gravel</td>
<td>Appendix H, 382</td>
</tr>
<tr>
<td>Britannia 13, 1982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kingscote (Gloucestershire)</td>
<td>Limestone</td>
<td>Appendix H, 378-9</td>
</tr>
</tbody>
</table>

Evidence for clay pits in the fourth century. At Artillery Lane excavation within the Roman cemetery area of Spitalfields revealed several pits probably dug for gravel and backfilled in the second century.
London (Londinium), Southwark, Sand/Gravel 377 (TQ 3241 7973). Borough High Street, "revealed evidence of quarrying for sand and gravel in the mid to late first century."

**Britannia** 14, 1983

Great Waltham, Gravel 350 (TL 699132). Large late Roman feature, probably a gravel pit.

London (Londinium), Cutler Street, Brickearth 351 (TQ 3340 8160). Shallow brickearth quarries of second to third century date.

Southwark, Hibernia Wharf, Gravel 353 (TQ 3270 8035). South-east part of site used as a gravel quarry in the first century.

**Britannia** 16, 1985

Chester (Deva), Unspecified 281 (SJ 406658). At Bridgegate House, "extensive quarrying in the earliest years of military occupation, but from the early second century on the quarry was disused and became filled with rubbish and peaty silt."

**Britannia** 17, 1986

Great Cansiron Farm (East Sussex), Ironstone 191 (TQ 4560 3835). Possible large Roman iron ore quarries about 1 to 2 km NE.

**Britannia** 18, 1987

Canterbury (Durovernum Cantiacorum), Clay 356 (TR 146576). 41 St. George Street, shallow clay pits were found.

Chedworth Villa (Gloucestershire), Limestone 337-9 (SP 052134). "West of Room 5, the triclinium, continued work has revealed a small limestone quarry."

Chelmsford (Caesaromagus), Unspecified 332 (TL 7055 0609). Behind Moulsham Street lay quarry and rubbish pits, dated to first and second centuries.

Chester (Deva), Stone? 320-1 (SJ 403649). South of the fortress, the face of the old river cliff quarried in Roman times.

London (Londinium)

Nos. 91-100 Gracechurch Street, Unspecified 333-6 (TQ 3340 8110). Early quarry pits sealed by thick layers of burning. Pottery of A.D. 60-80 above the burnt layer.

Minories, Brickearth 336 (TQ 3363 8116). Trench showed a series of massive brickearth quarries up to 2.5m deep.

Moorgate, Gravel 335 (TQ 3267 8147). A gravel pit backfilled in the second century.
<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Street Gravel 335</td>
<td>Gravel</td>
<td>(TQ 3228 8125)</td>
</tr>
<tr>
<td>Ironmonger Lane Gravel 335</td>
<td>Gravel</td>
<td>(TQ 3254 8123)</td>
</tr>
<tr>
<td>Sapperton (Lincolnshire) Gravel 322</td>
<td>Gravel</td>
<td>(TF 019327)</td>
</tr>
<tr>
<td>Swindon, Old Town (Wilts) Limestone 347</td>
<td>Limestone</td>
<td>(SU 1584)</td>
</tr>
<tr>
<td>Wareham (Dorset) White Clay 347</td>
<td>White Clay</td>
<td>(SY 9125 8490)</td>
</tr>
</tbody>
</table>

**Britannia 19, 1988**

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chedworth Villa (Gloucestershire) Limestone 465</td>
<td>Limestone</td>
<td>(SP 052134)</td>
</tr>
</tbody>
</table>

**Britannia 21, 1990**

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashstead (Surrey) Chalk 356</td>
<td>Chalk</td>
<td>(TQ 193581)</td>
</tr>
</tbody>
</table>

**Britannia 22, 1991**

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chedworth Villa (Gloucestershire) Limestone 274</td>
<td>Limestone</td>
<td>(SP 052134)</td>
</tr>
</tbody>
</table>

**London (Londinium)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 8 Austin Friars Square Gravel 266</td>
<td>Gravel</td>
<td>(TQ 3298 8139)</td>
</tr>
<tr>
<td>No. 11 Ironmonger Lane Gravel 267</td>
<td>Gravel</td>
<td>(TQ 3253 8128)</td>
</tr>
<tr>
<td>Mansion House Station Unspecified 267</td>
<td>Unspecified</td>
<td>(TQ 3234 8096)</td>
</tr>
<tr>
<td>Nos 62-63 Queen Victoria Street Unspecified 267</td>
<td>Unspecified</td>
<td>(TQ 3235 8096)</td>
</tr>
</tbody>
</table>
Wardrobe Court  (TQ 3189 8104). Trial excavation found brickearth quarries. 267
East Central.
Bishopsgate  (TQ 3311 8135), Roman period represented by quarry and rubbish pits. 267
Nos 1-4 Great Tower Street  (TQ 3316 8076). First and second century clay and timber buildings superseded by late Roman quarry. 269
Nos 145-6 Leadenhall Street  (TQ 3311 8115). Earliest features were gravel and brickearth quarries. Pits filled and levelled for later structures. 268

Extra Mural Areas.
Nos 274-80 Bishopsgate  (TQ 3380 8156). Earliest features brickearth quarries. 272
Nos 274-80 Bishopsgate  (TQ 3339 8184). A very large quarry pit, later filled with water and ponded, plus several smaller quarry pits. 272
Nos. 20-6 Cutler Street  (TQ 3344 81380). Early Roman gravel or brickearth pits. 272
Nos. 15-17 Eldon Street  (TQ 3296 8164). Early quarries cut into the natural gravels. 271

No 32 Furnival Street  (TQ 3121 8149). Trial excavation uncovered gravel pits. 271
Nos 24-30 West Smithfield, Cock Lane  (TQ 3181 8153). Earliest features Roman gravel quarries. 271

Outer London
Tower Hamlets  (TQ 3684 8351). At Armagh Road early Roman gravel quarries, later backfilled, followed by cultivation, and later by cemeteries. 272

*Britannia* 23, 1992
Chedworth Villa (Gloucestershire)  (SP 052134). Further details of the quarry recorded, including spade marks. 294
Cirencester (*Corinium Dubunnorum*)  (SP 0213 0173). At Sheep Street an early Roman quarry pit sealed beneath the street. 294
London (*Londinium*), Bishopsgate  (TQ 3327 8159). Early quarry pits backfilled in the second century. 291
Moffat (Dumfries and Galloway)  (NT 062082). Yoke Knowes Roman road: four quarry pits for Roman road noted and one excavated. At Muckle Hill (NT 062073) a further eight quarry pits noted. 266
**Britannia 27, 1996**

London (Londinium)  
(TQ 32538126). Ironmonger Lane.  
Roman quarry pit cut into natural gravels.  
(TQ 32498128). 15-17 King Street  
Brickearth  
(TQ 32068149). Little Britain, 10 King Edward St.  
Quarry pits: type not specified.  
(TQ 32698020). Southwark, Borough High Street Station  
Early Roman quarry pits, probably associated with construction of main north-south road.

Bristol (Avon)  
(ST 55437852). Kings Weston Road-Long Cross, quarry pits  
Late second to third century infant inhumations in area of quarry pits.

Doulting/Oak Hill (Somerset)  
(ST 638460). Beacon Hill. Remains of quarrying activity for querns, millstones and possibly hone.

**Britannia 28, 1997**

Chartham (Kent)  
(TR 111542). Roman chalk quarry 20m long by 17m wide: quarried in three phases, first to early second century.

Latton, Court Farm,(Wiltshire)  
(SU 0932 9528 to SU 0970 9494). Amorphous pits, probably gravel quarries for the Roman road (Ermine Street).

**Britannia 31, 2000**

Harmston, Church Lane(Lincolnshire)  
(SK 972 622). Extensive but undated quarry pits were located in the core of the medieval village, near an area of known Roman finds.

Swaffham Bulbeck (Cambridgeshire)  
(TL 5564 6328). Quarries and limestone blocks. Finds suggest one quarry may have been Roman.

London (Londinium)  
Holborn Viaduct  
(TQ 3153 8159). Some quarry pits.

Hosier Lane  
(TQ 3170 8157). Possible Roman quarry pits.

**Britannia 32, 2001**

Shiel Hill watch-tower and road (Perth and Kinross)  
Gravel?  
(NN 856 122). Roman road with flanking quarry pits.
Annex 2 to Appendix H: A Note on Romano-British Quarries

Notes on Quarries along Hadrian's Wall
Annex 2 to Appendix H: A Note on Romano-British Quarries
Notes on Quarries along Hadrian's Wall

From:
Breeze, David J., and Brian Dobson
Bruce, J. Collingwood
Hindson, Newcastle upon Tyne.
Johnson, Stephen

*Note:* For much of the information on Roman quarries along the line of Hadrian's Wall, we have to use publications of the latter half of the nineteenth century and the early part of the twentieth century. Throughout much of this period quarrying was active at many of the Roman sites, and this recent activity has destroyed or obliterated all traces of the Roman workings. Only at less desirable locations, such as those along the River Gelt, have remains of the workings survived. A further serious loss has been the destruction of sections of the wall itself where modern quarrying has removed the ground on which the Wall stood.

1. General Note on the Wall Construction (Bruce 1966:33-38)
   Both faces of the wall were covered in carefully squared freestone blocks. The blocks are fairly uniform, 6-7" high x 10-11" wide with a front to back measurement of about 20". Outside faces were cut across the bedding plane to avoid flaking. They were tapered slightly to the back. Faces were tooled to a smooth finish, or sometimes a distinctive pattern.
   The size enabled them to be easily quarried, man-handled and positioned. There were larger stones in the gates, and in the lower courses for the first 17 miles from Newcastle. Facing blocks were a quartzose grit.
   Between the ashlar faces the core was packed with rubble quarried locally from small pit-quarries.
   The broad wall rubble is set in mortar or tough puddled clay. The narrow and intermediate walls and all repairs are set in lime mortar. In the eastern half lime is locally abundant. At the Cumberland end, lime is scarce.
   The Wall foundations are of flagstones set on the natural soil with clay and cobbles between the two lines of flagstones.
   In general the geology of Cumberland on the west end of the Wall makes quarries rarer and more distant from the Wall. At the extreme west end stone was brought across the Solway Firth for work between Carlisle and Bowness.

2. Identified Quarries
   a. Fallowfield Fell, east of Chollerford.
   Inscription: (P)ETRA FLAVI CARANTINI
   The rock of Flavius Carantinus (Now in the Chesters Museum).
   *(RIB I,1442; Bruce :33, 77; Johnson 1989:13)*
b. Barcombe, above Chesterholm.
Finds: a Hadrianic arm purse (Bruce :34, 134).
c. Busy Gap.
Wedge holes remain in an exposure of rock just to the north (Bruce :34).
d. Centre Section
Throughout the centre section numerous ancient quarries, mostly without doubt Roman, visible within a half mile south of the wall (Bruce :34; Johnson :39).
e. Irthington, east of Glebe Farm.
Extensive ancient quarries (Bruce :35).
f. Grinsdale.
A quarry just north of the wall (Bruce :35).
g. Shawk, south of Thursby (Bruce :35).
A once famous example with inscriptions, now destroyed.
h. Black Pasture Quarry.
A little past and to the north of milecastle 26, a first class fine grained sandstone (Bruce :78).
i. Queen's Crag.
Between the Crag and the Wall there are many traces of Roman quarrying, including wedge holes in the rocks (Bruce :109).
j. Sewingshield Crags.
Near the branch road to Haydon Bridge, south of the B6318 are limestone outcrops quarried by the Romans (Bruce :111).
k. Vindolanda (Chesterholm).
East of the fort on Barcombe are a number of Roman quarries (Bruce :133).
l. Haltwhistle Burn.
Clayton in 1844 noted LEG VI V cut in the quarry face which was here (Bruce: 34, 141). The quarry has since been destroyed.
m. Combe Crag.
Two miles west of Birdoswald, and a quarter mile south of the Wall, there is a freestone quarry extensively worked by the Romans. Many Roman names were inscribed on the rock faces (RIB I:1946-52; Bruce: 34, 176).
Also comparable inscriptions existed at Lanerton and were seen in the past at Wetheral. (Bruce :34-35).
n. Pigeon Crag, on the River Gelt.
About two miles south of Brampton, 1 km east of the A69, and 1.6 km south-east of Low Gelt bridge on both banks of the River Gelt, the quarried area has the names of men of the Legio II Augusta and Legio XX Valeria Victrix (RIB I: 998-1016). Two inscriptions refer to a Mercatius, one records "In the consulship of Aper and Maximus, the working face of Mercatius.". In the second just the name Mercatius survived (RIB I:1009 and 1010). Mercatius appears to have been in charge of the business of extracting stone. Whether Mercatius was a military officer or a civilian contractor suppling army needs is not known (Johnson :102-103). The inscriptions along the Gelt is the largest group of rock cut inscriptions surviving on the Wall.
o. Bleatarn.
A quarry of considerable size used in building the Wall was revealed by excavation in 1895 (Bruce 12th ed., 1966:35, 192)

Note: Breeze and Dobson have a very small map showing locations of some of the quarries along the wall. However, a much clearer picture can be obtained from the Ordnance survey map *Historical Map and Guide; Roman Britain*, 5th Edition, 2001, which shows the location of the Roman period quarries along the Wall.

3. Discussion

Several points of interest relating to the transportation of stone arise from the material above and Kendal’s 1996 paper on the transport logistics of building the wall. There is the relatively small size of the dressed stone facing blocks, about 0.3 m x 0.3 m x 0.45 m (Kendal 1996:133). These would weigh from 40 to 50 kg, a size and weight easily manhandled. From the spread and spacing of the quarry sites along the length of the stone Wall full use was made of sources of stone in the immediate vicinity to minimize transportation time and costs. From the epigraphic evidence it appears likely that much if not all of the quarrying was done by the army, at least in the initial construction of the Wall. Kendal has suggested that the wall was built by the legions to keep them busy (Kendal:151).

---

1 Kendal has suggested that the initial decision to build the western part of the Wall in turf was due to the absence of limestone outcrops in the west. Lime for making mortar could not be produced in this area, hence a decision to build in turf (Kendal:137).
Annex 3 to Appendix H: Notes on Roman Masonry in Britain. Its Sources and Points of Use
Annex 3 to Appendix H: Notes on Roman Masonry in Britain. Its Sources and Points of Use

A consideration of the transportation requirements for stone and masonry involves both the source of the material and its destination. The principal users of masonry for structures and buildings were: cities; towns and small towns; villas; fortresses and forts; Hadrian’s Wall; some temples; and roads and bridges. Because of the weights and volumes involved, stone and masonry for structural purposes would generally be sought as close to the point of final use as possible to minimize the cost of transportation. An interesting question relating to the weight of stone to be moved is whether the quarry shipped quarry-run lumps, or whether blocks were dressed to the approximate finished size and shape at the quarry before shipping. The local availability of building stone, the quality and the workability varies widely over Britain. East Anglia and the London basin are almost devoid of building stone, although gravel, sand and clay are easily obtained. Flint nodules occur widely in south-east Britain, and were widely used in Roman buildings in that part of the country. In the eastern part of southern England chalk and limestone are widely available, with Purbeck marble to the west. In the south-western peninsula red sandstone is common, and granite outcrops are found on the high moors. North of the line from the River Severn to the Wash a variety of rock formations occur. In the Cotswold Hills in the western Midlands oolitic limestones of a rich cream colour make excellent building stone, which is easily quarried, but hardens and weathers well on exposure. In Wales and the North there are widespread outcrops of moderately folded sedimentary rocks, plus a variety of igneous and metamorphic rocks, all of them good building material (Espenshade 1990:132-3).

In general, apart from East Anglia and the London basin, suitable stone could be quarried from local outcrops, for example at Chester (Frere 1985:281, 1986:321), at various sites along Hadrian’s Wall (see Annex 2), and at Inchtuthil (Pitts and St. Joseph 1985:61). Most of the transport for these local hauls would be by road. London obtained Kentish ragstone from quarries near Maidstone in Kent, and this was transported down the river Medway and then up the Thames to London. The Blackfriars 1 shipwreck, dated to about AD 150, was sunk while carrying a cargo of 26 tonnes of this ragstone. In this particular case the cargo was undressed quarry-run rock, weighing between 2.7 to 31.0 kg per piece.

1 Stone for sculptural or decorative use could be shipped economically over long distances. The end product was a relatively high value item. For example, in London fourteen varieties of imported marble have been recovered: ‘Aquitaine’ marble from St. Giron in southern France; Luna marble from Tuscany; Bardiglio from Carrara; white marbles from various Aegean quarries; marbles from Euboea, Skyros, and Chios; marble from Docimium in Phrygia; and marble from Anatolia and Turkey. Green porphyry from Laconia in southern Greece, red porphyry from Gebel Dokhan in Egypt and diorite and dolerite, also from Egypt, have also been identified. Other stones from Gaul are also present. British stone used for fine work include Purbeck marble from Dorset; ‘Forest marble’ from Northamptonshire; white limestone from Somerset; fine grained white chalk from southern Britain; and limestone from the Weald (Pritchard 1986:169-75). Cunliffe in the excavation reports on the Romano-British palace at Fishbourne lists more than nine imported marbles and other high value stone from as far away as Phrygia and Turkey (Cunliffe 1971: Vol. II, 16-17).
Kentish ragstone was used extensively in London and throughout south-east England for public and other buildings. For the London city wall 45,000 tonnes of stone were needed (Marsden 1994:80-3). Loading the Blackfriars I Ship to capacity it could carry about 50 tonnes of a high density cargo, and the 45,000 tonnes would make up about 900 ship loads. The round voyage time from London to the Maidstone area, including time for both loading and discharging the cargo, would be about twelve days. Allowing for periods of bad weather, the ship could make about 25 round trips per year. Assuming the wall took three years to build, the 300 ship loads each year would need twelve ships in this service. This is a small number compared with the more than 500 ships engaged in other trades. It would also be an irregular demand, depending on the level of activity in building major works.

Shipping stone for construction projects in London was probably much the largest demand for shipping stone in seagoing vessels. Other major Roman centres such as Chester, Bath, York, Silchester and Cirencester could obtain good building stone from local sources. For example, at Chester the Roman quarry is less than a kilometre away, just across the River Dee.
APPENDIX I

Timber and Wood: Sources, Conversion and Uses in Roman Britain
APPENDIX I

Timber and Wood: Sources, Conversion and Uses in Roman Britain

1. Timber and Wood

Rackham has defined a number of different types of sources for timber and wood in Roman Britain:

a. Wildwood is the original forest cover that became established as the ice sheets retreated after the last ice age, some 10,000 years ago. Today there is no wildwood left in Britain, and it had probably largely disappeared by the LPRIA and Roman period. Trees that populated the land as the ice retreated were birch, aspen, sallow (a form of willow), pine, hazel, alder and oak, followed later by lime and elm, and then holly, ash, hornbeam and maple. The wildwood species continued to flourish, with some retreats, through to modern times.

b. Woodland is land on which trees have established themselves naturally, without the aid of man. By prehistoric and Roman times, much woodland was managed to produce successive crops indefinitely. When felled the trees replace themselves by natural means from seeds and seedlings.

c. Wood-pasture is land managed for the use of grazing animals and the production of timber and wood. Generally this involves protecting young trees until they have grown to a height where animals cannot eat the leaves.

d. Non-Woodland is trees growing in fields and hedgerows.

e. Orchards and Gardens: deliberate planting by man.

f. Plantations: trees are not the natural vegetation, are generally of only one or two species, and have been planted by man as a crop. Conifers are a common plantation tree, usually die when felled, and the site has to be replanted.

The Romans introduced some further species, such as chestnuts and walnuts. Some species were ‘natural’ only in certain areas. For example beech was native to the south-east and Scots pine to the Scottish highlands. Some imported species and species with a limited range, over time ‘naturalize’, that is they become self-propagating and expand their range without human intervention. Chestnut, beech and Scots pine have done this, but walnut requires human intervention to spread, and is largely confined to gardens (Rackham 1994:25, 28-36)

Some trees, such as most conifers die when cut down. Other species will coppice or sucker. Ash, elder, oak, hazel, wych-elm, lime, hornbeam and others will coppice when felled. The stump and root system remain alive, and the stump will produce a large number of small diameter new shoots. Oak for example will produce shoots 2.5 cm diameter and 2.0 m high after one year. When of a useful size the coppice wood can be harvested and another crop will grow. The coppice wood can be harvested in between three to ten years, depending on the growing conditions and the species (Rackham 1994:30-31). 1

---

1 Columella says coppice wood can be harvested after five years for chestnut and seven for oak (Columella Rust. IV.xxxiii.4.)
coppice stools in Britain which are hundreds of years old (Rackham 1986:Plate IV). In suckering species, such as elm, aspen and cherry, the stump dies when the tree is cut down but the root system remains alive, and sends up a large cluster of suckers, which provide useful wood with a similar result to coppicing. In general the coppice and sucker growths were both more productive and more useful than the original tree. A third mode of producing a continuing crop from a tree is by pollarding or cropping. With certain species, notably willow and oak, the tree is cut off at between 2 m and 4 to 5 m above the ground. It then produces a large cluster of new sprouts on the stump at the point where it was cut. Pollarding has the advantage that the trees and grazing animals can coexist, as the foliage is out of reach of the animals. With coppicing and suckering, grazing animals, either wild or domestic will eat the fresh foliage (Rackham 1990:5-10).

2. Uses of Timber and Wood

Timber was the main product that resulted from felling a whole tree. The trunk was stripped of branches, de-barked, and hauled out by ox teams, and could then be converted into beams, large posts and planks (Meiggs 1982:332). Wood is the product of coppicing, suckering, and pollarding, and includes the branches lopped off trees after felling. In the LPRIA and Roman period it was used for wattlework, fencing, a wide range of specialized purpose, and was the main source of fuel, either as wood or after conversion to charcoal. The use of wood remained of enormous importance from the Paleolithic to the Industrial Revolution. Coppicing and pollarding were used to produce the wood for the Bronze Age trackways in the Somerset Levels about 2,400 B.C. (Rackham 1977:65-72). From the Neolithic through the LPRIA and Roman periods, and on into Saxon and medieval times, wood remained the most commonly used raw material in daily life.

3. Conversion

The poles and small dimension wood from coppicing, suckering and pollarding would generally have the bark peeled off. They could be used in the round, just being trimmed to length (round wood), or they could be split or cleft into halves or quarters. The principal uses would be for wattles, hurdles and fencing. The smaller boughs detached by trimming the branches off the bole of a timber tree could be treated in a similar manner if fairly straight. The large boughs, particularly if curved or of irregular shape, would be used as natural crooks for special applications, such as knees and breasthooks in boat building, or for the main structural members of the ard, the prehistoric plough. The great advantage of using natural crooks and forks is that the grain of the wood runs in directions that best resist the stresses imposed. Shaping curved or angular pieces out of straight grained baulks or planks leaves serious planes of weakness, leading to splitting along the grain and early failure. Waste ends or scrap from small dimension wood could be added to the piles of wood for charcoal burning, or used for fuel.

The trunk of the felled tree, after lopping off the branches and de-barking, can be converted into useful lumber in several ways. The simplest is to use the round bole as a post or beam after cutting it to the required length. If required for a square or rectangular
cross-section post or beam, it can be squared with the axe, and if necessary given a fine finish with an adze. The first step would be to remove the sapwood by cutting notches across the trunk, and splitting off the pieces between the notches with an axe or adze. The log could then be trimmed to the desired dimensions by hewing with the broadax or adze. A 10 m long oak log, 0.2 m in diameter can be squared in about four hours with the axe (Darrah 1982:221-222, Figs. 12.13, 12.14, and 12.19). If planks or timber of smaller size were the desired end product, there are several possible methods of converting the log. It can be split radially or tangentially, or it can be sawn. Oak, the most commonly used structural timber in Roman Britain, splits easily along the radial medullary rays, but produces wedge shaped planks with an irregular surface, that requires further work, hewing with axe and adze to produce rectangular cross-section planks.² Tangential splitting can produce planks of roughly uniform thickness, but with a different grain orientation, Fig. App.I.1 and App.I.2, and is more wasteful. Sawing the original round log, or a log that has been hewn into a rectangular cross-section, produces posts, beams and planks that require much less finishing, but the process is slower. Splitting can be remarkably quick if the trunk is relatively straight. In experiments an unseasoned oak log about 0.9 m diameter and 4 m long was split into halves with seasoned oak wedges and a wooden mallet. After carefully examining the log for the best plane for the initial split, Darrah drove an oak wedge in at one end until the split reached the centre. The log was rolled over and a second wedge driven in from the opposite side. Further wedges were driven in along the line of the split, working on each side alternately, until the tree split in two. The log was split in half in under two minutes (Darrah 1982:221). An ash trunk was split using wooden wedges and a mallet, and once the split had started, splitting was completed bylevering in the crack with a wooden lever (Heal 1982:Figs. 5.5, 5.6).

In working with oak, there is a substantial advantage in doing all the preliminary conversion fairly soon after felling. In unseasoned oak both the sapwood and heartwood are fairly easily worked. In between two and four years the heartwood becomes much more difficult to work. In another experiment, a mortise 12 mm wide and 35 mm deep could be cut in 10 mm thick steps in unseasoned oak. In oak seasoned for four years, with the same tools the depth of cut was reduced to 10 mm and the steps to 5 mm, a reduction to one seventh in the rate of removal of material (Darrah 1980:222). Working with a 25 mm spoon bit Darrah was able to cut circular holes in unseasoned oak at about 20 mm per minute (Darrah :220).

In Roman Britain there is ample evidence of cleaving or splitting all sizes of trees, branches and coppice shoots. The practice dates back to the Iron and Bronze Ages, and even earlier. There is evidence for saw cuts across the grain of the wood from lap joints in quay timbers in London, “It showed that the lap joint was marked out by sawing deep cuts at either end, after which the intervening wood was cleared out with axes.” (Milne 1985:62). Milne goes on to mention “roughly squared timbers”, “most of the logs had

² Wedge shaped planks are no particular disadvantage for certain applications, such as clap-board siding on small dwellings. In parts of the County of Essex they were quite common.
simply been squared” (Milne :62, 65). Marsden, discussing Romano-British ship wrecks from the Thames, made the following observations:

On the Blackfriars Ship 1: “Although it is not now possible to find tool marks, the way in which the planks had been fashioned tangentially from the tree trunks suggest that they were sawn or hewn instead of split from the log.” (Marsden 1994:38).

The planks of the Blackfriars ship were tangentially cut from heartwood logs, presumably by using very large saws,...In contrast the floor timbers of the ship were hewn from substantial whole logs, and the side timbers were cut from smaller timbers grown to the appropriate shape (Marsden :76).

On the planks from the New Guy’s House boat: “Judging from the fragments recovered from trench 1 they were tangentially cut, presumably by saw though no saw marks could be seen on the dried timbers.” (Marsden :99).

On the County Hall Ship’s planks “....tangentially fashioned from oak logs - no traces of the cutting tools but presumably originally sawn frames - from grown crooks.” (Marsden :113).

The emphasis in these four passages is mine. There is no hard evidence for sawing, and technically all the timbers could have been shaped with the axe, and then finished with the adze. By contrast Rule and Monaghan on the St. Peter Port Gallo-Roman wreck say that the timbers retained extensive tool marks of the axe, adze and saw. The saw marks were across the face of the strakes, keel timbers and deck planking, that is the timber had been sawn along the length of the log, and “In all cases, strakes and keel timbers were tangentially sawn....The parallel scars shown on Plate 3 are typical of those produced by a two-handed saw, when the timber is resting on trestles.” (Rule and Monaghan 1993:17 and Plate 3), Fig. II.6.10.5.3 Rule and Monaghan’s Plate 3 is very convincing evidence for sawn planking. They also comment on the floor timbers and side frames, with extensive areas showing tool marks from the axe and adze. The dates for the construction of the vessels

3 A frame saw has a narrow toothed iron blade mounted in a wooden rectangular or other convenient shape of frame, and with a tensioning device to keep the blade taut. It is represented in a number of surviving illustrations from the Roman world, and frequently in medieval illustrations showing banausic occupations. The common modern equivalents are the ‘swede’ saw with a metal bow shaped frame for cross-cutting logs, branches etc, and the metal cutting hacksaw. In historic times frame saws have come in all sizes from small to very large. A pit saw has no frame and the blade is wide enough to be self-supporting. Pit saws, used with a saw pit, were in widespread use in the 19th and into the early 20th century in Britain, in trades such as country cart and wagon building. They were about 2.4 m long, and at the widest part at the top were about 0.36 m wide tapering uniformly to about 0.06 m wide at the bottom end. (see Glossary of Tools and Technology, Fig. 1.) Walker believes that the pit saw was “...probably invented in England in the Eighteenth century. Before that time frame saws seem to have been used, and the tree was propped up on a trestle so that the lower Sawyer could work without need for a pit, a method still practised in many parts of the world.” (Walker 1996:16). A number of medieval illustrations show Noah or his assistants shaping planks with an axe, and using frame saws to cut timbers longitudinally (Unger 1991:Figs. 2-70). An engraving by De Vos from 1646 shows two men using a long frameless saw, about 0.3 m wide in the centre and tapering sharply towards the ends, but for cross-cutting a log, not for cutting longitudinally (Unger :Fig. 74).
are:

Blackfriars Ship 1: AD 130-175.
New Guy’s House Ship: Second half of the second century AD.
County Hall Ship: After AD 296.
St. Peter Port Wreck: About AD 280.

There appears to be some uncertainty about the use or existence of large frame saws in Britain, at least until well after the conquest. In the LPRIA most domestic structures were built from poles or relatively small trees, which were used in the round, as shown in the plans and experimental reconstructions of an Iron Age dwelling at Butser (Reynolds 2000:92-7). All the working and shaping of wood and timber could be done with the axe and the adze, and it is doubtful if saws were widely used.

Large frame saws were certainly used in the Roman Mediterranean. Writing of conditions in the Mediterranean world in the Roman period, Meiggs is of the opinion that, “The conversion to beams, boards and battens was normally the work of the saw (Meiggs 1982:346). There are depictions of frame saws from wall paintings from Herculaneum (Meiggs :Figs. 14a and 14b), and from Pompeii (D’Ambra 1998: Fig. 47). A relief sculpture from the Antiquarium Comunale, Rome, shows a frame saw hanging on the wall of a carpenter’s shop (D’Ambra 1998: Fig. 48). (see Figs.I.4.1.1, I.4.1.2, and I.4.5.1b). There is a tomb relief from Gaul depicting two men sawing a large baulk lengthwise, raised on a trestle with one man on top and one below, using what might be a crude pit saw (Meiggs:.Fig. 14d). A long deep trench in the Rhineland has been interpreted as a saw pit used by legionary detachments to saw timber for the frontier forts (Meiggs :349). In Roman Britain there is ample evidence for the cleaving or splitting of all sizes of trees, branches and coppice shoots. The practice dates back to the Iron and Bronze Ages, and probably even earlier. In a study of gate timbers and uprights in fort buildings from thirty-four sites, Hanson has noted that both round and roughly squared posts were used. Gate timbers ranged from 20 to 30 cm square or round, and uprights from 10 to 25 cm. Uprights were quite often round, and in some cases round and square posts were mixed in the same building (Hanson 1978:300-303). In most Romano-British settlements and small towns the standard dwelling for the banausic occupations was a single storey rectangular building with a short side facing the street. They were commonly of timber and wattle and daub construction, and their structural and other members could be fabricated entirely with the axe and adze. Stone built villas and town houses used stone for the foundations and lower walls. They would need timber and wood for scaffolding during construction, for the framing and floors of the upper storeys, for the roof structure and internal fittings and furnishings. If the roof was tiled, the roof framing would be fairly substantial, and could be put together from moderate sized trees, hewn into a square or rectangular cross-section. In finishing the building, sawn small dimension lumber would be needed mainly for joinery, doors and windows, and for furniture. In wagon building much of the woodwork for wheel naves, spokes and felloses requires shaping pieces of timber or wood specially selected for their natural configuration, and the body and superstructure could be built without sawn material. Sawyers using pit saws in the nineteenth century in the wagon making and village carpenter work had “....a skilled and exhausting job...” and “The important thing to the sawyers was the sharpness of their saws, and they took great pains in the sharpening and
setting of them.” (Bailey1998:11-12). For boat and ship building sawn planks could be a convenience. From the archaeological record most of the other structural members of Romano-British vessels were shaped with axe and adze. All the structural members of a wharf or jetty could be conveniently produced by hewing with axe and adze, and if necessary the decking as well. In a large number of cases from the archaeological record, timber was used in the round or roughly squared.

In general it is probable that the manufacture of efficient large frame saw blades would stretch the metallurgical and metal forming skills of the Romano-British blacksmith to the limit. He had to produce a 2.4 m long relatively thin blade with a hard edge, and then form regular teeth, and set and sharpen them. The sawyer then had to re-sharpen the tool in the field. The difficulties are such that large frame saws for converting logs into planks were probably not used in early Roman Britain. By the early second century they may have come into limited use, particularly for producing thin planks. As noted previously in footnote 3, the frame saw appears to have been the method used for producing thin planks and similar items right into the Renaissance and later. Thick planks may have been produced by finishing with axe and adze after preliminary radial or tangential splitting from a log. There is no evidence for pit saws in the Roman period in Britain. One tomb relief from Gaul shows what might be a pit saw, but the iconography can be better interpreted as the side view of a large frame saw, see Fig. 1.1.4.2 (Meiggs 1982:348, Fig. 14d; Rule and Monaghan 1993:17, Fig. 11) Initially in Roman Britain frame saws were probably scarce, and those that did exist would be part of the base stores for a legion. By the later second and the third century they probably became more common, but their use would tend to be concentrated in areas such as towns, shipyards and military stores depots.

4 Planks: Sawing or Hewing? The Scandinavian Tradition

In Scandinavia, ships’ planking was fashioned exclusively with the axe until at least the eleventh century AD. The practice dates back to at least the Iron Age Hjortspring boat of the 4th century BC with planks fashioned with the axe. “The boards are very broad and quite thin, hewn (my emphasis) out of limewood.”. The planks also had cleats along the centre of each plank, formed integrally in one piece with the plank. The cleats were shaped in the process of reducing the plank to the desired thickness (Brogger and Shetelig 1951:33). This could not be done by longitudinal sawing of the plank.

Crumlin-Pedersen, discussing the Skuldelev 3 wreck from Roskilde, dated to about AD 1000 comments:
“Close inspection of the way all the various building elements of this ship had been cut from the trunk had shown that the saw had not been used at all. All the elements had been split out of logs or cut to shape in one of four ways shown in Figure 4.” Radial splitting from the log was used to produce all the planks, and he notes that “.... we had to admire the

4 Pit saws did not come into use in Europe until the eighteenth century, possibly as an offshoot of the production of better iron and steel (Goodman 1964:131-141; Walker 1996:16).
very fine strength properties of these radially cut planks. They could withstand extreme bending without splitting, since no fibers had been cut across.”. He further comments:-

“There is no indication, however, of the use of the saw in wood-working and I have failed to find any traces of the saw in ships of the Scandinavian building tradition from the whole of the medieval period.” (Crumlin-Pedersen 1989:29-31). Discussing the Hedeby I wreck, dated to c. AD 982, he writes, “All the planks are made of radially hewn best quality oak wood in large breadths....” (Crumlin-Pedersen 1997:86). All planks employed are made of radially split oak, “....the cross-sections of the planks are adapted to the shape of the hull, so that the lowest ones are concave on the outside and correspondingly convex on the inside, while the situation is reversed for the fourth strake.” (Crumlin-Pedersen :227). In another context, discussing the tools used in Viking ship building, he notes, “During the careful examination of every single piece of wood from the Skuldelev ships not a single trace of a saw cut was found. Everywhere there are clear signs of axes and planes in various forms, but even in places where today a saw would obviously be used, marks are found on the surface of the wood show that the axe instead has been used instead.” Most of the axe marks come from the axe called a smidarox, in which the edge of the axe blade is parallel to the haft. Even the smoothing of the wide oak planks has been done with such an axe. The axe has been used so deftly that no additional planing or smoothing was necessary (Crumlin-Pedersen1977:10).

Bill, discussing the tools and techniques used in ship construction, notes that, “The early thirteenth-century cog wreck from Kallerup shows only axe marks on the tangentially split oak planks,...” (Bill 1994:154).

All the evidence from Scandinavia shows that saws were not used in boat-building until the late medieval period. From Bronze Age and Iron Age Britain there is no evidence for the use of large saws.5 For the boats recovered from the archaeological record for these periods, the tool marks are of axe and adze.

Some further considerations on sawing versus splitting and hewing concern the availability of suitable trees. For satisfactory splitting, tree trunks must be of a good length, free from knots, and without twisted grain. Mature forest grown oak meets these specifications, and is an ideal timber for shipbuilding, as evidenced by its use for this purpose in northern waters from prehistoric times up to the 19th century AD. Sixteen or more planks 0.4 m wide could be split from a tree 1.0 m in diameter. From the evidence of wrecks, planks from 3 to 6 m long were common, and in exceptional cases planks over 10 m long have been found. Crumlin-Pedersen has pointed out by early in the second millenium there was a shortage of suitable trees, “....All points to a drastic shortage in South Scandinavia of large clear logs for planks in the centuries after A.D. 1000.” (Crumlin-Pedersen 1997:30). Bill has expressed similar opinions, and notes that although radial splitting provides a large number of planks, in the final shaping a lot of material is wasted in forming the cross-section. Ash and elm split very poorly (Bill 1994:152-3). Tangential splitting provides inferior planks, prone to splitting, and fewer are produced from each tree.

---

5 Small toothed saws are known from the Bronze Age, but could only have been used for cross-cutting small dimension wood, see page 19, fn..14.
Once good oak became scarce, there would be the need to use inferior oaks or other timbers. Sawing then would become more attractive, both because it could utilize trees with knots and other imperfections, and because a sawn plank could be used without significant further surface finishing. There would also be less waste if the sawyers were competent. With two man saws cutting a log longitudinally, either with a frame saw on trestles or with a pit saw over a pit, the top sawyer is the more skilled man and is responsible for guiding the saw, keeping the cut straight and lifting the saw at the end of each stroke. If the cut is not straight, the plank will be of poor quality, and in extreme cases not usable for ship planking. The bottom sawyer, a man of remarkable stamina, does the main cutting on the down stroke, and has the additional handicap of being showered with all the sawdust.

Radial splitting produces unfinished planks very quickly. With a good oak about 5 m long, a plank can be split off about every few minutes. After that, much time would be spent in shaping the plank with the axe. Sawing the log into planks would take many hours, but produce a plank requiring much less finishing.

The unanswered question is how were planks for boats and ships produced in the early Romano-British period? Based on the indigenous traditions of northern Europe they could have been radially split. Alternatively, the Romans could have brought the large frame saw with them. Possibly both systems could have been in use concurrently, as they were in northern Europe about AD 1000.

5. Discussion and Conclusions (See also Section 1.5.2)

In Roman Britain there is ample archaeological evidence for the felling and use of local timber for every sort of structure. Much of the conversion into finished sizes was certainly done with the use of axes, probably of more than one style, and by final shaping and surface finishing with the adze. The legions certainly had small saws suitable for cross-cutting timbers into shorter lengths. The direct evidence for the use of frame saws for cutting timber longitudinally is sparse. From the archaeological record a number of fragments of bow or frame saw blades have been recovered, but none of sufficient length that they could be firmly attributed to large frame saws. Because of their widespread use in the Mediterranean area, it seems likely that at some time after the conquest, frame saws for producing planks and similar items would appear in Britain. Their use may not have been widespread, as the pre-Roman woodworking traditions with axe and adze probably remained strong. There is no evidence for the use of pit saws. In the building of ships and boats, the axe and adze were used extensively, as can be seen from the tool marks on surviving components. At some point frame saws were probably used in the production of planks for strakes, ceiling and decking, but as in Scandinavia into the eleventh century AD, some vessels may have been planked with strakes fabricated with only the axe and adze.

---

6See page 255. An unseasoned oak log about 0.9 m diameter and 4 m long was split in half in less than two minutes.
APPENDIX J

Coal Production in Roman Britain: Sources and Distribution
APPENDIX J

Coal Production in Roman Britain: Sources and Distribution

The mining and use of coal in Roman Britain has been examined in a number of publications in the past sixty years, from Collingwood in 1937 to Smith in 1997. From the widespread occurrence of coal or its debris on both military and civilian sites over much of Britain, and the concentration of outcrops in the north and centre of Britain, its use must have involved both local and long distance transportation. The coal was extracted from coalfield surface outcrops, from Northumberland in the north to Somerset and South Wales in the south. No Roman sources are known in south-east England. Collingwood suggested that mining was generally at outcrops, but also proposes some use of shafts and galleries (Collingwood and Myres 1937:231-2). Webster believes that coal was quarried from convenient outcrops, and that there is no reliable evidence for underground working, a conclusion supported by Dearne and Branigan (Webster 1955:200, Dearne and Branigan 1995:73). Webster lists fifty-one sites with evidence for coal use, and for seventeen suggests the uses: ten sites were metalworking; three were hypocausts; two were associated with cooking, one with cremations; and one possibly with corn drying. He found no direct evidence for the use of coal for space heating (Webster:204-16). Dearne and Branigan list 232 sites or areas with evidence for the use of coal (Dearne and Branigan:88-98). For many of their sites the evidence was in the form of ashes in dumps or ditches, but coal or ashes were also associated with hearths, cooking, metal working, baths, cremations, and dryers.

Frere comments on the extensive use of coal in Britain, and discusses its movement from source to point of end use (Frere 1987a:268, 288). He notes that coal could be a return cargo for barges returning from the north by inland waterways, including the Car Dyke in Lincolnshire. In general much of it was consumed at local sites near the source, but a significant amount was probably exported to East Coast sites from the Rivers Tyne and Humber, and from the Forest of Dean in South Wales to coastal sites on the Welsh side of the River Severn estuary. From the available archaeological data it is difficult to make any sound estimate of the quantities involved, but they may have been considerable. For example, for ships bringing cargoes of pottery, tiles or other bulk materials to the Tyne or Humber, a shipment of coal would make a convenient return cargo. Dearne and Branigan list over two hundred sites with reported finds of coal, but add that “....the corpus of

---

1 The large increase in the number of sites between Webster (1955) and Dearne and Branigan (1995) reflects the substantial increase in both excavation and publication of results since W.W.II. The data-base for all aspects of archaeology in Britain is now much larger than in the first half of the twentieth century.

2 Simmons has argued that the northern part of the Car Dyke was blocked off into sections by causeways for road crossings, which would have prevented its use as a continuous waterway (Simmons 1979:183-196). Webster has suggested that the unexpected widespread use of coal in the Fenland could have occurred from its use as ballast on vessels returning from delivering cargoes of corn to the northern granaries (Webster 1955:203)
evidence for coal use presented here is probably a considerable under-representation of that excavated to date," and that "....the recognition, collection, recording and especially the publication of coal finds is still unsystematic." (Dearne and Branigan 1995:72). Coal is probably not the most exciting find for the excavator! All the authors make similar comments on this problem. Although there is no significant evidence for the use of coal in the LPRIA in Britain, by the later first century A.D. it occurs on widely distributed sites, with an expansion of use in the second century, and continues at this level of consumption until at least the mid-fourth century. There is some site evidence for its sporadic use continuing into the post-Roman fifth century (Dearne and Branigan :75-77). As well as being used locally near the outcrops in north and central England and South Wales, four other areas show concentrations of coal using sites. These are: Hadrian’s Wall; the area between the Mersey and Flamborough Head in the north; the area from East Anglia to the Bristol Channel; and in the areas bordering the Severn estuary and Bristol Channel. The south-west peninsula and southern England south of London have few sites with evidence for coal (Dearne and Branigan :79, figs 4 & 5). Coal has been found at a variety of sites: major towns; the coloniae of York, Lincoln and Gloucester; civitas capitals; small towns; roadside settlements; villages, native farms and homesteads; military sites; and industrial establishments. The availability of coal is perhaps more related to communications facilities and trading links than the status of a site (Dearne and Branigan :80). Local transportation from the outcrop to the points of use would be by mule panniers or cart, while for use at places distant from the outcrops sea and river transport were probably employed.\(^3\) An average bituminous coal has a calorific of about 60,000 kJ/kg compared with about 32,000 kJ/kg for dry wood (less than 20% moisture). Assuming the costs of moving a kg of coal is the same as that for a kg of wood, the transportation cost per unit of heat output for coal is about half that for wood. A kg of wood would have a larger volume, so the costs could be even more favourable for coal.

The principal uses of coal appear to have been for: domestic hearths; hypocausts; baking or cooking ovens; craft processes, principally metalworking; possibly for drying but not for firing pottery; possibly for salt evaporation in the Fens; possibly for burning lime; possibly for drying grain\(^4\); and for a cremation site (Dearne and Branigan :82-5, Webster 1955:204, Smith 1997:303-6). Although wood and charcoal were the principal fuels in Roman Britain, coal was widely used and transported over significant distances. Pressure on timber resources, particularly in areas with easy access to coal outcrops, would encourage the use of coal for fuel.

---

\(^3\) The relative costs of sea, river and land transport in the Roman Empire have been estimated at 1:4.9:28 (Duncan-Jones 1982:366-9, Greene 1986:39-41), but in some circumstances the costs of sea movements could be even more favourable.

\(^4\) There is some disagreement over whether the structures conventionally identified as ‘corn driers’ on Romano-British sites were used for drying grain, or whether they were used for malting in making beer (Reynolds 2000:96).
Using advances in the field of coal microscopy Smith has examined coals from seventy sites, and has been able to assign a provenance for the source of the coals. Summarizing from Table 1 in Smith, domestic or farming use of coal was identified at thirty sites, industrial use at sixteen, and at thirty-seven sites coal or its ashes appeared in pits, dumps or layers that could not be associated with a specific activity (Smith 1997:303-6). The sources and localities supplied are shown in the table below, abstracted from Smith (Smith 323).

**Table App.J.1: Sources for mining and locations for the use of coal**

<table>
<thead>
<tr>
<th>Coalfield Source</th>
<th>Localities Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Durham, Ebchester.</td>
<td>Wall garrisons west of Newcastle, export to East Coast sites by way of the River Tyne.</td>
</tr>
<tr>
<td>Northumberland and Durham, valley of the River Tyne.</td>
<td>East Coast sites.</td>
</tr>
<tr>
<td>Yorkshire, south-east of Leeds.</td>
<td>Local sites including York, and to Humber for export to East Coast.</td>
</tr>
<tr>
<td>Yorkshire, Castleford.</td>
<td>Local sites and those in Lincolnshire, including Lincoln, Brough in Derbyshire and sea trade via the Humber.</td>
</tr>
<tr>
<td>North or South Derbyshire.</td>
<td>Local sites in the direction of the Wash.</td>
</tr>
<tr>
<td>Warwickshire.</td>
<td>Local sites to Cambridgeshire in the east and Oxfordshire in the south.</td>
</tr>
<tr>
<td>Forest of Dean, west and south sides of coalfield.</td>
<td>Local sites mainly in Gloucestershire, and coastal sites on Welsh side of River Severn estuary.</td>
</tr>
<tr>
<td>South Wales, south-east outcrop.</td>
<td>Local sites.</td>
</tr>
<tr>
<td>Avon, Coalpit Heath.</td>
<td>Local sites to Gloucestershire in north and Wiltshire in the east.</td>
</tr>
<tr>
<td>Somerset, Farrington and Radstock.</td>
<td>Local sites from Severn estuary to Ilchester.</td>
</tr>
</tbody>
</table>

In summary, it appears from the more recent work that coal was widely used in Roman Britain for a variety of purposes that required heat. Coal was a material that required bulk but cheap transport from its source at coal outcrops to widely distributed
points of use. Although direct archaeological evidence for the modes of transport, such as a sunken ship load of coal off the East Coast is not available, from practical technical and economic considerations it can be inferred that all three modes of transport were used, sea-going ships, barges on inland rivers and waters, and pack animals and wheeled vehicles on land. For short distances close to an outcrop human porters could be employed.
APPENDIX K

Bricks and Tiles: Manufacturing and Distribution
APPENDIX K

Bricks and Tiles: Manufacture and Distribution

1. Introduction

The manufacturing of tile and bricks is a relatively low technology activity. Apart from the firing and control of the kiln, the work could be done by unskilled labour. The four basic requirements are a source of reasonably good clay, water, a source of fuel for firing the kiln, and labour. Labour is required to dig and prepare the clay; to collect suitable fuel; to form the brick or tile using simple forms and tools; to build and operate the kilns; and to load and unload the kiln. Tile and brick are bulky and heavy items of relatively low value per piece. Movement from the place of manufacture to the point of use could be a significant part of the installed cost. Ideally, tile and brick should be made close to the point of use. Suitable clay is widely available in the lowland parts of Britain, particularly in the south and east, and the north-west.

There is practically no evidence for the deliberate making of tiles or bricks in LPRIA Britain. Timber was plentiful, and the wide availability of good iron axes and adzes made felling and forming it straightforward. Clay daub was used extensively with wattle for walls, but firing clay was restricted to making pottery. Initially the Roman forts and other buildings and structures were built using timber, turf and earth. By the end of the first century AD, bricks and tiles of good quality were being produced in Britain (Brodribb 1987:2). Tiles were used in vast quantities, and in the archaeological record are one of the commonest finds.\(^1\) It is difficult to identify who made tiles, other than by association with occupiers of a site, until the practice of stamping military and civilian tiles became common in the late first century or early second century (Rib II Fasc. 4:2459 to 2480, Fasc. 5:2481 to 2491).\(^2\) A large number of tile stamps of the three permanent legions have been found, 72 of Legio II Augusta, 94 of Legio VI Victrix, and 64 of Legio XX Valeria Victrix. In addition 16 of Legio IX Hispana are known, plus stamps from a number of auxiliary units (Rib II, Fasc. 4:2464 to 2480).\(^3\) It is probable that the initial making of tiles was done by

---

\(^1\) Brodribb comments, “Fresh material is still coming to light, and at long last is being looked at, instead of being cast instantly on the spoil heap.” (Brodribb :4). From personal experience I can confirm that roof tile fragments are often “cast instantly on the spoil heap”.

\(^2\) A Neronian tile stamp from Little London, near Silchester (Calleva), and dated to the third quarter of the first century AD, is the earliest tile stamp known in Britain. Greenaway has suggested that it could be connected with “...the initial building boom under Cogidubnus at Calleva early in his reign there and to regard it as part of the official support and expertise which must have been extended to him during the creation of the ‘early town’.” (Greenaway 1981:290-1).

\(^3\) Tile stamp inscriptions for Legio II Augusta are numbered 2459-1 to 2459-72. The same system is used for all the legions and auxiliary units. Text references show the inscription number for each unit.
the legions, or at least under their supervision. The *Classis Britannica* also stamped tiles, as did a number of imperial and civic officials, and seventy-six private tileries have also produced stamps (*RIB II, Fasc. 5* :2481-2485). Stamped legionary tiles cluster around the base fortresses. For Legio II *Augusta* they cluster around Caerleon and south Wales, with outliers in Dorset and Carlisle: for Legio VI *Victrix* around York and the eastern half of Hadrian’s Wall, with outliers at Inchtuthill and in Norfolk: for Legio IX *Hispana* around York with outliers at Carlisle and in the Midlands: and for Legio XX *Valeria Victrix* around Chester and in north Wales with outliers in Cumbeland up to the western end of Hadrian’s Wall (*RIB Fasc. 4* :p.26, Fig.1, shows maps of the distribution). The quantities of roofing tiles used could be very large. At Inchtuthill legionary fortress, Shirley has estimated that 3,200 tonnes of tiles were needed (Shirley 1996:121). Kendal in his calculations on Hadrian’s Wall has calculated that 4,000 tonnes were used (Kendal 1996:142). At Fishbourne, a notice in the Museum suggests that 43,000 *tegulae* were needed for the Fishbourne palace, or about 2,500 tonnes, plus about the same number of *imbrices*.

2. Types of Roman Tile and Brick

a. Roofing Tiles (Brodribb 1979:143-4; 1987:11-12)

The two principal components of a Romano-British tiled roof were *tegulae*, flat tiles with a flange on each side and notches at the ends, and *imbrices*, cover tiles of semicircular cross-section, which covered the gaps between the *tegulae*. The notches in the ends of the *tegulae* allowed the upper tile to overlap the lower tile as they were installed from the eave upwards. A detailed study of the tiles from the bath house at the tile manufacturing site of the *Classis Britannica* at Beauport Park by Brodribb has given the following average dimensions and weights for forty-one complete *tegulae*:

Size: 0.397 m long x 0.31 m wide x 0.02 m thick, with flanges averaging 0.055 m in depth, and 0.01 to 0.04 m wide.

Weight: 5.8 kg.

For 47 complete *imbrices* the figures are:

Length: varies from 0.41 m to 0.333 m.

Width varies from 0.21 m to 0.16 m at the wider end to 0.16 m to 0.13 m at the narrower end.

Weight: 2.47 kg.

From other sites in Britain both larger and smaller *tegulae* have been recovered, and

---

4 In *RIB II* all inscriptions from the same source have the same number, but are identified by suffixes. For example, civilian tile stamps are numbered 2489.1 to 2489.70.

5 The figures given for weights in Brodribb 1987 are totally scrambled and wrong. From the dimensions for sizes and the typical density for fired clay I have calculated the probable weights of the tiles. My weights agree with those given in Brodribb 1979, and I have used his 1979 figures in calculations.
variations in size are known from other areas in the Empire (Brodribb 1987:12). Any one tilery would presumably have its own standard, and as long as the user acquired all his tegulae and imbrices from one supplier, there would be no problem.


Roman bricks are in the form of flat slabs rather than the cuboid shape of modern bricks. Five rectangular sizes were used, plus some circular and semi-circular shapes. In Italy, for example at Ostia, bricks were used for the facing of entire buildings and the construction of arches. In Britain their principal use seems to have been as bonding courses of masonry faced rubble walls, as in the fort at Richborough, Kent, for the construction of the supports for hypocausts, and in some cases as flooring. A few walls apparently faced entirely in brick are known from London, Silchester, Colchester and Lincoln, and there are a few examples from small towns. Stones, and in many areas flint nodules, were freely available, and with the aid of mortar and a few bonding courses of brick, could be built into sturdy walls. In some villas bricks were used for forming arches and stairways, as at Lullingstone (Neal 1991:9), and for floors, as at Fishbourne (Cunliffe 1998:120, Fig. 61). At Piddington villa in Northamptonshire bricks were made on site, and used for flooring (Friendship-Taylor 1989:291-2).

The nominal size in plan view of each of the five standard sizes of flat slabs was:

- bipedalis: 2 Roman feet square, 0.592 m x 0.592 m.
- sesquipedalis: 1½ Roman feet square, 0.444 m x 0.444 m.
- pedalis: 1 Roman foot square, 0.296 m x 0.296 m.
- bessalis: 2/3 of a Roman foot square, 0.197 m x 0.197 m.
- lydion: 1 x 1.33 Roman feet, 0.296 m x 0.395 m.

Thickness varied from 0.025 m to 0.09 m.

Other forms of brick found in Britain include hollow box tiles for heated walls, brick voussoirs, and various special shapes for architectural effects (Brodribb 1987:50-83).

3. Transportation of Tiles and Bricks

Roman tiles and bricks were reasonably robust items. They could be moved by simple barges on inland waters, or by carts and wagons by land. A modest padding of straw or similar material would be the only dunnage needed. If shipped in coastal vessels, rather more dunnage would be prudent, and they would be stowed low in the ship’s hold to aid stability. They would make a convenient cargo for a coasting vessel, which might otherwise be returning empty. They would serve as ballast in lieu of loading and later dumping gravel or stone ballast with no commercial value. Their size, shape and weight would allow quick and easy loading and discharge by the vessel’s crew. A vessel the size

---

6 The standard sizes of tiles and more particularly bricks were based on the Roman foot, the pes, normally about 0.296 m, and commonly called the pes monetalis from the standard kept in the temple of Juno Moneta at Rome. At various times and places three other pedes were used of 0.297 m, 0.332 m and 0.294 m respectively (Adkins and Adkins 1994:313).
of the Blackfriars I ship, if fully loaded could carry about 3,500 tegulae, enough to roof a mid-sized villa, or similar building.

Annex 1 to this Appendix lists the known tile kilns sites in Britain. These have been plotted in Fig. App.K.1. This shows that the known tile kilns are concentrated in the south, east and central parts of Britain. This would correlate quite well with the distribution of towns, small towns and villas in Roman Britain (Burnham and Wacher 1990:2, Fig. 1; Rivet 1969:211, Fig.5.6; Wacher 1995:2, Fig. 1).

4. Discussion and Conclusions

In the archaeological record tiles and bricks occur in conjunction with most of the stone built buildings of the Roman period in Britain. Because of the weight of these materials required for a building, the most economic way to provide them would be by local manufacture at or close to the building site, provided that clay and fuel could be obtained in the immediate vicinity. For example, the colonia at Gloucester had its own tile-works outside the northern walls of the town, on the site of St. Oswald’s Priory (RIB II Fasc. 5:41-49, 2486.1 to 2486.42). The military and naval forces made tiles on a large scale, and from the pattern of distribution of their stamped tiles, a certain amount of this production was transported to other military sites in the same region of the country. The correlation between the distribution of towns, small towns and villas, the principal users of tiles and bricks, suggests that, if possible, tiles and brick for civilian use were made locally. Sixty of the seventy-six sites listed in Annex 1 were on or close to navigable rivers. Bricks and tiles for use in the immediate vicinity of the manufacturing site were probably delivered using wagons and carts. For a number of sites scattered along a navigable river, a simple barge, such as the New Guy’s House boat from the Thames, could carry about six tonnes (Marsden 1994:104). It could easily deliver brick and tile over distances of up to about 100 km at a rate sufficient to keep the building site supplied for a villa or similar structure. For supplying towns engaged in active building programmes, stock piles were probably maintained at the towns while the demand lasted.

---

7 A larger but cruder barge, such as the Zwammerdam barge 2, could carry about 35 tonnes (de Weerd 1988:41). This is the equivalent of a mixed cargo of about 2,400 tegulae and an equal number of imbrices. With a crew of two poling or towing, the barge could make good about 30 km per day. The hypothetical Barge 3 described in Section II.6.6, p.57 and Appendix N could carry about 12 tonnes of tile or brick.
Annex 1 to Appendix K

Tile Kilns in Roman Britain

Note: This list is principally from McWhirr and Viner 1978:97-190 and McWhirr 1979:372-6. Where there is a river, probably navigable, within 5 km of the site, the river is named.

<table>
<thead>
<tr>
<th>Place</th>
<th>Map Ref</th>
<th>River</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bedfordshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luton</td>
<td>TL0921</td>
<td>Lea</td>
</tr>
<tr>
<td>Harrold Lodge Farm</td>
<td>SP9355</td>
<td>Nene</td>
</tr>
<tr>
<td><strong>Berkshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall Park</td>
<td>SU4166</td>
<td>Kennet</td>
</tr>
<tr>
<td><strong>Caernavonshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caernavon</td>
<td>SH4862</td>
<td>Menai Strait</td>
</tr>
<tr>
<td><strong>Cumberland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brampton</td>
<td>NY5261</td>
<td>Gelt</td>
</tr>
<tr>
<td>Muncaster</td>
<td>SD1938</td>
<td>Aire</td>
</tr>
<tr>
<td>Scalesceugh</td>
<td>NY4449</td>
<td>Petteril</td>
</tr>
<tr>
<td><strong>Dorset</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milton Abbas</td>
<td>SY8090</td>
<td>Frome</td>
</tr>
<tr>
<td><strong>Northumberland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Shields</td>
<td>NZ3668</td>
<td>Tyne</td>
</tr>
<tr>
<td><strong>Essex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alphamstone</td>
<td>TL8735</td>
<td>Stour</td>
</tr>
<tr>
<td>Ashdon</td>
<td>TL5838</td>
<td>Granta</td>
</tr>
<tr>
<td>Braintree</td>
<td>TL7623</td>
<td>Pant</td>
</tr>
<tr>
<td>Colchester</td>
<td>TM0125</td>
<td>Colne</td>
</tr>
<tr>
<td>Lexden</td>
<td>TL9826</td>
<td>Colne</td>
</tr>
<tr>
<td>Mount Bures</td>
<td>TL9132</td>
<td>Stour</td>
</tr>
<tr>
<td>Theydon Gannon</td>
<td>TL 4703</td>
<td></td>
</tr>
<tr>
<td><strong>Gloucestershire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deerhurst</td>
<td>SO8729</td>
<td>Severn</td>
</tr>
<tr>
<td><strong>Hampshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bishop’s Waltham</td>
<td>SU5416</td>
<td>Hamble</td>
</tr>
<tr>
<td>Braxell’s Farm</td>
<td>SU5155</td>
<td></td>
</tr>
<tr>
<td>Crookhorn Farm</td>
<td>SU6807</td>
<td>Langstone H</td>
</tr>
<tr>
<td>Silchester</td>
<td>SU6259</td>
<td></td>
</tr>
<tr>
<td>Scotland Farm,</td>
<td>SU7453</td>
<td>Loddon</td>
</tr>
<tr>
<td><strong>Hereford and Worcester</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Sandlin Farm</td>
<td>SO7551</td>
<td>Teme</td>
</tr>
<tr>
<td><strong>Hertfordshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Humberside</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Messingham</td>
<td>SE8904</td>
<td></td>
</tr>
<tr>
<td><strong>Kent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canterbury</td>
<td>TQ1558</td>
<td>Stour</td>
</tr>
<tr>
<td>Eccles</td>
<td>TQ7160</td>
<td>Medway</td>
</tr>
<tr>
<td>Iwade</td>
<td>TQ8868</td>
<td>Medway</td>
</tr>
<tr>
<td><strong>Lancashire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quernmore</td>
<td>SD5259</td>
<td></td>
</tr>
<tr>
<td><strong>Lincolnshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knaith</td>
<td>SK8284</td>
<td>Trent</td>
</tr>
<tr>
<td>Heckington Fen</td>
<td>TF1745</td>
<td>Stream</td>
</tr>
<tr>
<td>Heighington</td>
<td>TF0569</td>
<td>Witham</td>
</tr>
<tr>
<td><strong>London</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gresham Street</td>
<td>TQ3181</td>
<td>Thames</td>
</tr>
<tr>
<td>Newgate Street</td>
<td>TQ3181</td>
<td>Thames</td>
</tr>
<tr>
<td><strong>Northumberland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corbridge</td>
<td>NY9864</td>
<td>Tyne</td>
</tr>
<tr>
<td><strong>Oxfordshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shakenoak</td>
<td>SP4014</td>
<td></td>
</tr>
<tr>
<td><strong>Suffolk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blythburgh</td>
<td>TM4776</td>
<td>Blyth</td>
</tr>
<tr>
<td>Capel St. Mary</td>
<td>TL8238</td>
<td></td>
</tr>
</tbody>
</table>

Place | Map Ref | River
---|---------|---
Eleswell | TL9863 | Gipping
Farnham | TM3758 | Alde
Melton | TM2850 | Deben
<table>
<thead>
<tr>
<th>Location</th>
<th>Grid Reference</th>
<th>River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimley St. Mary</td>
<td>TM2736</td>
<td>Orwell</td>
</tr>
<tr>
<td>Wissington</td>
<td>TL9633</td>
<td>Stour</td>
</tr>
<tr>
<td><strong>Shropshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ismore Coppice</td>
<td>SJ5509</td>
<td>Severn</td>
</tr>
<tr>
<td><strong>Somerset</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philip's Norton</td>
<td>ST1924</td>
<td></td>
</tr>
<tr>
<td><strong>Surrey</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ashstead</td>
<td>TQ1860</td>
<td>Mole</td>
</tr>
<tr>
<td>Horton</td>
<td>TQ1861</td>
<td>Mole</td>
</tr>
<tr>
<td>Reigate</td>
<td>TQ2650</td>
<td>Mole</td>
</tr>
<tr>
<td>West Park</td>
<td>TQ1861</td>
<td></td>
</tr>
<tr>
<td>Wykehurst Farm</td>
<td>TQ0840</td>
<td>Wey</td>
</tr>
<tr>
<td><strong>Sussex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bardown</td>
<td>TQ6629</td>
<td>Rother?</td>
</tr>
<tr>
<td>Chichester</td>
<td>SU8302</td>
<td>Lavant</td>
</tr>
<tr>
<td>Danny Park</td>
<td>TQ2815</td>
<td></td>
</tr>
<tr>
<td>Itchingfield</td>
<td>TQ1429</td>
<td>Arun</td>
</tr>
<tr>
<td>Wiston</td>
<td>TQ1513</td>
<td>Arun</td>
</tr>
<tr>
<td><strong>Warwickshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arbury</td>
<td>SP3489</td>
<td></td>
</tr>
<tr>
<td>Griff Hill Farm</td>
<td>SP3688</td>
<td>Anker</td>
</tr>
<tr>
<td>Kenilworth</td>
<td>SP2752</td>
<td></td>
</tr>
<tr>
<td>Lapworth</td>
<td>SP1869</td>
<td>Ane</td>
</tr>
<tr>
<td><strong>Wiltshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minety</td>
<td>ST9992</td>
<td></td>
</tr>
<tr>
<td><strong>Worcestershire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Sandlin Farm</td>
<td>SO7551</td>
<td></td>
</tr>
<tr>
<td>Saddlington</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Yorkshire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grimescar</td>
<td>SE1319</td>
<td>Calder</td>
</tr>
<tr>
<td>York</td>
<td>SE6052</td>
<td>Ouse</td>
</tr>
<tr>
<td><strong>Scotland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barochan Hill</td>
<td>NS4169</td>
<td>Clyde</td>
</tr>
<tr>
<td>Mumrills</td>
<td>NS9179</td>
<td>Avon</td>
</tr>
<tr>
<td><strong>Wales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>SH7231</td>
<td></td>
</tr>
<tr>
<td>Holt</td>
<td>SJ4054</td>
<td>Dee</td>
</tr>
<tr>
<td>Gellygaer</td>
<td>ST1396</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX L
Major and Minor Towns, and Legionary Fortresses in Roman Britain
Their River and Road Connections
APPENDIX L

Major and Minor Towns, and Legionary Fortresses in Roman Britain
Their River and Road Connections

1. Introduction

The purpose of this section is to identify towns and small towns which had possible navigable river connections for the transport of goods, see Maps 3 and 7. Places with possible direct seaborne trade have been discussed in Section II.8, Annex 4 and Annex 5. For each town listed, the river and road connections are noted, together with the evidence from the archaeological record for manufacturing and trade. Were the manufacturing industries just serving a purely local market, or were they producing for export to other parts of Britain, thus requiring the use of land or river borne movement of goods? The trading and manufacturing information from the archaeological record noted under the heading “Remarks and Economy” for each site is very variable in its quality. From some places, such as Silchester, which have never been built over since Roman times, and which have been the subject of extensive and modern excavations, the information is reasonably reliable. Many other sites are under modern towns, and only very limited excavation has been possible. For some sites where no excavation has been carried out, there may be only surface collections available. Nevertheless it is believed that by looking at a large number of sites, their environs and the natural resources accessible to them, a general picture can be built up of their economic basis. For most of the small towns and settlements, agriculture, stock raising and their supporting craft activities would be the major activity. Roads have been identified by Margary’s numbering system (Margary 1973), and the prefix M has been used for all roads identified by Margary.

Modern place names have been used in this Appendix for two reasons. We do not know the Roman names for most of the Roman sites of Britain, and in using current maps of the Ordnance Survey 1/50,000 Landranger series only the modern names appear.

Principal references used for this appendix are: A.E. Brown 1995, Roman Small Towns in Eastern England and Beyond; Burnham and Wacher 1990, The Small Towns of Roman Britain; Wacher 1995, The Towns of Roman Britain. Detailed references are not given in the text, as it would have become overly congested, but the books have excellent indexes, and are laid out with separate sections for each place. Some material has been extracted from reports in volumes of Britannia, JRS and other sources.

2. Major Towns, Coloniae, Fortresses (listed alphabetically)

Aldborough
River: Roman site about 1 km from River Ure, which joins the Yorkshire Ouse, flowing

1 “Many country districts depended on the services provided by towns and villages for repairs and replacements to equipment.” (Wacher 1995:285).
into the Humber
Road: M 8a, 8b, 8c, from York to Piercebridge
Remarks and Economy: Little archaeological evidence for the commercial and industrial life of the town. Finds include farrier’s tools; weaving on a domestic scale; tanning; bone industry; enamelled bronzes. Extensive arable land around the town suggests agriculture as the main activity.

Brough-on-Humber
River: Humber Estuary (north shore)
Road: M2c, York to Brough.
Remarks and Economy: Probably had a military and naval function as a base and stores depot rather than a civilian town.

Caerleon
River: Usk, flows into Severn estuary.
Road: Junction of three roads, M60a to Caerwent, M62a to Usk and M606 to Cardiff.
Remarks and Economy: A legionary fortress.

Caerwent
River: Close to west bank of River Severn.
Road: Junction of three roads, M60a to Severn crossing, M606 to Caerleon, M60aa, short local road to Severn estuary.
Remarks and Economy: From the evidence, the normal trades; carpenter’s and mason’s tools; cobblers; weaving; and blacksmithing.

Caistor-by-Norwich (also known as St. Edmunds)
River: Yare, flows into North Sea at Great Yarmouth.
Road: Terminus of M3d from London. Local roads towards the coast.
Remarks and Economy: Glass making; bronze-working; pottery; woollen goods.

Canterbury
River: Great Stour which today flows to the English Channel at Pegwell Bay by Richborough. In the Roman period it probably joined the Wantsum Channel, now silted up, which separated the Isle of Thanet from the rest of Kent. In the Roman period the Wantsum was navigable from Pegwell Bay to the Thames at Reculver.
Road: Junction of six roads: M1a Watling Street from Dover; M1b Watling Street to London; M12 to Lympne; M130 across Romney Marsh to join M13 Rochester to Hastings road; M110 to Reculver; M10 to Richborough.
Remarks and Economy: Extensive LPRIA settlement. Manufacture of bricks, tiles, pottery, numerous kilns; chalk quarrying; metal-working in iron, bronze; some iron smelting; enamelled bronzes; silver-smithing; bakeries.

Carmarthen
River: Towy, flows south into Carmarthen Bay on south coast of Wales.
Road: Junction of two roads, M69d from North Wales and M623 up the valley into the Cambrian Mountains and to Llandrindod Wells.
Remarks and Economy: Metal-working; tanning; production of querns.

Chelemsford
River: River Chelmer flowing into the River Blackwater estuary at Maldon.
Road: On M3a, 3b from London to Colchester; M300 to Dunmow and Great Chesterford,
M33a to Ixworth.
Remarks and Economy: Industries included bone, horn and leather-working; metal-working in iron and bronze; pottery and associated kilns.

Chester
River: Dee estuary.
Road: Junction of five roads, M6a, M66a, M67a, M7a, M701.
Remarks and Economy: Primarily a legionary fortress, with industrial activities in the vicinity (major legionary works activity and depot at Holt about 12 km south of Chester).

Chichester
River: Close to head of tidal inlet in north-east of Chichester Harbour at Fishbourne. River Lavant runs by town.
Road: Stane Stree M15 to London, M155 to Silchester, M420, 421 to Bitterne and Winchester, M153 to Selsey.
Remarks and Economy: Early forts and stores buildings. Industries included fulling; bronze-working; enamelled jewellery; iron smelting and working; quarrying.

Cirencester
River: River Churn, a tributary of the Thames fairly near its source.
Road: Junction of six roads: M16b from St Albans, M41b from Silchester, M5c from Bath, M544 towards Severn crossing, M41c to Gloucester, M5d to Lincoln, and M55, a local road.
Remarks and Economy: Quarrying; cattle and meat market; mosaicists for a wide area; sculpture; blacksmithing; bricks; goldsmiths; glass making and working; and bakeries.

Colchester
River: Essex River Colne, flowing directly to the sea.
Road: Junction of roads M3a from London via Chelmsford, M3c and 3d to Caistor-by-Norwich, M24 to Godmanchester, M32 to Braughing, and M320, 322, local roads.
Remarks and Economy: A major LPRIA site with industrial and trading activities. Initially a Roman fortress, later replaced by a colonia. Modest evidence for light industry, pottery and metal-working. A trading centre with connections by sea to the Rhine.

Dorchester (Dorset)
River: River Frome flowing into Poole Harbour at Wareham.
Road: Junction of four roads: M4e to Old Sarum, M4f to Exeter, M47 to Ilchester, and M48 to Portland quarries area.
Remarks and Economy: Shale-working; lead-working; blacksmithing; bricks; and quarrying Purbeck marble.

Exeter
River: River Exe, with downstream harbours at Topsham and Exmouth.
Roads: Junction of five roads: M4f and M49 from Dorchester; M492 to Cornwall, and M490, 491, local roads.
Remarks and Economy: Initially a legionary fortress. Later a town with metal-working; flagons and mortaria; some bone and shale goods; masons.

Gloucester
River: River Severn.
Road: Junction of four roads: M180 to Worcester, M41c to Cirencester, M541 to Sea Mills,
278. Appendix L

M62 to Wales.
Remarks and Economy: Originally a fortress, later a colonia. Little evidence for industry within the town. In the environs: pottery kilns and iron-working furnaces; brick and tile manufacturing; bone-working; smithing; quarrying and lime-burning.

Leicester
River: River Soar which flows into the River Trent and thence into the Humber.
Road: Junction of four roads: M5f to Lincoln, M57a to Godmanchester, M5e to High Cross, M1g to Mancetter and Wall.
Remarks and Economy: Tanning; horn working; metal working; glass making; lime burning; some pottery and tiles.

Lincoln
River: River Witham flowing to the north-west corner of the Wash, but the connection used was more likely the Roman canal, the Foss Dyke which connected the Witham to the River Trent and thence to the Humber estuary.
Road: Junction of four roads: M2c Ermin Street from the south, m2d Ermin Street to the north, M5f Fosse Way to Leicester, M27 to East Coast.
Remarks and Economy: Legionary fortress becomes a colonia ca. AD 100. Only modest evidence for manufacturing and trade.

London
River: Tidal part of the River Thames, about 75 km from the open sea. Tributaries into the tidal part include the River Medway with its tributaries into Kent, River Roding, and River Lee. Numerous tidal creeks and inlets along the estuary. Above the tidal limit other tributaries to Cirencester in the west and Braughing in the north.
Road: The hub from which the road network spreads out to cover England and later southern Scotland.
Remarks and Economy: The largest urban centre in Britain, the centre for the provincial administration, a major trading centre by sea, inland waterways and land. Many secondary industries converting materials produced by the primary industries. Warehouses and distribution centres for both imports and goods produced elsewhere in Britain.

St. Albans
River: River Ver which joins River Colne, which joins the Thames at Staines.
Road: A major road junction, five roads radiate from St. Albans in all directions, see Map 7.
Remarks and Economy: Metal-working in bronze, iron and gold; a high degree of coin loss suggests a vigorous commercial activity; numerous shops, wine, food, butchers, bakers. Industries: fulling; leather-working; brick- and tile-making; working stone from British quarries and imports from as far away as Carrara.

Silchester
River: Foudry Brook about 1 km to the east flows into the River Thames at Reading. Thames is about 12 km away.
Road: Junction of five roads: M4a to London, M42a to Winchester, M41a to Cirencester, M160b and 160c to Dorchester.
Remarks and Economy: Silver refining; tanning; cobblers and leather working; dyers; pewterers; bronzesmiths; blacksmiths; iron smelting; carpenters’ tools; agricultural
implements; coopering; bricks and tiles; masons; glass making.

**Winchester**
River: River Itchen flowing into Southampton Water.
Road: Junction of five roads: M42a to Silchester, M420 to south coast, M426 to Bitterne, M422 to the New Forest (potteries), M45g to Old Sarum, M43 to Mildenhall.
Remarks and Economy: Information is sparse, but woollen goods, fulling and bronze-working are likely.

**Wroxeter**
River: On upper reaches of the River Severn.
Road: Junction of four roads: M1h from Wall, M6a and 6b to Welsh Marches, M64 to central Wales.
Remarks and Economy: From the market place evidence for merchants selling hardware; mortaria; Samian ware from different factories; and whetstones. Metal working in bronze and silver; enamelling; pigments for painting; glass making; tanning; pottery and tiles.

**York**
River: Yorkshire Ouse, flowing to the Humber.
Road: Junction of five roads: M8a to Corbridge, M801 and 810 to local areas, M2e to Brough-on-Humber, M28c to Tadcaster and Doncaster.
Remarks and Economy: Extensive trading connections from as far afield as Bordeaux, Bourges, and the Rhineland. Industries include the carving of Whitby jet; flax and linen production; smithing; glass working; copper working; leather working; no local pottery (used Crambeck wares), but legionary tile production.

3. **Small Towns, Religious Sites, Industrial Sites, Defended and Undefended Settlements**

Note: numbers in parenthesis indicate location of site on Map 7.

**Alcester (1)**
River: junction of Rivers Arrow and Alne, which join the River Avon, which flows into the upper Severn estuary.
Road: M55b east to Eatonville and west to Droitwich, M18a to Bourton, M18b to Wall.
Remarks and Economy: Tannery; leather working; small scale metal working; pottery shop with samian ware; a service centre for the local agriculture.

**Alchester (2)**
River: close to a small stream which joins the River Cherwell just north of Oxford and thence to the Thames.
Road: junction of two main Roman roads, M160a and 160b north-south from Dorchester-on-Thames to Towcester, and M16a and 16b Akeman Street east-west from St, Albans to Cirencester.
Remarks and Economy: Information on economic base is minimal: a number of workshop type buildings known, but not enough has survived to indicate the trades involved.

**Ancaster (Lines) (3)**
River: River Slea, joining River Witham and thence to the Wash.
Road: M2c Ermine Street, from Lincoln to Water Newton.
Remarks and Economy: Finds suggest quarrying from nearby Jurassic limestone ridge, and school of local sculptors.

Ashton (4)
River: River Nene
Road: M570 from Irchester to Peterborough.
Remarks and Economy: Strip settlement along the road from Water Newton to Thrapston; some evidence for smithing.

Baldock (5)
River: River Ivel flowing north and east into the Ouse.
Road: M32, junction to Braughing and M22 to Water Newton.
Remarks and Economy: Extensive Iron Age and Roman settlement, with a predominantly agricultural base.

Bath (6)
River: in a loop of the River Avon
Road: Junction of five roads: M53 to London, M52 to south coast, M5b to Ilchester, M54 to Sea Mills, M52 or 5c to Cirencester.
Remarks and Economy: A major spa and religious centre.

Bourton-on-the-Water (7)
River: Rivers Windrush and Dickie, flowing into the upper Thames.
Road: M5d, Fosse Way, and M18 to Alcester.
Remarks and Economy: A large but sprawling settlement, with a substantial mansio.

Braintree (8)
River: River Brain, flows into headwaters of the River Blackwater estuary.
Road: Stane Street and M33a from Ixworth to Chelmsford.
Remarks and Economy: Ribbon development within 100 m of roads. Agricultural activity and some smithing and iron working.

Brampton (9)
River: River Bure, flowing to the North Sea at Great Yarmouth. Remains of timber wharf and gravelled surfaces found.
Road: M38 from Water Newton.
Remarks and Economy: Pottery production, 132 kilns found, and iron working.

Braughing (10)
River: junction of Rivers Rib and Quin, which join the River Lee, then to Thames.
Road: Junction of five roads: M32 east to Colchester and west to Baldock, M2a from London, M2b and 2c to Lincoln, M21b to Caistor.
Remarks and Economy: Several large masonry buildings; iron, bronze and bone working; possibly pottery and tiles.

Buxton (11)
River: Derbys River Wye, headwaters of a small stream at 300m above sea level, flowing into the River Derwent. Not navigable.
Road: Junction of four roads: M71a to Littlechester, M71b to Manchester, M710a to Doncaster, and a local road M713
Remarks and Economy: A spa site.
Caistor-on-the-Wolds (Lincs) (12)
River: North Kelsey Beck, not navigable, a very small stream, joining the old River Ancholme flowing to the Humber. Land drainage schemes have overlaid the former river systems.
Road: M270 from Horncastle to South Ferriby.
Remarks and Economy: A walled site with some bastions, but little else is known as excavation has been very limited.

Cambridge (13)
River: River Cam, flows into the Ouse and thence into the Wash at Kings Lynn.
Road: Junction of five roads: M24 south-east to Colchester, and north-west to Godmanchester, M23a and 23b from Ermine Street to Denver, and M231 a local road.
Remarks and Economy: Agriculture the principal activity; smithing; bone working; some pottery.

Camerton (14)
River: On a limestone ridge between the Rivers Cam and Wellow, which join the River Avon, which flows into the Severn. The two rivers are barely navigable.
Road: On M5b, Fosse Way.
Remarks and Economy: Some evidence for pewter working and iron working.

Carlisle (15)
River: River Eden and estuary of the Solway Firth
Road: Junction of four roads: M7e and 7f across the border, M85b to Corbridge, M750 to Maryport.
Remarks and Economy: Little known of the trade and industry: some tanning and copper working, but may be military; Merchants were in the area, dedication slabs from Bowness, presumably servicing the garrison of the Wall.

Catterick (16)
River: River Swale, which joins the River Ouse, which flows into the Humber estuary.
Road: M8b from York to Scotch Corner.
Remarks and Economy: Little evidence for industrial activity: one copper-smith's workshop; quern manufacture; some military tanning activity.

Charterhouse (17)
River: none in the vicinity. Site is in middle of Mendip Hills.
Road: End of M45b from Old Sarum.
Remarks and Economy: a major industrial complex, lead mining, smelting and casting into pigs.

Chesterton-on-Fosse (18)
River: only a local stream, not navigable.
Road: M5d Fosse Way.
Remarks and Economy: Small walled settlement, third and fourth century occupation.

Corbridge (19)
River: River Tyne.
Road: M8d, Dere Street and M85a Stanegate junction.
Remarks and Economy: Much archaeological work on the military sites; granaries remained under military control. Civilian town site not yet well understood compared to fort and
military installations. Civilian strip housing and workshops.

**Cowbridge (20)**
River: River Thaw
Road: M60c from Cardiff.
Remarks and Economy: Early military occupation, with a bath house; occupation first to fourth century with smithing and other indeterminate industrial activities.

**Dorchester-on-Thames (21)**
River: River Thame at junction with Thames.
Road: M160b.
Remarks and Economy: A tax collecting centre: centre of an agricultural district; lime burning; some pottery production for local use; smithing; no evidence for other industrial activities.

**Dorn (22)**
River: A few small streams or brooks in the area, but nothing navigable or close.
Road: M5d, Fosse Way.
Remarks and Economy: Two steelyards recovered from second century building, suggesting commerce or trade: occupation continued to fourth century.

**Droitwich (23)**
River: River Salwarpe, flows into the upper Severn.
Road: Junction M180, M56b, M193.
Remarks and Economy: Industrial evidence from the town related to large scale salt production, probably continued into the fifth century until it became impossible to send it to market: Lime burning.

**Frilford (24)**
River: on a small stream flowing into the River Ock, a tributary of the Thames.
Road: On M164 from Alchester to Mildenhall.
Remarks and Economy: Extensive religious complex with associated settlement: extensive pottery finds, but little known of other economic activities.

**Godmanchester (25)**
River: the Cambridgeshire Ouse, flowing to the Wash at King’s Lynn.
Road: Junction of M2b Ermine Street, M22, and M24.
Remarks and Economy: Agricultural roots: some copper and blacksmithing; bone working; some pottery production; industrial activity increased over time as place grew from village to small town.

**Great Casterton (26)**
River: River Gwash, tributary of the River Welland flowing to the Wash.
Road: M2c, Ermine Street.
Remarks and Economy: Pottery; a smelting hearth.

**Great Chesterford (27)**
River: River Cam flowing to the Wash after joining the Ouse.
Road: Junction of M21b and M300.
Remarks and Economy: Traces of metal working; commerce indicated by two steelyards.
Harlow (28)
River: River Stort, flowing into the River Lee, and thence to Thames. Navigable.
Road: Possible road from Braughing.
Remarks: Romano-Celtic temple site with 12 ha civilian area. Bronze and iron working hearths; iron slag; lead waste; some finds of leather; many agricultural features.

Hibaldstowe (29)
River: Stream in bottom of valley crossed by Ermine Street. Flows into Old River Ancholme, which joins Humber Estuary. Probably not navigable.
Road: M2d, Ermine Street.
Remarks: Strip buildings with one winged corridor house: no evidence for the economic base of the settlement.

Holditch (30)
River: Close to the head waters of the River Trent, flowing across the Midlands to the Humber.
Road: M70a near Middlewich: site not found until 1969.
Remarks and Economy: Iron working site; charcoal, coal, cinders; lead waste; iron ore; large quantities of slag used for road surfacing; commerce indicated by lead weights, food shops, eating house, bakeries.

Horncastle (31)
River: River Bain, joins River Witham which flows into the Wash
Road: At end of M270.
Remarks and Economy: no evidence for economic activity: possible military connections.

Ilchester (32)
River: River Yeo, joins River Parret and flows to Bristol Channel. River Yeo possibly straightened in Roman period.
Road: Junction of M5a and 5b, and M51 and 47.
Remarks and Economy: Agricultural activities; building trades; iron working; bone working; glassworking.

Irchester (33)
River: River Nene, flowing to the Wash.
Road: M170
Remarks and Economy: Virtually no evidence for industrial activity in either the town or suburbs. One isolated pottery kiln. A market and service centre for the surrounding villas and countryside.

Kenchester (34)
River: River Wye, flows into the Severn estuary
Road: M6c.
Remarks and Economy: Furnaces and hearths; iron and lead slag.

Little Chester (35)
River: River Derwent on outskirts of Derby.
Road: Junction of M18c and 18d, M181, M182, and M71a.
Remarks and Economy: Initially a fort site. Pottery with Roman forms. Iron working developed in the second century, flimsy timber framed buildings along the roadsides. Furnaces, hearths and slag suggest the working of iron blooms into ironwork.
Mancetter (36)
River: River Anker, joins River Tame then River Trent, and thence into Humber estuary. Mancetter is close to the sources of three largest river systems, those flowing into the Humber, the Wash and the Severn.
Road: Astride M1c, Watling Street, junction with M57b.
Remarks and Economy: Pre-Flavian vexillation fort. Industrial activity; pottery; mortaria; more than a dozen potters’ stamps on mortaria; mortaria distributed throughout northern Britain up to Antonine Wall, North Wales and South Midlands: glass working also active.

Margidunum (37)
River: on small tributary of the River Trent, flowing into the Humber. Trent is only 1.6 km from the site.
Road: M5f, Fosse Way.
Remarks and Economy: First century specialist military iron working: later probably mostly agricultural.

Middlewich (38)
River: River Croco flowing into the River Dane, which joins the River Weaver flowing into the Mersey.
Road: Junction of M7a and M700.
Remarks and Economy: Large scale salt extraction and iron working: some evidence for smelting; trades included metal working in iron, bronze and lead; window glass manufacturing; weaving; cobbling; small pottery production; generally industrial and craft specialization.

Mildenhall (39)
River: River Kennet, which joins River Lark and then the River Cam.
Road: Junction of two roads, M58, M43, M44.
Remarks and Economy: Little known of town’s everyday life and economic activity.

Neatham (40)
River: River Wey.
Road: On M155, Roman road between Chichester and Silchester. Junction with local roads to Alice Holt potteries.
Remarks and Economy: Ribbon development along the roads, with a number of alterations and changes to the layout over time. Agriculture; bronze and iron working; pewter industry; bone working; and pottery: a bath house and possible mansio. Two steel-yard pieces indicate commercial activity.

Nettleton (41)
River: Broadmead Brook, flowing into the Avon above Bath.
Road: M5c, Fosse Way.
Remarks and Economy: Shrine or temple dedicated to Apollo Cunomaglos in first or second century. In the fourth century the manufacture of pewter tableware and bronze casting activities noted, together with some iron working. In 1968 the remains of a Roman water-mill were exposed with a 2.5m diameter wheel and well built mill race.

Rochester (42)
River: River Medway, flows into the lower Thames estuary.
Road: M1c M1b, Watling Street.
Remarks and Economy: Was it a secondary naval base, together with Brough-on-Humber, and Caistor-by-Yarmouth? North gate probably led to quay or docks. Salt extraction from sea water. Service centre for potters in the area, and for the large villas in the Darent valley and others in north Kent.

Sapperton (43)
River: East Glen River running into Glen River, and thence to the Wash
Road: M26, beside the main road from Bourne to join Ermine Street at Ancaster
Remarks and Economy: About 4 ha site with typical strip development: iron working both smelting, probably from local limonite, and smithing.

Springhead (44)
River: head waters of a tidal creek off the Thames between London and Rochester, still navigable in 1939. Head of creek revetted with flints and surrounded with metalled area, forming a dock reaching into the settlement.
Road: M1c, Watling Street
Remarks and Economy: A religious area with small temples, second to fourth century.

Staines (45)
River: River Thames at confluence with River Colne.
Road: M4a.
Remarks and Economy: Ribbon development on a gravel island and surrounding areas: economy in later first and second centuries fairly flourishing, based on imports found. Lack of evidence for economic activities. A trading and exchange centre.

Thorpe-by-Newark (46)
River: River Trent.
Road: M5f, Fosse Way.
Remarks: Claudian-Neronian fort, abandoned in Flavian period. Little evidence for economic activities found to date.

Tiddington (47)
River: River Avon, flowing into Severn estuary.
Road: by-passed by main road M56b, from Alcester to the Fosse Way, which crossed the river about 2.4km away.
Remarks and Economy: extensive settlement with mixed agricultural and light industry economy. Strong agricultural base, with some small scale industrial activities.

Towcester (48)
River: River Tove, which flows into the Ouse and thence to the Wash.
Road: M1c, M1f, Watling Street, junction with M160a.
Remarks and Economy: Agricultural activity. Shops and workshops along the main street: smithing; iron smelting; lead, pewter and bronze manufacturing; a service centre.

Wall (49)
River: On small stream flowing into Black Brook, which joins Rivers Tam and Anker at Tamworth. These flow into river Trent, and thence to Humber.
Road: Junction of M1g and M1h, Watling Street, and M18b and 18c.
Remarks and Economy: Succession of early military bases: bath house and mansio identified; timber buildings. Except for traces of copper working and iron slag, no archaeological evidence for economic activities.
Wanborough (50)
River: No significant rivers within 15 to 20 km.
Road: Junction of M41b and M43.
Remarks and Economy: Some local manufacture of pottery; large quantities of iron slag, possibly from local smelting of nodules of iron ore found in the Kimmeridge clay.

Water Newton (51)
River: River Nene, which flows to the Wash.
Road: Junction of M2b, M2c, Ermine Street, M570, M25, M571.
Remarks and Economy: Considerable industrial potential; pottery production; various workshops including ailed buildings with kilns and furnaces; iron smelting and working spread over an area around the town; leather working; a processing and marketing centre for the Fens with both road and river transportation systems; some luxury trades such as goldsmithing.

Wilderspool (52)
River: River Mersey, south bank.
Road: Junction of M7a, M7b, M701.
Remarks and Economy: Extensive timber buildings, metal working and pottery manufacturing.

Worcester (53)
River: River Severn
Road: Junction for M180 and some local roads from Alcester, Droitwich, Gloucester, and Kenchester.
Remarks and Economy: Evidence for iron working and possibly smelting, using ore from the Forest of Dean. Coins from Claudian period to fourth century.

Wycomb (54)
River: River Coln or Syreford stream, tributary to the upper Thames near Cheltenham: Not navigable.
Road: M55 from Cirencester.
Remarks and Economy: A religious site, but also tools and agricultural implements found. Probable bath and possible theatre.

4. Discussion and Conclusions

From the above summary all the major towns are on or fairly close to a navigable river. All but five or six of the small towns have access to at least a minor navigable waterway.
APPENDIX M

A Hypothetical Transport for Fifty Men in Caesar’s Expedition to Britain in 54 BC
APPENDIX M

A Hypothetical Transport for Fifty Men in Caesar’s Expedition to Britain in 54 BC

Shown in Fig. App.M.1 are the lines for a theoretical transport to carry fifty men or a mix of men and horses. The design is based on a combination of Caesar’s description of the ships of the Veneti, and the archaeological remains from the Barland’s Farm boat and the Blackfriars 1 ship.

**Dimensions of the Ship**
- Length: 15 m
- Breadth: 4.5 m
- Depth amidships: 1.5 m
- Draught, empty: c. 0.35 m
- Draught, loaded: c. 0.55 m
- Freeboard, loaded: 0.95 m

**Dimensions of the Timbers**
- Keel planks: 0.66 x 0.076 m
- Side and bottom planking: 0.40 x 0.05 m
- Floor timbers: 0.3 x 0.21 x 4.5 m
- Frames: 0.2 x 0.01 x 1.5 m
- Cross-beams: 0.3 x 0.3 x 5.0 m
- Frame and floor spacing: 0.6 m
- Nails required: c.4560

**Load**
- 50 soldiers with personal equipment @ 104 kg each = 5.2 tonnes
- 10 sailors/ marines with equipment @ 104 kg each = 1.04
- Military stores, rations and baggage = 4.0
- Total load = c.10.0 tonnes

The vessel could carry more cargo or men, but the freeboard would be reduced. For a Channel crossing, even in settled weather a good freeboard increases the safety margin, and probably the morale of the troops.
APPENDIX N

Five Hypothetical Romano-British Flat-Bottomed River Barges
APPENDIX N

Hypothetical Romano-British Flat-Bottomed River Barges
(See Figs. App.N.1 and App.N.2)

Shown below are form, dimensions and carrying capacity for five hypothetical simple flat-bottomed river barges in a range of sizes. The materials, their dimensions and the constructional techniques have been derived from a combination of those used for the New Guy's House barge from the Thames at London, and the Roman barges from Zwammerdam in the Netherlands.

Table App.N.1: Dimensions and quantities of materials needed
(Note: All timbers are oak with a specific gravity of 0.86, and all nails are wrought iron with a specific gravity of 7.74)

<table>
<thead>
<tr>
<th>Barge No.</th>
<th>Barge 1</th>
<th>Barge 2</th>
<th>Barge 3</th>
<th>Barge 4</th>
<th>Barge 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length m</td>
<td>15.0</td>
<td>12.0</td>
<td>10.0</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Beam m</td>
<td>3.75</td>
<td>3.0</td>
<td>2.5</td>
<td>1.75</td>
<td>1.25</td>
</tr>
<tr>
<td>Depth m</td>
<td>1.20</td>
<td>0.96</td>
<td>0.80</td>
<td>0.56</td>
<td>0.40</td>
</tr>
<tr>
<td>Mean water-plane area m²</td>
<td>51.75</td>
<td>33.0</td>
<td>22.5</td>
<td>11.27</td>
<td>5.63</td>
</tr>
<tr>
<td>Area of planking m²</td>
<td>93.12</td>
<td>60.16</td>
<td>40.8</td>
<td>20.05</td>
<td>10.2</td>
</tr>
<tr>
<td>Number of strakes</td>
<td>20</td>
<td>16</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Thickness of planking m</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
<td>0.03</td>
<td>0.025</td>
</tr>
<tr>
<td>Weight of planking kg</td>
<td>5605</td>
<td>3104</td>
<td>1754</td>
<td>517</td>
<td>219</td>
</tr>
<tr>
<td>Frame cross-sections m</td>
<td>0.20 x 0.10</td>
<td>0.16 x 0.09</td>
<td>0.146 x 0.076</td>
<td>0.12 x 0.07</td>
<td>0.10 x 0.06</td>
</tr>
<tr>
<td>L shaped frame length m</td>
<td>4.95</td>
<td>3.96</td>
<td>3.3</td>
<td>2.21</td>
<td>1.65</td>
</tr>
</tbody>
</table>
### Table App.N.2: Draught, freeboard and weight of cargo

<table>
<thead>
<tr>
<th></th>
<th>0.24</th>
<th>0.20</th>
<th>0.155</th>
<th>0.12</th>
<th>0.088</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draught, light</td>
<td>1.10</td>
<td>0.86</td>
<td>0.70</td>
<td>0.46</td>
<td>0.30</td>
</tr>
<tr>
<td>Draught loaded</td>
<td>0.96</td>
<td>0.76</td>
<td>0.645</td>
<td>0.462</td>
<td>0.312</td>
</tr>
<tr>
<td>Freeboard light</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Freeboard load</td>
<td>44.5</td>
<td>21.78</td>
<td>12.26</td>
<td>3.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Weight of full cargo</td>
<td>3.53</td>
<td>3.32</td>
<td>2.85</td>
<td>2.78</td>
<td>2.42</td>
</tr>
<tr>
<td>Ratio: cargo weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to barge hull weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although the five barges described in this appendix are “hypothetical”, in the sense that no vessels of this type have been recovered from archaeological sites in Britain, the general design is perfectly practicable. The Rhine barges from Zwammerdam in the Netherlands, dated to the late first century A.D., are somewhat similar. The smaller sizes could easily be built with simple Romano-British tools, axe, adze and spoon bit. Fashioning the planking would be the only problem. By the middle and later Roman period in Britain large frame saws for cutting planks may have been in use, as shown by the sawn
planks from the St. Peter Port ship. However, there would be no particular difficulty in hewing planks from either radially or tangentially split logs, using axe and adze. This was the practice in Scandinavia until the eleventh century A.D.

The smallest barges, the 5 m Barge 5 and 7 m Barge 4 could be built by a family or extended family unit. The nails would probably have to be acquired from a specialist blacksmith, but the woodworking skills required would be widely available. Of the five sizes proposed, Barges 4 and 5 would be for small scale local traffic. They could be operated by one or two people and would be employed in moving agricultural products from farms and villas to local markets, and moving modest amounts of pottery, salt and other commodities to small regional markets. Barge 1, the largest with a total weight of hull and cargo capacity of about 57 tonnes, would need a crew of at least four or five men to propel it by towing or poling. Barge 1 would be used for bulk cargoes of grain, quarried stone or tiles. The Barge 1 type could be owned and operated by the army, large civic authorities or large industries. Barge 2 with a cargo capacity of about 22 tonnes would be engaged in similar activities. The mid-sized Barge 3 would be a convenient vessel for transporting materials and products for large scale industries.

In general, for the movement of goods, some animals and people, vessels in a range of sizes would be needed on the inland rivers. On small rivers and streams only small vessels would be practicable, and in general there would be far more small and mid-sized vessels in use than the large Barge 1 and 2 types. The New Guy's House boat from the Thames, a river barge of different hull form, is estimated to have had a cargo capacity of about 6 tonnes (Marsden 1994:104). It seems quite probable that many mid-sized and large farms and villas sited on or close to navigable rivers would have had their own vessels. Similarly, large potteries and similar industries would have one or more vessels, either operated as part of the business, or hired on standing contracts with specialist barge owners.
APPENDIX O

Possible Haven Sites from The Firth of Tay in the North along the East and South Coasts to the River Exe in Devon
APPENDIX O

Possible Haven Sites from The Firth of Tay in the North along the East and South Coasts to the River Exe in Devon

Note: Much of the material in this Appendix appears in a shorter form in Annex 5 to Section II.8. It has been repeated in this Appendix to save endless switching back and forth between the two.

The figures against each site are the volume and page numbers of Britannia with notes or articles on the site. An examination of the articles and indexes in The Journal of Roman Studies from 1923 to 1969 produced no information on haven sites. Where just the name of the site is shown, no references to maritime connections for it were found. These havens with no references are practicable havens for vessels of modest size, and in fact many have been used as such from medieval times to the present day. Many today are filled with yachts.

East Coast Havens

Monkwearmouth
Sunderland
Ryhope
Seaham
Hartlepool 18:318
A double burial of a man and woman, a necklace of glass beads; 4th-5th c. A.D.
Middlesbrough
Stockton-on-Tees
Whitby 6:174-75
A Mayen sherd from Germany.
Robin Hood's Bay
Bridlington
Hull 17:386; 24:287; 25:478, 29:387
Bronze Age and Roman material; boundary ditches of 2nd to 4th centuries; sufficient ditches, tombs and structures to suggest a small town. Roman period river bank, a riparian settlement?
Brough-on-Humber 10:287
Probable hard surfaced area. Brough was a haven and fortified site and almost certainly a supply base at different periods, see Wacher 1969.
Goole
Selby 29:385
Fourteen Roman period coins found.
The Wash
Boston
Kings Lynn
Wisbech 1:19; 12:120-27, 135
Coin finds, gold stater, coins of Gallienus, a cruciform broach.

Wells-Next-The-Sea
Blakeney
Lowestoft
Walberswick
Hollesley 6:262
Roman ditch system and a number of storage pits; a nearby settlement suggested, but not found.
Orford
Snape
Waldringfield 18:332
A large number of clay moulds (30+) for bronze casting found; late Iron Age to mid 1st century A.D..
Finds include pottery, roof and other tiles, small bronze figurines, lamps, cosmetic set, coins, date range 117-346 A.D.. Gallic and British coins found, suggesting pre-Roman use of the site.

Rivers Stour and Orwell
Felixstowe 11:318; 16:186; 18:331; 26:357
Ditches, pits, postholes, large quantities of pottery, tile, bronze cosmetic mortar set, lead seal of LegioVI Victrix with officer's (?) initials, aureus of Marcus Aurelius, A.D. 160. Material spans 2nd to 4th century. First century A.D. Roman rubbish pits, ditches, structures and well preserved Roman deposits.
Levington
Ipswich 11:376; 15:307; 23:289; 31:413
Three sides and part of interior of a ditched enclosure, 1st to 3rd centuries; two bronze brooches, one enamelled, 2nd-3rd century. Ditches, pits, post-holes and cremation burials dating to the first century A.D.
Harwich
Shotley 18:332
Gold quarter stater of Addedomarus.
Mistley
Manningtree

Hamford Water
River Colne

**Brightlingsea** 26:359
Pieces of Roman brick, box flue tile, septaria, a villa?

**Wivenhoe**

**Fingringhoe**

**Rowhedge**

River Blackwater

**Mersea Island** 31:414
Five denarii to c. A.D. 37

**West Mersea** 9:452
Roman wall, floors, associated deposits.

**Tollesbury** 9:452
Salt recovery site; hearths, briquetage, includes fire bars, pedestal and clay lined gully.

Late Iron Age levels with large amount of pottery including significant amount of imports, it was concluded that Heybridge was a trading port in the Iron Age. Roman period: metalled roads, large metalled areas with traces of timber structures, pits, post holes, ditches, wells, domestic areas, manufacturing areas, evidence for 1st century brick built structure (a mansio?), five well preserved pottery kilns, mould fragments and other evidence for metal working, four timber lined wells, cemetery. An early Roman gravel digging area levelled off with industrial waste including iron slag, charcoal, ash, kiln debris, lead droppings, later gravelled over to make a yard, probably associated with a wharf on the river Blackwater. Other finds include a tegula fragment with graffito CCXX cut retrograde before firing (from a batch of 220?): Samian bowl fragment found with 2nd century material, stamped BORILUS I of Lezoux (c. AD 150-60), graffito cut after firing on inside of foot ring VET FIR[...]. A plank from a well lining is stamped SV. The general conclusion is that it was the site of a small town of about 9ha (22 acres), most active in the 1st and 2nd centuries, but fading out of use by the 3rd century. Local research has suggested important trading connections with Chelmsford (Caesaromagus). The River Chelmer, partly canalized in the 19th century connects the two. The most recent excavations and publications have downgraded the Roman site to a "market village", rather than a small town, partly because of the lack of good road communications. On the other hand there is the river which connects to Chelmsford. This could have substituted for a road for the movement of goods.

**Maldon** 4:305; 20:303-4; 22:263; 31:414
A substantial settlement, ditches, flue tiles, Roman cremations, pottery, silver brooch. Saltpans, two main groups of clay lined evaporators, tanks, artificial basin, many fragments of pedestals and firebars of three types. Sherd of Italian Arretine,
an amphora stamp reading PIRP.C. A farming settlement and salt manufacturing area. Three gold staters of Dubnovellaunos found, dating to c. B.C. 25.

Maylandsea
Salcott

River Crouch

Burnham-on-Crouch 4:301
A 1st century settlement with 3rd century occupation.

Fambridge
Hullbridge 16:296; 17:407
A brushwood platform, possibly used as a jetty, dated to 340-450 A.D.
In the area twelve "Red Hill" sites, late Iron Age and Roman salt production.

Rochford 11:379
2nd and 3rd century Roman occupation.

Paglesham

River Thames

Southend-on-sea 17:407
Hoard of 33 Gallo-Belgic E staters.

Canvey 27:442; 29:437
Wall sherd of a Samian cup. From an eroded foreshore deposit, an Upchurch ware beaker with a graffito cut in neat capitals after firing.

Benfleet 25:280

Gillingham
Chatham

South Coast

Ramsgate 1:304
Hoard of 27 sestertii, from Hadrian to Postumus.

Pits and ditches covering more than 4 ha, coins, terra nigra platter with graffito COMMUNIS, winged corridor house, ovens, walls of chalk and flint lumps set in clay. Occupation 1st to 4th century, but most intense in 1st-2nd centuries. Samian ware and cremation burials.

Minster 18:359; 20:236; 23:307; 29:432
Site of a villa, much building debris, floors 30m long, internal masonry wall 4m long. Two hoards of 3195 and 99 radiates down to AD 282. West wing up to twice width of east wing.

Hythe
Rye
Winchelsea
Norman’s Bay
Eastbourne  2:186; 10:148
Greensand stone used as Roman building material, probably from Maidstone, and shipped
from the River Medway. One complete voussoir tile found.
Cuckmere Haven
Rescue excavation, ditches, enclosures timber structures, painted plaster, tiles, window
glass, dated to early 2nd century. Extensive timber building with ironstone and flint
foundations, timber granary 14m x 5m, and several other large buildings. Pottery suggests
site abandoned before 4th century.
Shoreham
Littlehampton  6:131
Evidence for crops, spelt, barley, rye brome, vetch (as a fodder crop?).
Bognor Regis
Pagham Harbour
Chichester Harbour

West Itchenor
Bosham  2:189; 20:11; 25:289
Claudian base known. Tiles, fragments of tiles, painted plaster, opus signinum.
Southbourne
Thorney Island
Emsworth
Chidham  21:359; 23:27-44
Two salt production sites on the foreshore, Late Iron Age to 2nd century A.D.; solar
evaporation pan, shallow trenches for further evaporation, fragments of salt cake
moulds. Much briquetage and pottery, from the rescue excavation.
15:324; also Current Archaeology 2001, No.176:333-35
A circular Roman temple 13m diameter in temenos 30m x 30m, surrounded by
ambulatory with its own entrance, dated to A.D.60, enlarged c. A.D.100, no activity
after c. A.D.200. Agricultural and domestic activity to 4th century, from coin
evidence. Fragmentary inscription of Legio IX Hispana. Below Roman levels Late
Iron Age, with imported Celtic bronzes, votives, hearths. A separate site at South
Hayling has ditches and pits with 1st to 3rd century pottery.

Langstone Harbour  2:190
A surface scatter of roof tiles.
Havant  8:418; 25:287
Romano-British pits and pottery, 3rd to 4th century ditch and pit, no trace of
possible Roman road found.

**Portsmouth Harbour** 1:5; 18:20,31  
Coins of Iceni found.

**Fareham** 5:456; 8:418; 22:288  
Cobbled area, flint footings, drainage ditches, ditches, pottery, tiles, two hearths, animal bones, pits densely packed with remains of shellfish, 30 coins, 16 dated 253-337, remainder 364-392.

**Gosport**

**Titchfield Haven**

**River Hamble**

**Hamble** 7:366  
2nd and 3rd century pottery.

**Warsash**

**Bursledon**

**Botley**

**River Itchen**

**Southampton** 8:332; 25:31  
Structures, occupation and demolition deposits, including material up to 3rd and 4th century. Roofing tiles, calcareus roofing tiles with unusual rounded tegula flanges are a significant part of tile assemblage. These unusual tiles have a distribution from London to Devon. Movement of tile from the as yet unidentified tilery was almost certainly by ship along the south coast. Many sites no longer used locally produced tiles, but depended on specialized production centres. Dating is difficult, but 3rd and 4th century probable (Betts and Foot 1994:33-34).

**Swaythling**

**River Test**

**Totton**

**Beaulieu River**

**Lymington**

**Keyhaven**

**Isle of Wight**

**Bembridge** 17:420; 19:477  
Hoard of 26 sestertii, Domitian to Commodus. 27 coins found in intertidal silt c.
130m offshore, Domitian to Faustina II.
St Helens
Wootton Creek
Cowes, River Medina 10:477
Gurnard Bay, 3km east of Cowes, hoard of counterfeit lead-tin denarii of Lucius Verus and the two Faustinas, together with residue of copper alloy smelting. Site 300m from Roman building destroyed by coastal erosion in 1864.
Newton Creek
Yarmouth 19:477
East of harbour mouth, 16m deep, Dressel 1A and 20 amphorae found, late 1st century mortaria and sherds of BB1, and a tegula fragment of Armorican origin.

Christchurch Harbour

Poole Harbour 12:383; 19:475; 27:223-281
"Poole Harbour and the Isle of Purbeck appear to be the scene of one of the most remarkable varied and substantial concentrations of later iron Age and Romano-British export industry to be found anywhere in Britain, supported by settlements that were comparatively large (c. 10ha) and evidently planned... there is evidence that imports from overseas were flowing into the area for much of the period" (Allen and Fulford 1996:240). Purbeck marble for mortars and architectural decoration, Kimmeridge shale for personal ornaments, iron, salt and vast quantities of Black-burnished pottery were produced. Fish caught and oysters raised in the area were also exported. Twenty-three Romano-British sites have been positively identified in the area, and the total number of sites is probably in the tens (ibid. 241-242). Pottery was moved by sea, road and inland waterways (ibid. 260). The extensive study by Allen and Fulford has enabled them to trace the movement of pottery to its final destination, and to evaluate the different roles of road, river and sea as transport media (ibid. 271).

Wareham 3:346; 5:268; 18:347; 24:305; 26:367
Extensive system of ditched enclosures Late Iron Age to 3rd century A.D. Some indications of iron working in Iron Age. Mid 2nd century activity switched to production of Black-burnished ware. Large quarry pit producing fine white clay, preparation trough for cla, a pit clamp, five kilns excavated, single chamber, single flue design with no permanent raised floor or portable kiln furniture. One kiln still contained its final load. Various coin hoards to A.D.282.

Swanage Bay
Studland Bay
Lulworth Cove
Weymouth 1:299
Remains of Roman building on cliff edge, south-east of temple on Jordan Hill. Floor of building sealed pottery of 3rd to 4th century, but no occupation material overlying it.
Lyme Regis
Seaton
Beer
Sidmouth

River Exe

Exmouth 9:459; 17:415
Excavations produced box tile fragments, pottery, suggesting a hypocausted building.

Topsham 6:276; 31:424
Large number of features from gravel subsoil, mostly 1st century A.D. Three roomed building 10.6m x 4.3m with veranda on south-east front. Second building 4.5m wide, length uncertain, a four post structure, a circular structure c. 6m diameter, cremation in Black-burnished cooking pot in small square timber structure. Pottery Durotrigan and native forms, but surprising amount of samian and other imported finewares. Ditches of a rectangular enclosure.

Exeter 31.424
Extensive excavations and investigations over the past thirty years on the fortress and its surroundings. Excavation reports and annual reports in Britannia have delineated the fortress, the Legionary Bath-House and the Basilica and Forum plus a number of other structures (Bidwell 1979). Buildings possibly used as store house sit above the River Exe. Barrack blocks and part of city wall identified.

Channel Islands

Alderney, The Kennels, Longy Common 4:304
Excavation of a short length of wall, 0.9m thick, of massive granite and sandstone blocks, dated to late first-early second century. Part of Roman harbour works?

Scotland

There are several probable sites for harbour facilities. All are military sites connected with the Antonine and Severan advances.

East Coast

(Carpow is possibly the place named Orrea by Ptolemy [Keppie 1986:153]).

The fortress of about 12 ha is set back about 300 m from the Firth of Tay, on rising ground. A slab from the East Gate has a dedication to the emperor Caracalla from the Legio II Augusta. Roof tiles stamped by Legio VI Britannica (RIB 11. Fasc.4.,2460.71-74) have been found on the site. Internal buildings were a mixture of stone and timber. To date no harbour facilities have been noted, but possibly no one has looked for them. The Firth is
about 200 m wide at the fort, and it would have been possible with care to beach ships on
the foreshore, preferably on a prepared hard.

Camelon

Camelon, a small fort, is situated on a plateau beside the River Carron, off the Firth of
Forth. It was a probable Antonine period harbour, and supply base for the Antonine Wall,
and may have been used for this purpose both earlier and later. The fort covers about 2.4 ha,
and the internal buildings are all of stone. A Flavian fort probably preceded the Antonine
structure. It was a staging post for more than one or two campaigns. At least ten temporary
camps lie west and south of the fort. In the Roman period the river was easily navigable
from the Firth of Forth by vessels the size of the Blackfriars Ship 1 (today it is somewhat
obstructed by bridges and weirs). No trace of Roman wharves or quays have been reported
to date. It would have been a convenient transhipment point. The Roman road leads north
from it to Stirling, where it crosses the River Forth, and continues on to the Gask Ridge, to
Bertha and beyond (Margary 1973:491-5, Fig. 16).

Cramond

Cramond (on the Firth of Forth) 3:8, 20, 29-31, 36, 40, 42-45, 48, 50-52, 304; 5:199-206, 163-

The first major excavation of the site was carried out in 1954 to 1966 (Rae
1974:163-224). Since then the work has continued and is currently still active in
conjunction with the construction of a major new sewage outfall for Edinburgh and Leith
(personal observation June 2001)

Cramond is a fort site on the east bank of the River Almond, where it runs into the
Firth of Forth. Occupations include the Antonine and Severan periods, with civilian
occupation extending into the fourth century. The estuary of the Almond, although it
almost dries out at low tide, is an excellent haven for small craft. It is only open to winds
from the north, and provides shelter from all other winds. Today it is full of small yachts.
The bottom of the river at the mouth is soft mud, and Romano-British ships of all sizes
could safely sit on the bottom. No remains of harbour installations have been reported, but
one or two small jetties built out into the river, or a simple wharf would be adequate. The
banks of the Almond are quite steep, and it would probably have been possible to let ships
take the ground close to the bank and use a gangplank for discharging cargo.

Keppie has commented “Cramond in Roman times can be envisaged as a port of
some importance.” (Keppie 1986:111).

Inveresk

31:384.

The principal excavations are reported in the Proceedings of the Society of

The fort at Inveresk is on high ground close to the mouth of the River Esk where it
joins the Firth of Forth. It has a substantial civilian settlement to the east. There are two
phases of military occupation, and three phases of civilian use. There was deliberate demolition between the two phases of military occupation (Britannia 31, 2000:384). A small amphitheatre was noted in Britannia 29, 1998:381. The River Esk where it flows into the Forth is a little smaller than the Almond, and also almost dries out at low water. It could accommodate small craft that could take the ground, certainly up to the size of the Blackfriars 1 ship from the Thames. The entrance is an awkward and narrow channel between gravel banks, and would need local knowledge. Some beacons on the banks would have been helpful.

**West Coast**

Glenhead Fort (near Ardrossan) 1:204

"....Glenhead Fort, near Ardrossan (Ayrshire), might give a hint of the location of the presumed Roman harbour on the Ayrshire coast..." (Anne Robertson, Britannia 1, 1970:204). This comment by Robertson appears to be the only information on possible Roman harbours on the West Coast. Agricola’s main campaigning thrusts were up the East Coast, although in A.D. 81 he placed garrisons in the area south of the Clyde, Ayrshire and Galloway, and placed troops on the coast facing Ireland. He also established forts along the Forth-Clyde line (Tac. Agr. 23,24). With troops along the coast and on the Clyde, some local maritime traffic may have been established. Certainly by the period of the Antonine Wall with its west end on the Clyde, there would be advantages in having maritime transportation links up the West Coast, from Chester and Maryport at the west end of Hadrian’s Wall area to the Clyde. South-East Dorset Black Burnished pottery is found on both Hadrian’s and the Antonine Wall (Allen and Fulford 1996:247-9, Fig. 11a). It certainly reached Hadrian’s Wall by sea, followed by local distribution by land. It could have reached the Antonine Wall from depots on the Tyne-Solway line either by sea or up the Roman roads running to the Forth-Clyde area. There is no firm evidence to date from either the archaeological or literary record for harbour or port facilities on the West Coast of Scotland.
APPENDIX P

The Times and Costs for Various Activities in Building a Boat or Ship
APPENDIX P

The Times and Costs for Various Activities in Building a Boat or Ship

1. Introduction

There is little information from Classical literature, iconography or epigraphy on the times and costs for the various activities and processes required in craft and manufacturing industries.¹ The Price Edict of Diocletian of A.D. 301 attempted to fix prices for a wide range of finished goods, including timber in various sizes, but is not in a form that can be easily used to estimate the times for felling and converting timber into baulks and planks.² Apart from other considerations, it is one hundred and fifty years later than the mean period, the mid-second century, covered in this Appendix, and there had been major price inflation in the whole Roman empire during those one hundred and fifty years.³ Caius Julius Columella, discussing work on the farm in winter, writes: "One workman can cut down, strip and sharpen a hundred stakes a day; he can also split, smooth on both sides and sharpen sixty oaken or olive-wood props, and he can finish ten stakes or five props by artificial light in the evening and the same number by artificial light before dawn. If the wood is oak, twenty square feet ought to be perfectly hewn by one workman in a day; this will make a wagon’s load." (Columella, Rust. XI. ii.12-13). Cato notes that "The following is evening work for winter: Work up into vine poles and stakes the wood which was brought under cover the day before to dry out; make faggots; ..." (Cato, Agr. XXXVII). Although informative for agriculture these observations are not very useful for boat building.

The sources that can be used are: a very limited amount of experimental archaeology, which is often not published and hard to obtain; comparisons with later medieval practice; personal or anecdotal experience or evidence; and theoretical or hypothetical analysis, of what was possible, based on natural constraints and comparison with related or similar activities.⁴ In this Appendix times and costs are derived from all the

¹ Various ancient authors mention iron mines and production, for example Strabo 3.2.8, 3.4.6 on mines in Turditania, Iberia and Aethalia (Elba) respectively, as well as in Britain, but details of how to make nails and other iron instrumenta domestica were apparently too banal to merit attention.

² The section of the Edict concerning timber has been largely recovered (Erim and Reynolds 1970:124-6; Crawford and Reynolds 1977:134-5, 143-6).

³ Duncan-Jones has estimated that inflation was rampant by the end of the third century. Discussing the price of wheat, a basic necessity, he concludes that prices “...were roughly thirty times the first century level by the 290s.” (Duncan-Jones 1990:190).

⁴ There was very little change in the tools and technology for working timber and wood, and for forging wrought iron artefacts from the Roman period to the medieval period, and even later.
sources noted above for: making, driving and clenching iron nails; for pre-drilling holes for the nails; for shaping a ship’s frames, floors and stem and stern posts with axe and adze, and for felling trees and converting them to planks either by sawing or hewing with an axe. Few of the results are based on precise measurements, and in general figures are rounded to whole numbers. For each result the final check has been the question “Is this reasonable? Can it be justified by common sense?” The figures should at least be internally consistent across the range of ships studied.

2. The Production of Iron Nails

In the Roman period the making of iron nails would start with a marketable bloom of iron from a smelting site. The smelter would have produced the raw bloom, and by repeated heating and hammering have expelled most of the slag. The finished bloom weighed in a range from about 1 kg to 9 kg (Manning 1976:147), or 9 kg to 18 kg (Cleere 1974:213-7), while Tylecote using a Roman iron beam from Corbridge made up by forge-welding a number of blooms, proposes a mean bloom weight of about 7 kg (Tylecote 1986:163). For the purposes of this section a bloom of about 9 kg will be assumed.

From experimental smelting of iron in a Roman type furnace by Cleere, Crossley and others, to produce a tonne of iron in the form of marketable blooms required the expenditure of about 6 BEUs, see Appendix D, Section 1. Assuming an average bloom weight of 9 kg, each bloom would have a value of 0.054 BEU. The number of nails that could be produced from each bloom would vary with the size of the nails. The table below gives the number of nails and the size needed for each of the four craft discussed in this paper, the total weight, the number of blooms needed and the value of the blooms used for each.

Table App.P.1. Number, weight and value of blooms for iron nails for hull construction

<table>
<thead>
<tr>
<th>Vessel</th>
<th>No. of nails</th>
<th>Size cm cross-section x length</th>
<th>Total weight of nails kg</th>
<th>No. of blooms</th>
<th>Value in BEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>528</td>
<td>1 x 1 x 20.5</td>
<td>86.4</td>
<td>9.6</td>
<td>0.518</td>
</tr>
<tr>
<td>Barge 3</td>
<td>1680</td>
<td>1 x 1 x 32</td>
<td>420</td>
<td>46.67</td>
<td>2.52</td>
</tr>
<tr>
<td>Barland’s Farm Boat</td>
<td>650</td>
<td>1 dia. x 27</td>
<td>99.2</td>
<td>11.02</td>
<td>0.595</td>
</tr>
<tr>
<td>Blackfriars Ship 1</td>
<td>800</td>
<td>1.7 dia x 34</td>
<td>400.0</td>
<td>44.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1500</td>
<td>1.7 dia x 48</td>
<td>637.73</td>
<td>70.82</td>
<td>3.824</td>
</tr>
</tbody>
</table>

Notes:
1. The nails for the barges are square, while those for the Barland’s Farm Boat and Blackfriars Ship 1 are round for most of the length of the shank, but square at the point.
2. The length of the nails shown here is the length of forged rod needed to make the nail,
including an allowance for forming the head. The finished length would be 3-5 cm shorter.

3. Figures for Barge 5, Barge 3 by author: figures for Barland's Farm Boat computed by author from information in McGrail and Roberts 1999: figures for Blackfriars Ship 1 from Marsden 1994:51, 56 and 57.

4. The Blackfriars Ship 1 nails appear to have tapered from about 1.7 cm diameter under the head to less than one cm approaching the point (Marsden 1994:56-7, Figs. 46 and 47). This taper would have facilitated clenching the ends of the nails.

The value in the table is for the blooms only. They then have to be worked into nails by the blacksmith. The typical 9 kg bloom is about 5 cm square and 46.5 cm long. To produce nails from this piece of wrought iron the blacksmith has to work through a number of steps. These are probably as follows:

<table>
<thead>
<tr>
<th>Activity (see Fig. App.P.1)</th>
<th>Time in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Fire up his forge with charcoal, blowing the fire with bellows to attain the 1200° C needed to bring the iron to red-hot.</td>
<td>20</td>
</tr>
<tr>
<td>b. Heat the bloom in the forge to red-hot.</td>
<td>15</td>
</tr>
<tr>
<td>c. Cut it into four pieces on the anvil with a handled hot chisel.</td>
<td>5</td>
</tr>
<tr>
<td>d. Return the cut pieces to the forge, one for immediate re-heating to red-hot, and the other three keep them at a low red heat.</td>
<td>5</td>
</tr>
<tr>
<td>e. Forge one piece, 5 cm x 5 cm x 11.6 cm into a round rod 2.5 cm dia. by 59.2 cm long, 12 mins. hammering with two 4 minute reheats.</td>
<td>20</td>
</tr>
<tr>
<td>f. Cut the bar into four pieces with a hot chisel.</td>
<td>5</td>
</tr>
<tr>
<td>g. Repeat steps e and f with each of the remaining three pieces</td>
<td>75</td>
</tr>
</tbody>
</table>

The smith now has 16 pieces, 2.5 cm dia., 15 cm long.

---

5 This is about the size of a bloom from Newstead in the Museum of Scotland in Edinburgh, case Q 16 in the Roman section.

6 From 1957 to 1959 the author was the Superintendent of a small workshop with about thirty tradesmen, machinists, millwrights, boilermakers, welders, carpenters, electricians and one blacksmith, Toni Cristini, a middle-aged Italian trained in 'the Old Country'. He had a coke fired forge and made a wide range of special pry bars, chisels, hooks, and picks from bars of steel, entirely by hand forging. His only mechanical aid was an electrically powered blower for his forge. Each morning we would spend a few minutes discussing the items needed that day, and I soon acquired a good feel for how long it took him to make various items. Later in the 1960s I was General Manager, Engineering Services, with twenty different trades reporting to me, including a Blacksmiths' Shop with 26 blacksmiths and helpers. My estimates of the times for the various forging operations are based on my recollections from that period.
h. Forge each piece into a rod 1 cm dia. by 92.5 cm long, with four reheats, @ 20 minutes per rod⁷.
The smith now has 16 rods 1 cm dia. by 92.5 cm long. These can be cut into nail lengths with a cold chisel.
Total time to produce the 16 rods

Each nail length has to be pointed, and have the head formed. The quickest and most economical way to do this is by working on a number of nails simultaneously. For forming the points and heads only the end of the nail has to be red-hot. With several nails in the forge one is taken out and pointed, then returned to the forge to heat the other end for heading. A second nail is taken out and pointed, and possibly a third or fourth, but as soon as the first nail’s head end is hot enough to form the head it is taken out headed and tossed on to the pile of finished nails. This process goes on with the smith working continuously on pointing and heading until the batch is finished. It is estimated that it would take about 2 minutes to point or head a nail, or a total of 4 minutes per nail.⁸ The time to point and head a nail is independent of the length. For the four vessels considered in this paper the number of nails from each bloom is:

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Number of Nails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>55</td>
</tr>
<tr>
<td>Barge 3</td>
<td>36</td>
</tr>
<tr>
<td>Barland’s Farm Boat</td>
<td>59</td>
</tr>
<tr>
<td>Blackfriars Ship 1: floor nails</td>
<td>18</td>
</tr>
<tr>
<td>Side frame nails</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Table App.P.2. below summarizes the blacksmithing time needed to produce the nails for each vessel.

---

⁷ More reheats are needed because the smaller section cools more quickly, but this is offset by the fact that the mass of material being forged is only a quarter of that in the first forging.

⁸ Manning has commented on Roman nail making: “These were needed in very large quantities, but to forge and ‘head’ each one by conventional means would be excessively time consuming and so the nail-heading tool was developed, and remained in use until the advent of machine-made nails in recent times (see Fig. App.2). A nail-heading tool is a bar, expanded at one or both ends where it is pierced by a square or round tapering hole. A rod which could be conveniently handled, with the cross-section of the intended nail, was prepared and one end forged into a point, the length of metal required for the nail plus an allowance for forming the head was the cutoff, and while still red-hot dropped into the nail-heading tool with the narrow end of the tapering hole upwards. Simple though this sounds, great skill was required to ensure that the nail stem tapered correctly so that it fitted into the hole with just enough metal projecting above to form the head. The tool was then rested over the anvil hole and the head of the nail forged. As the metal cooled it contracted and the nail could be removed by turning the tool over and tapping it on the edge of the anvil. In skilled hands, nails could be produced with great rapidity by this method.” Manning 1976:151-2).
Table App.P.2. Time required to forge nails for Barge 5, Barge 3, The Barland’s Farm Boat and the Blackfriars Ship 1

<table>
<thead>
<tr>
<th>Vessel</th>
<th>No. of blooms needed</th>
<th>Time to forge blooms into rods, @ 4 hrs</th>
<th>Number of nails</th>
<th>Time to point and head @ 4 mins. each</th>
<th>Total Time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>9.6</td>
<td>38.4</td>
<td>528</td>
<td>35.2</td>
<td>73.6</td>
</tr>
<tr>
<td>Barge 3</td>
<td>46.67</td>
<td>186.68</td>
<td>1680</td>
<td>112</td>
<td>298.68</td>
</tr>
<tr>
<td>Barland’s Farm Boat</td>
<td>11.02</td>
<td>44.08</td>
<td>650</td>
<td>43.3</td>
<td>87.38</td>
</tr>
<tr>
<td>Blackfriars Ship 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor nails</td>
<td>44.4</td>
<td>177.6</td>
<td>700</td>
<td>46.67</td>
<td>224.27</td>
</tr>
<tr>
<td>Frame nails</td>
<td>26.42</td>
<td>105.68</td>
<td>800</td>
<td>53.3</td>
<td>158.98</td>
</tr>
<tr>
<td>Total</td>
<td>70.82</td>
<td>283.28</td>
<td>1500</td>
<td>99.97</td>
<td>383.25</td>
</tr>
</tbody>
</table>

Converting these times into equivalent BEUs and assuming that the smith would require a helper to operate the forge bellows and generally assist with two man jobs such as cutting the blooms with a hot chisel, the BEUs to produce the nails for each vessel are shown in Table App.P.3. After allowing time for gathering wood and making charcoal, for maintenance and repair of the forge, for festivals, and for some domestic activities about, 230 days per year could be available for forging. The effective working day was probably between eight and ten hours, and an average of nine hours has been assumed here. One working day is the equivalent of 1/230 or about 0.0044 BEUs.

---

9 Smelting required about 120 kg of charcoal to produce a 9 kg bloom, see Appendix D, Section 2. Forging might require about half this amount, or 60 kg per forging day. To make this amount of charcoal about 240 kg of wood would be needed. Assuming that forging took place on about 230 days, over 55 tonnes of wood would have to be felled and converted to charcoal.

10 In Rome there were about 116 festival days in a year, or an average of over 9 per month. In the provinces there were far fewer but about 30 days per year may have been taken up by festivals in Britain.
Table App.P.3. BEUs expended to forge Nails

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Hours to make nails</th>
<th>BEUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>2 men x 73.6 = 147.2</td>
<td>0.072</td>
</tr>
<tr>
<td>Barge 3</td>
<td>2 men x 298.68 = 597.36</td>
<td>0.292</td>
</tr>
<tr>
<td>Barland’s Farm Boat</td>
<td>2 men x 87.38 = 174.76</td>
<td>0.085</td>
</tr>
<tr>
<td>Blackfriars Ship 1</td>
<td>2 men x 383.25 = 766.5</td>
<td>0.375</td>
</tr>
</tbody>
</table>

The total BEUs required to smelt the iron into blooms and manufacture the nails is shown in Table App.P.4.

Table App.P.4. Total BEUs to make nails from smelting to finished product

<table>
<thead>
<tr>
<th>Vessel</th>
<th>BEUs to make blooms</th>
<th>BEUs to forge nails</th>
<th>Total BEUs for iron fastenings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge 5</td>
<td>0.518</td>
<td>0.072</td>
<td>0.590</td>
</tr>
<tr>
<td>Barge 3</td>
<td>2.52</td>
<td>0.292</td>
<td>2.812</td>
</tr>
<tr>
<td>Barland’s Farm Boat</td>
<td>0.595</td>
<td>0.085</td>
<td>0.680</td>
</tr>
<tr>
<td>Blackfriars Ship 1</td>
<td>3.824</td>
<td>0.375</td>
<td>4.199</td>
</tr>
</tbody>
</table>

3. The Felling of Trees (see Fig. App.P.3)

The time taken to fell a tree with an axe is proportional to the amount of wood that has to be cut out, and this is proportional to the cube of the diameter of the tree for the wedge shaped cut usually used. The cut has to be wide enough to avoid having the axe jam in the cut, and for the Roman axe shown in Fig. a in the Tools and Technology Glossary, the angle of the apex of the wedge shaped cut has to be not less than 30°. Darrah, in a number of experiments working with unseasoned oak to simulate the working of timber in the medieval period, found that a 0.2 m diameter log 10 m long “....could be squared up with an axe or adze in a morning.” (Darrah 1982:222). The squared piece of timber would have been about 0.144 m square. The volume of the original log would have been about 0.31416 m³, and the volume of the squared piece about 0.207 m³. Thus about 0.107 m³ was axed and adzed away in say four and a half to five hours. This gives a removal rate of 0.107/270 to 0.107/300 m³ per minute, or 396 to 357 cm³ per minute. As an experiment, I have made a number of V shaped notches, across the grain to simulate felling, in small baulks of several species of wood from hard seasoned rock maple (Acer sacharrum sp.) to air dried Douglas fir (Pseudotsuga taxilalia sp.) and spruce (Picea glauca sp.), using a
modern felling axe. By measuring the size of the notch, the average volume cut per minute was calculated. It varied from about 180 cm\(^3\) per minute in rock maple to about 300 cm\(^3\) per minute in the softer woods. Darrah was cutting along or across the fibres of the timber in squaring his log, and this requires considerably less energy than cutting across the fibres, and this would account for the difference in our rates of removal. In addition he was working with unseasoned oak, while my samples were all at least air dried, and therefore harder. For calculating the time for felling trees, I have taken a rough mean of 360 cm\(^3\) per minute as a representative rate of material removal. From this figure, Table App.P.5 below has been compiled.

**Table App.P.5. Time for felling trees with an axe**

<table>
<thead>
<tr>
<th>Tree diameter cm</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of cut cm(^3)</td>
<td>227</td>
<td>1814</td>
<td>6121</td>
<td>14210</td>
<td>28341</td>
</tr>
<tr>
<td>Time to fell, minutes</td>
<td>1</td>
<td>5</td>
<td>17</td>
<td>40</td>
<td>79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tree diameter cm</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of cut cm(^3)</td>
<td>48972</td>
<td>77766</td>
<td>116083</td>
<td>165282</td>
<td>226724</td>
</tr>
<tr>
<td>Time to fell, hours, mins.</td>
<td>2 16</td>
<td>3 36</td>
<td>5 22</td>
<td>7 39</td>
<td>10 29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tree diameter cm</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of cut cm(^3)</td>
<td>301770</td>
<td>391780</td>
<td>498114</td>
<td>622155</td>
<td>765196</td>
</tr>
<tr>
<td>Time to fell, hours, mins.</td>
<td>13 59</td>
<td>18 08</td>
<td>23 04</td>
<td>28 42</td>
<td>35 24</td>
</tr>
</tbody>
</table>

The figures in the table above have been taken as the time to fell English oak trees (*Quercus pedunculata*) growing in areas such as Kent, Surrey and Sussex.

**4. Splitting Oaks and Finishing the Surfaces with Axe and Adze**

The information summarized in this section is from Darrah 1982: 219-230. Experiments were made with unseasoned oak from trees more than 0.15 m in diameter. Oak splits easily in the radial direction using seasoned oak wedges, but for splitting in half,
wedges must be driven in alternately from each side. If split from one side only, the split bifurcates at the centre of the log. A large oak can take several hours to split in half, but a segment 4 m long from a tree originally 0.9 m in diameter could be split in less than two minutes. Sap wood can be removed by cutting notches up to 5 cm deep along the length of the trunk, and then with axe or adze splitting off the sections between the notches. The equivalent of a 10m length of trunk 0.2 m diameter could be squared on all four side to about 0.14 m square in a morning, see Section 3 above. This translates into hewing with axe and adze to a finished surface at the rate of 1.1 to 1.4 m\(^2\) per hour. For the four vessels in this paper the rate has been taken at about 1 m\(^2\) per hour to allow for the shaping necessary for a ship's floors and frames, periodic tool sharpening and other interruptions. From two months personal experience in 1949 shaping some large timber with adzes in a shipyard, this seems to me a reasonable rate for levelling and smoothing a surface.

5. Drilling Holes with a Roman Style Spoon Bit

Darrah using a modern steel replica of a Roman spoon bit with a heavy iron shaft and a strong wooden handle across the top drilled holes 2.5 cm diameter at a rate of 2 cm per minute. He notes that it required considerable force to operate (Darrah 1982:220). Roman and medieval bits operated with a cross handle that could only be turned half a revolution at a time, then the operator had to change his hands to the opposite ends. This was not only much slower than using continuous rotary motion as is possible with a brace, but also took the pressure off the drill point every half revolution.

The author has made some experiments with barefoot ship augers, a tool with no screw point to pull them into the wood, and turning them with a cross handle (in my case a tap wrench for large threading taps). Three sizes were used, 1 cm, 1.3 cm and 2.5 cm. A number of holes were drilled in 4 cm thick rock maple with each size and the results averaged. Darrah’s figures and the author’s are plotted on as time versus hole depth in Fig. App.P.4. for the several bit sizes, and have been used in this discussion.

6. The Time Needed to Drive and Clench Nails (see Fig. App. P.5.)

The nails used in both the Barland’s Farm boat and the Blackfriars 1 Ship were driven into holes of smaller diameter that the nail. In the case of the Blackfriars Ship the holes were first drilled to 1.9 cm diameter and oak pegs inserted. A hole of 1.3 cm diameter was then drilled through the oak peg, and the nails of 1.7 cm diameter were driven through the oak peg, an interference fit of 4 mm. For the Barland’s Farm Boat the same system was used, but for the two hypothetical barges the square nails are assumed to have been driven directly through holes with about 2 mm interference, drilled through the planking, floors and frames.

A number of rough steel nails 7mm diameter were driven through pre-drilled holes of 4 mm and 5mm diameter in hard rock maple (Acer saccharum Marsh) 4 cm thick, giving an interference fit of 3 mm and 2 mm respectively. Two weights of hammer were use, an

---
11 Metal wedges are not necessary.
0.675 kg carpenter’s hammer, similar to the Roman example shown in the Tools and Technology Glossary, Fig. g.1, and a 2.27 kg light sledge hammer, similar to Fig. g.2 in the Glossary. A number of nails were driven and the mean time to drive a nail 1 cm with each size of hammer was derived. This was about 5 seconds with the light hammer and 4 seconds with the sledge hammer. After the nail had been driven it had to be clenched, and for the purpose of this paper the time for clenching the nail has been taken as the same as the time for driving it. For example a 25 cm nail in the Barland’s Farm Boat takes 1 minute 40 seconds to drive, plus 1 minute 40 seconds to clench, for a total of 3 minutes 20 seconds.

An additional amount of time is needed for the two man driving and clenching crew to move themselves to the next hole and position themselves for driving and clenching the next nail. Because of the awkward positions, one man crouched under the hull and first driving the nail up through the planking and floor and then ‘holding up’ the head of the nail, while the clencher crouched inside the hull hammers the nail end over across the floor and then the point into the floor, time has to be allowed for these manoeuvres. It seems likely that this re-positioning time would take about as long as driving or clenching the nail. Hence the total time for driving, clenching and moving on the next nail position for each nail would be about three times the driving time, or about 5 minutes for the Barland’s Farm Boat.

7. Sawing Logs or Squared Baulks into Planks

There are several sources for this operation, with significantly different times. DeLaine, in her book on the building of the Baths of Caracalla, has elected to use Pegoretti II:291, an Italian builders’ manual of 1869, which gives times of 0.058 to 0.067 man-days per m² for sawing, which can be converted to 17 to 15 m² per man-day. This is in line with a figure from a London handbook of (Hurst 1865) of 0.048 man-days per m², also used by DeLaine, converting to 20.8 m² per man-day. Delaine says “...I have preferred the modern figure, while admitting that the real figure could be up to four times higher.” (Delaine 1997:269). Dividing the modern figures by four gives a range of 3.75 to 5.2 m² per man-day. Meiggs discusses the problem in a note on Columella, Rust. XI.i.13 and Greek accounts of the Erechtheum, and in comments on the Price Edict (Meiggs 1982:368 and n.145). Delaine notes the figure she derives from Meiggs, 0.26 man-days per m² or 3.8 m² per man-day. Shirley in her book on the construction of the Legionary Fortress at Inchtuthill quotes a 1902 handbook, which gives a rate for sawing oak at 58 minutes per m², or about 8 m² per man-day (Shirley 2000:115), but this is for crossing-cutting in trimming posts to length, which is a significantly different operation from sawing logs into planks.

In Rule and Monaghan’s publication on the St. Peter Port Ship plates 3 and 15 show very clear saw marks on planking and the keel. The marks suggest that each stroke of the saw advanced the cut about 0.002 to 0.003 m on a plank about 0.3 m wide. At 14 strokes per minute, a steady pace for pit sawing, this would advance the cut 1.68 to 2.52 m per hour in a 0.3 m wide plank, or a rate of 0.50 to 0.76 m² per hour, equivalent to 4.0 to 6.0 m² per day.

In an attempt to sort out these varying figures this author experimented with sawing a 0.14 m deep baulk by hand, with a saw with six triangular teeth per inch. This saw tooth configuration is comparable with Roman saw blades from archaeological sites in Britain.
The average advance per minute was about 0.05 m, or 3 m per hour. In 0.14 m thick timber this corresponds to 0.42 m² per hour or about 3.4 m² per day.

Summarizing the figures from various sources:

<table>
<thead>
<tr>
<th>Authority</th>
<th>m² per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeLaine, modern figures</td>
<td>15 to 17</td>
</tr>
<tr>
<td>DeLaine, alternative figures</td>
<td>3.75 to 5.2</td>
</tr>
<tr>
<td>Meiggs, according to DeLaine</td>
<td>3.8</td>
</tr>
<tr>
<td>Shirley, cross-cutting only</td>
<td>8.0</td>
</tr>
<tr>
<td>From Rule and Monaghan Plate 4</td>
<td>4.0 to 6.0</td>
</tr>
<tr>
<td>As interpreted by this author</td>
<td>3.4</td>
</tr>
<tr>
<td>This author’s experimental cuts</td>
<td></td>
</tr>
</tbody>
</table>

Looking at this tabulation, a reasonable figure for pit sawing planks for ships and boats in Roman Britain appears to be about 4.0 m² per eight hour effective working day. The high modern figures used by DeLaine were achieved with much better steel saws, easily and quickly sharpened. The 4.0 m² figure will be used in this thesis. Two men are needed for sawing large timbers over a pit or on a trestle, one on top and one underneath. Hence the man-hours required for sawing 4.0 m² in a day are sixteen. Two men for eight hours.

8. Discussion and Conclusions

In developing times for the various activities in building the vessels described and discussed in this paper, it would obviously be of great advantage to be able to spend some months, possibly even several years, in experimenting with the techniques that were used. This would involve making tools from the materials used at the time, with the techniques that were available in the Roman period. For example, saw blades would have to be forged and the teeth cut and set by hand. The tools should be used by skilled craftsmen accustomed to handwork in the various trades. This might best be done in a Third World country where such skills still exist. Blacksmithing is probably the easiest craft to simulate, followed by felling timber with just an axe, finishing timber with axe and adze, and pit sawing with a large frame saw.

The figures that have been derived in this Appendix are believed to be reasonable, using the evidence available to the author. For each type of activity they are internally consistent. For example, the time used to fell and shape timber would be in the correct proportion between each of the vessels studied. Similarly for the blacksmithing activities, the times for making nails are consistent. An error may occur between the times for different activities. For example, blacksmithing times may be too high or low compared to the times for felling and working timber. However, the author feels that the figures derived are of the right order of magnitude, based on the evidence and sources available. Further experimental work would be useful and desirable for wide application when analysing ancient structures involving timber and iron, but it is felt that the conclusions arrived at in the main text are reasonably valid.
GLOSSARIES
Maritime
Tools and Technology
Agricultural and Woodland
GLOSSARY OF MARITIME TERMS

Athwartships: From side to side of the vessel.

Bailing: Removing water from inside a vessel with a scoop or container and throwing the water overboard.

Batten: Length of square edged light flexible wood used for temporarily securing components, or for fairing (see also fairing below).

Beam: 1. Athwartships timbers supporting a deck or holding the side of the vessel in place.
2. A measurement of the breadth of the ship’s hull. When used with no qualification it is the maximum breadth.

Beam Shelf: A longitudinal timber running along the inside of the planking at deck level to support the ends of the deck or other beams.

Bilge: The lower part of the inside of the bottom of the ship, where water from leaks or spray accumulates.

Bulkhead: An internal wall or partition, usually across the beam of the vessel.

Butt: To fit one piece of timber squarely against another.

Carvel: Planking fitted edge to edge to give a smooth exterior to the hull.

Caulking: A soft compressible material such as moss, wood shavings, usually mixed with resin or pitch, used to fill gaps where planking or timbers fit together.

Ceiling: Planks lining the interior of the bottom and sides of the vessel to carry cargo, and protect the ship’s structure from damage: also holds cargo above bilgewater.

Chine: The point in the cross-section of the hull where the planking changes from a generally horizontal to a near vertical plane.

Clench (or clamp): To turn the projecting end of a nail over twice so that the point is driven back into the timber through which it has been driven. Also called a hooked nail.

Clinker: A method of planking where the bottom edge of one strake overlaps the top edge of the strake below. If the overlap is on the outside of the hull it is normal clinker, if on the inside it is reverse clinker.

Deck Beam: A transverse timber across the width of the ship to support the deck planking.

Depth: The height of the hull from the top of the gunwale to the underside of the keel or bottom.

Displacement: The weight of water displaced by a vessel. The displacement is equal to the weight of the vessel plus any cargo and crew.

Fairing: 1. The process of checking the various drawings of the ship’s hull, the cross-sections, the plan views and the side elevations so that they all agree. This will be done both on the small scale drawings, and on the full-size drawings made on the floor of the mould loft when making patterns for shaping the various pieces of timber.
2. A similar process during construction. Battens, thin strips of wood, are bent round the erected frames, and final adjustments are made to ensure a smooth curve in the planking.
Feather, Feather-heading: The narrow end of a plank, usually close to or on the stem or stern post.

Floor, Floor timber
The transverse frames across the bottom of the vessel.

Frames: The athwartship components of the internal skeleton of a vessel. They can run in one piece from the top of one side to the top of the other, but in ships of the Roman period they were usually in separate pieces, the floors and side frames.

Futtocks: An alternative nomenclature for side frames.

Garboard strake: The strakes immediately next to the keel.

Gunwale: The uppermost strake: the top edge of the hull.

Hanging knee: See knee

Hard: A hard is a piece of ground at the water's edge, smoothed and covered with sand and gravel, sometimes laced with timber, on which small vessels can safely take the ground. The hards are covered at high tide and dry out at low tide. The hard surface is usually carried well above the high water mark to facilitate the movement of carts and people engaged in loading or unloading, or in servicing the vessels.

Heel: The lowest part of a mast: also the list or inclination of the vessel from the vertical.

Hull: The main body of a vessel.

Ile or chine log: A piece of timber with a quarter circle cross-section shaped from splitting a log into quarters. It formed the junction between the side and bottom in some flat-bottomed barges, see Fig. II.9.3.1a.

Joggle: The outer face of a frame which has been notched to fit over clinker planking.

Keel: The central longitudinal structural member of the bottom of the ship to which the stem and stern posts are attached. Normally its cross-sectional vertical dimensions exceed its horizontal dimensions, except for plank keels made up of one or two thick planks laid with the widths horizontal.

Keel Plank(s): A broad and extra thick plank or planks used as the main fore and aft structural member instead of a keel, found on flat-bottomed vessels designed for beaching.

Knee: An L-shaped piece of timber, normally cut from a naturally angled piece of wood, and used as a bracket. A hanging knee fits below a deck beam, a lodging knee is fitted horizontally in the same plane as the beam, and a standing knee is fitted above the beam.

Leeway: The amount a vessel is carried sideways by wind or current.

Limber hole: Holes or notches cut in the underside of the floors to allow water to drain to a low point in the hull, from which it can be pumped or bailed overboard.

LOA: Length overall, from the top of the stempost to the top of the sternpost.

Loom: Loom of an oar: the shaft between the blade and the handle.

Mast partner or beam: A timber supporting the mast where it passes through the deck.

Mast step: A slot or socket holding the foot of the mast.

Moulding: The thickness of a frame in the transverse direction.

Pay: to coat or cover a ship’s, seams, planks, bottom with pitch, tar or the like.

Peg: A wooden nail, generally less than 10 mm diameter.
Plank: Originally flat lengths of wood, shaped and bent into strakes to form the outer skin of the vessel. Planking refers to the whole outer skin.

Port: The left hand side of the ship looking forward.

Quarter rudder: A rudder hung on the side of the vessel near the stern, often used in pairs, one on either quarter.

Rabbet or rebate: A longitudinal recess cut into the face of a timber, particularly the keel, stem and stern posts. A rabbet usually takes the end or edge of a strake.

Rove: A rove is a metal washer placed over the end of the nail before clenching, and the end of the nail is then rivetted over the rove, rather than being bent over and its point driven into the timber.

Scantling(s): A collective term describing the timbers used for framing members in a ship: a set of standard dimensions for members of a ship's structure.

Scarf: The bevelling of the ends of two timbers, so that when joined together they form one piece in appearance. In a hooked scarf one or more notches and matching raised ribs are cut across the timber, locking the two pieces together.

Seam: The gap between planks or other timbers, usually requiring caulking to make it watertight.

Sheer: The upward curve of the ship's profile at the bow and stern.

Sheer strake: The upper line of planks in the side of a vessel.

Shell built: A vessel built with the planks first, and the framing fitted in afterwards. In the Mediterranean this was achieved by using pegged mortice and tenon joints to fasten the planks edge to edge. In Scandinavia, clinker building was also shell first.

Ship: A large vessel able to make voyages lasting considerable periods of time.

Siding: Width of a framing member in a fore and aft direction.

Skeleton built: A vessel that has had the keel, stem and stern posts, and the frames assembled first, and then the planking added.

Spiling: Marking out the curved edge of a plank, usually with dividers, to fit tightly against the adjacent plank, or the keel, stem or stern rabbets.

Starboard: The right-hand side of a vessel when facing forward.

Stanchion: A vertical timber, often used to support a deck or deck beams.

Stealer: A narrow timber that does not run the length of the hull, fitted between two planks: often used at the bow or stern to avoid excessively narrow ends on the planks.

Steering oar: A long oar used for steering, fastened over the stern of the vessel, often used on inland waters instead of a rudder.

Strake: A plank of the outer skin running from one end of the hull to the other. In larger vessels strakes are usually made up of several separate pieces of planking, joined either with scarfs, or the ends butted together over floors or frames.

Stringer: An internal longitudinal member running the length of the ship to augment the strength fore and aft.

Taking the ground: Allowing the ship’s bottom to settle on the seabed as the tide goes out. This is a deliberate manoeuvre as opposed to running aground, which is an unplanned occurrence.
Thief: A timber which is inserted to replace part of a defective or damaged timber.

Thole pin: A wooden peg inserted into the gunwale to provide a pivot for an oar.

Thwart: A transverse beam used as a seat.

Timbers: A collective word for the wooden components of the ship's hull.

Treenail or Trenail: A wooden nail used to fasten timbers together, usually more than 10 mm in diameter. It has no head and is usually fixed in place with thin wedges driven into the ends. This makes the ends a very tight fit in the hole.

Wale: An extra-thick plank running fore and aft. It provides additional longitudinal strength, is usually positioned near the deck level and can help support cross-beams and a deck.

Wash-strake: Light moveable boards above the gunwale, which help keep out spray.

Yard: The horizontal spar near the top of the mast, on which the sail is set.
GLOSSARY OF TOOLS AND TECHNOLOGY

Note: Hundreds of Roman iron tools have been recovered from sites in Britain, and museums with Roman sections have modest to extensive collections, including some unique examples such as the try square from Canterbury. Over the years I have personally viewed, photographed and drawn a wide range of these tools. The notes below are compiled from Manning’s Catalogue of the Romano-British Iron Tools, Fittings and Weapons in the British Museum, supplemented by a number of excavation reports and from my own observations.

Adze (Fig. a.): A tool for cutting or trimming relatively thin shavings from timber or wood, either across or along the grain. The adze is more of a finishing tool than the axe, which is the principal tool for roughing out shapes on all sizes of timber. On Romano-British tools the cutting edge varies in length from about 2 cm on small adzes intended for light and delicate work, to 15 cm or more on an adze for working heavy timbers. The main cutting edge is at right-angles to the handle, and in some tools the sides can also cutting edges.

Axe (Fig. b.): The axe is the principal woodworking tool, used from felling and trimming the tree to final shaping of large timbers. The cutting edge is in line with the handle. Like the adze, axes come in a range of sizes, with cutting edges from about 8 to 20 cm long. A skilled workman can produce finished surfaces on large timber components.

Bit (Fig. c.): Bits were used for boring holes for treenails, iron nails and wooden pegs. The standard Roman bit was the spoon bit, where the cutting edges were on the edge of a hollow spoon shaped tool with a long shank. The bit was turned with a cross-handle.

Chisel (Fig. d.): The Romans had both paring chisels for cutting various carpentry joints and mortising chisels for cutting slots for the mortise and tenon joint. They were generally socketed for the handle, and closely resemble their modern counterparts.

Dividers (Fig. e.): Dividers (often termed a pair of dividers) were used for transferring measurements, as in spiling, and drawing circles.

Files: Small files were used for the fine shaping of metal and other materials, and would be needed for sharpening the teeth of saws.

Frame saw (Fig. f.): The frame saw, used for cutting planks and squared lumber from logs, consisted of a sturdy wooden frame holding a thin and narrow metal blade. The blade was tensioned in the frame by wedges or twisted cords. None have been found in Britain, but their use can sometimes be inferred from saw marks on surviving timber. The blades would have been 2m long or longer.

Hammers (Fig. g.): Hammers come in a range of sizes and types, from heavy tools for driving the long iron nails for fastening ships’ timbers, to those with head weights of about 0.45 kg, similar to some modern hammers.

Levels (Fig h.): Levels and plumb bobs were used for establishing horizontal and vertical planes.
**Mallets:** Wooden mallets were used, and a few have survived from archaeological contexts on military sites.

**Pit saws** (Fig.i): Pit saws were almost certainly not known to the Romans, and they do not appear in western Europe until the eighteenth century. They are mentioned here because a possible Roman period saw pit has been found at a military site in Germany, but it could have been used with a large frame saw.

**Planes:** Planes very similar to modern planes were used by Roman cabinet makers, but their use by shipwrights is difficult to prove.

**Rules:** Rules are depicted on Roman tombstones, and a bronze folding rule has been recovered from Caerleon (Goodman 1964:190, Fig. 197). In ship building their use was probably limited. Most of a shipwright’s work consists of fitting curved pieces together using measurements transferred by dividers. Longer distances were probably measured with cords or rawhide strips.

**Saws** (Fig. j): A number of Roman saw blade fragments have been recovered from archaeological contexts in Britain. In the form of handsaws or small frame or bow saws they were certainly used for cuts across the grain of pieces of timber.

**Square** (Fig. k): Try squares were widely used by Roman workers in wood and masonry, and are one of the common items depicted on tombstones. A fine example in bronze was found at Canterbury. In ship and boat building their use would be limited. There are very few right-angles in wooden ships.

**Note:** With the exception of fig. f., the large frame saw, and Fig. i., the pit saw, the scale on pages 320-31 is the same for all the illustrations. The frame saw and pit saw are both about 2.4 m long.
Fig. GT.1. Romano-British Woodworking Tools

Fig. a. Felling axe: Museum of Scotland, Case R14.
Fig. b.1 Adze: Museum of Scotland, Case U3.
Fig. b.2 Adze: British Museum.
Fig. b.3 Small adze: Tullie House Museum, Carlisle.
Fig. c. Spoon bit for 2 cm diameter holes: Tullie House Museum, Carlisle.
Fig. d.1 Socketed mortising chisel: Tullie House Museum, Carlisle.
Fig. d.2 Firmer or paring chisel with integral iron handle: Roman Museum, Canterbury.
Fig. e. Dividers: Museum of Scotland, Case J5, 6.
Fig. f. Large frame saw (Walker 1996). This saw is eighteenth century, but Roman frame saws would have been very similar. No large Roman frame saws have been recovered from archaeological contexts, but are known from a number of iconographic sources.

Fig. g.1 Carpenter’s claw hammer: Museum of Scotland, Case H8.

Fig. g.2 Heavy hammer: Chesters Museum, Hadrian’s Wall.

Fig. h Composite drawing of a Roman level, from a number of tomb reliefs.
Fig. i. Nineteenth century pit saw (Walker 1996)
Fig. j. Small Roman saw for cutting across the grain. Originally it had a bone or wooden handle rivetted on the shank with the two holes: National Museum of Scotland, Case U3, 8.
Fig. k. Square made of sheet bronze. The design allows it to be used for laying out internal and external angles of 45° and 90°, and the tee-shaped edge can be used to locate the square firmly against the edge of a work piece. Roman Museum, Canterbury (Blockley et al 1995:1018-1022).
GLOSSARY OF TIMBER CONVERSION, WOODLAND, AGRICULTURAL AND COUNTRYSIDE TERMS

Timber Conversion

Axed squared end: The end of a piece of timber that has been squared off with an axe, as opposed to being cut with a saw.

Bucking cut: A cut made with an axe to remove the crown of the tree, leaving a relatively straight trunk; also a cut or cuts made with an axe or saw to cut a felled trunk into two or more pieces.

Felling: The act of cutting down a tree with axes. In Roman Britain large trees were felled with axes. There is no evidence for large cross-cut saws.

Hauling Notches: Notches, grooves or holes cut at the end of a felled log for preventing ropes used for hauling from slipping off. Hauling notches with rope marks have been identified on large timbers used in quay construction in London (Brigham et al 1996:35-6; Brigham and Watson 1996b:68).

Notch and chop technique: In squaring a log with the axe, notches are first cut at intervals along the length of the log, and the material between the notches is then removed with the axe.

Squaring: Converting a round log into a square or rectangular section by hewing with an axe or adze.

Woodland

Bole: The main stem or trunk of a tree.

Bolling: Permanent base of a pollarded tree.

Coppice: a. Underwood trees which are cut to near ground level every few years, and then grow again from the stool.
   b. Woodland managed for producing such underwood.
   c. To cut such underwood.

Copse: Variant spelling of coppice.

Crooks: Naturally angular shaped or curved pieces of wood, much in demand for frames, knees, stem posts and stern posts in boat and ship construction.

Forest: Large area covered with trees and shrubs, sometimes mixed with wood-pasture trees growing in it.

Forest grown trees: Trees grown in a forest. Because of competition for light they have straight lower trunks with relatively few branches. Used for conversion into planks and squared baulks. Trees grown in the open, especially oak, have a much more spreading form, are poor sources for long planks, but good for providing crooks.

Log: The trunk or sections of the trunk of a tree after felling.

Pollard: A tree which is cut at 2.5 to 3.7 m above ground level, and allowed to grow again to produce successive crops of wood.

Stool: The permanent base of a coppiced tree.
**Sucker:** A shoot from the root system of certain trees.

**Timber:** Trunks of trees more than about 0.60 m in girth (about 0.20 m diameter), suitable for conversion into beams and planks.

**Undershrub:** Woody plant which is permanently low growing and is not a potential tree; e.g. bramble, furze, gorse.

**Underwood:** Consisting of coppice poles, young suckers or pollard poles, whether growing or cut.

**Wood:** Poles and branches of smaller diameter than timber: includes branch wood, faggots and underwood.

**Woodland:** Generalized term for areas covered with trees; a wood is a defined area of woodland. Secondary woodland is an area where trees are growing on sites that had formerly been something else, e.g. woodland naturally replacing cultivated fields. A plantation is where trees are deliberately planted on areas not previously wooded.

**Wood-Pasture:** Tree-land on which farm animals or deer systematically graze, eating the lower leaves as well as any ground cover.

---

**Agriculture and the Countryside**

**Ancient countryside:** Districts where fields and woods date to before A.D. 1700.

**Bog:** Acid peat-land.

**Heaths:** An uncultivated area, mostly covered with coarse grass and shrubs. See also moorland.

**Lynchet:** A difference in ground level made by ploughing, where ploughs turn at the end of furrows.

**Meadow:** Mown grassland.

**Moorland:** Rough land usually under shrubbery on a peat soil.

**Native:** Plants and animals not introduced by human agency.

**Natural vegetation:** That which is based on wild as opposed to planted or sown plants.

**Naturalized plants and animals:** Those which were originally introduced by man, but have since become wildlife.

**Pasture:** Grassland which is grazed.

**Plash, Plashing:** Plashing is the bending down and interweaving of branches and twigs to form a hedge. To make or renew a hedge.

**Wetlands:** Areas such as the Fens, Somerset levels, lake margins, where the water table is at or very close to ground level. They need draining or dyking to make them suitable for cultivation or habitation.

**Wildwood:** Wholly natural woodland unaffected by Neolithic or later civilizations.
MAPS
Map 1. The principal rivers and natural features of Britain (Jones and Mattingly 1990:40, Map 2.20)
Map 1:4  Main watersheds (thick line); principal rivers of Britain

Map 2. The main watersheds and principal rivers of Britain (Jones and Mattingly 1990:3, Map 1.4)
Map 3. Principal Roman harbours, anchorages and inland ports. (Jones and Mattingly 1990:199, Map 6.19). Note: Many more minor ones are listed and discussed in Section II.8, and its annexes, and in Appendix O.
Map 4. Boundaries of tribal areas in Britain at the time of the Roman conquest. Almost all had access to extensive coastlines (Jones and Mattingly 1990:45, Map 3.2).
Map 5. The main areas of silting, wetlands, and coastal change (Jones and Mattingly 1990:8, Map 1.12)
Map 6. Distribution of harbours proposed by Cleere, based on points where Roman roads terminated at the sea (Cleere 1978:36, Fig. 42)
Map 7. Road connections of the cities, major towns and small towns of Roman Britain
Map 8. Possible Haven Sites from the Firth of Forth in the North, along the East and South Coasts to the River Exe in Devon.

Haven sites: \( \times \)
FIGURES
Fig. I.3.1.1. River boat loaded with barrels. Upper register, amphorae and basketry work, possibly protecting amphorae. Relief from Cabrières-d’Aigues, now in Musée Calvet, Avignon (Bromwich 1993:Plate 20; Casson 1994:132, Fig.97)
Fig. I.3.1.2 Wooden box with cremation burial 30 at Skeleton Green
(de la Bédoyère 1989:173, Fig 106a)

Fig. I.3.1.3. Baskets for fruit picking (King 1990:101)
A small freighter, the *Isis Giminiana*, loading sacks of grain, second or third century A.D. Farnaces, the commander (*magister*), stands at the steering oars. Stevedores carry the sacks aboard and empty the goods, (*res*) into an official measure under the eye of the vessel's owner, Abascantus, and of a government inspector (holding an olive branch). A stevedore who has emptied his sack (marked *feci*, "I'm done) rests in the bows. The mast is stepped far forward: the ship was probably sprit-rigged.

Fig. I.3.1.4. Sacks of grain being loaded on to a small cargo vessel. Wall painting from Ostia, now in the Vatican Museum (Casson 1991, Plate 52)
Fig. I.3.1.5. Trajan's Column: legionaries and auxiliaries loading barrels and bales into river craft. (Lepper and Frere 1988:Plate V, Plate XXV. From the Cichorius Plates)
Fig. I.3.2.1. Amphora with olives recovered from the Thames Estuary (Milne 1985:110, Fig. 64).

Fig. I.3.2.2. Relief with hooped barrels and tubs. From Grand, in Musée des Beaux Arts, Nancy (King 1990:104).
Fig. 1.3.2.3. Relief showing a slave scooping flour from a sack (Tingay and Badcock 1972:141)

Fig. 1.3.2.4. Inscribed Romano-British barrel stave (oak) from Barhill Fort, Strathclyde, Scotland. In the Hunterian Museum, Glasgow (Robertson, Scott and Keppie 1975:52 No. 8, fig. 16.8; RIB II, Fasc. 4, 2442.9)

Fourteen staves were found of a small oak barrel. Each stave was 0.345 m long, 4.5 cm wide at the centre tapering to 3.0 cm at the ends. A narrow groove to take the heads was cut about 1.5 cm in from the ends. Barrel heads were also found. One stave, illustrated here, had IANVARIVS scratched along the length. The fact that the barrel was made of oak suggests that it was possibly made in Britain.
Fig. I.3.2.5. Stevedores carrying sacks ashore. Tombstone fragment from Mainz, in Mittelrheinisches Landesmuseum, Mainz (Ellmers 1978:12, Fig. 16b)

Fig. I.3.5.1. Stevedores rolling (wine?) barrels ashore. Tombstone fragment from Mainz, in Mittelrheinisches Landesmuseum, Mainz (Ellmers 1978:12, Fig. 16a)
Fig.1.3.5.2. Tombstone depicting a cargo of wine barrels in a vessel on the Moselle. From Neumagen, Moselle, in the Rheinisches Landesmuseum, Trier (Ellmers 1978:8, Fig. 12; Chevallier 1988:106).
Fig. I.3.5.3. Cargo of wine barrels on a river vessel, with bow and stern steering oars. The central figure has apparently tapped a barrel and is sampling the wine through a straw. Cast from a pottery mould fragment from Trier, in the Rheinisches Landesmuseum (Ellmers 1978:6, Fig.9)

---

1 Using a steering oar at both bow and stern is not uncommon when travelling with the current on fast flowing rivers. Another tombstone from the Rhine-Moselle area, in the Mittelrheinisches Landesmuseum, Mainz appears to show the same practice (Casson 1994:133, Fig.98). A similar practice is used in the rapids on the upper reaches of the Yangtze River in China. Bow and stern steering sweeps are used to control the junk in the boiling eddies of the rapids (Worcester 1959:144-6, plate between pages 142-143). The crooked stern junk of Fouchou also uses two steering sweeps to make the passage of the rapids on the Kung’t’an Ho, a gigantic stern sweep and a second smaller on the starboard quarter (Worcester 1966:122-125).
Fig. I.3.5.4. A cargo of wine barrels being punt ed. Fragment of altar from Colijnsplaat, Netherlands (Ellmers 1978:10, Fig. 9)
Fig. I.3.5.5. 'Wine Tanker': a large wine barrel on a wagon. From a relief in the Musée Saint-Didier, Langres. (Chevallier 1988:37)
Fig. 1.3.5.6. Tombstone of *Eppatricia*, from Portugal, in the form of a wine barrel
(Toynbee 1971:Plate 81)

---

1 This style of memorial seems peculiar to Portugal. Generally they have hoops, and in some case wineskins carved in relief on the curved surfaces. “The Evora (Ebora) Museum has one, the Conimbriga Museum, near Coimbra, one (without hoops), the Beja (Pax Julia) Museum as many as thirteen and fragments of a number of others; and there is a particularly well preserved example from Algarve in the National Archaeological Museum at Belém on the outskirts of Lisbon.” (Toynbee 1971:253).
Fig. I.3.5.7. Wooden bucket with staves and hoops from Newstead, Borders, Scotland. In the Museum of Scotland, Edinburgh. (Clarke, Breeze and Mckay 1980:58, Fig. 56; Curle:1911:284, pl. LXII)
Fig. 1.3.5.8. Barge with a load of bales of cloth, which is being towed. Relief on a tombstone from Igel, near Trier (Ellmers 1978:7, Fig. 10)
La fabrication et le commerce du drap. Bas-relief provenant de Saulnois (Moselle).

Fig. 1.3.5.9. Five men manhandling a large bale of cloth. Relief from the area of Saulnois, Moselle (Chevallier 1988:287)
Fig. I.3.5.10. Mosaic with cargo vessel carrying amphorae. Celtic vessel with a leather sail in the *Oceamus* mosaic from Bad Kreuznach. In the Karl-Geib Museum, Bad Kreuznach, Rhineland-Pfalz (Ellmers 1978:3, Fig. 3)
Fig. I.3.5.11. Ship with a deck cargo of amphorae resting on dunnage. Relief in the Villa Walkonsky, Rome. Photograph, German Archaeological Institute, Rome (Casson 1995:Fig. 155)
Fig. I.3.5.12 Stevedores unloading amphorae: a tally clerk keeps count. Relief from *Portus*, in the Torlonia Museum, Rome (Casson 1994:103, Fig. 76)
Fig. I.3.5.13a. Part of the cargo of amphorae in the La Madrague de Giens wreck off Toulon. Note the ceiling planks running fore and aft over the frames to protect the ship’s structure from damage by the cargo (Casson 1994:105, Fig. 78)
Fig. I.3.5.13b. Possible stowage system for amphorae in a ship's hold (after Chevallier 1988).

Fig. I.3.5.13c. Various sizes and shapes of shipping amphorae from wrecks off the Grand Congloué Island near Marseilles (Casson 1994:104, Fig. 77).
Fig. 1.4.1.1 A two man frame saw from a fresco in Pompeii. In the Museo Nazionale Archeologico, Naples (D’Ambra 1998:79, Fig. 47)
Fig. 1.4.1.2. A two man saw for sawing planks; from a tomb relief in Gaul (Rule and Monaghan 1993:17, Fig. 11, after Meiggs 1982:348, Fig. 14d: from Marion Cox, from Espérandieu, *Recueil* 6.4802)
Fig. I.4.1.3. Spoon bits from Roman Britain for boring holes in timber (Manning 1985:25-28, Plate 11, B51 to B54, Plate 12, B55 to B78)
Fig. 1.4.5.1a. Iconographic evidence for Roman tools: a shipwright using an adze to shape a frame. Relief on a shipwright’s tombstone from Ravenna, in the Archaeological Museum. (Casson 1994:34, Fig. 28)
Fig. I.4.5.1b. Iconographic evidence for Roman tools: a relief depicting a carpenter’s workshop. In the Antiquarium Comunale, Rome. Note the two small frame saws hanging on the wall, also the try square and pair of callipers (D’Ambra 1998:79, Fig.48)
Fig. I.4.5.1c. Iconographic evidence for Roman tools: a glass bowl from the Roman catacombs with six scenes of carpenters at work. In the Bibliotheca Apostolica Vaticana (Liversidge 1976:158, Fig. 264)
Elevation and plan: 10m long x 2.5 m beam x 0.80 m depth of hull. Cargo carrying capacity about 12 tonnes in calm waters.

Isometric view: typical cross-section showing six bottom planks, two side planks on each side, and alternating L shaped frames hewn from natural crooks. Fastenings are three to five clenched nails through each plank to the frame.

Fig. II.2.1.1. Hypothetical simple inland river craft: plan and elevations, dimensions and cargo carrying capacity.
Fig. II.2.1.2.a. Towing a river boat: from a relief found at Cabrières-d’Aigues, now in the Musée Calvet, Avignon; 3rd century A.D.

Fig. II.2.1.2.b. Five men towing a boat upstream on the River Thames. From Moses Glover’s map of 1635 showing Richmond Palace and Crane (Cowie and Eastmond 1997:92, Fig. 4)

Note: This illustration has been used as it shows towing with the rope attached high up on the mast, which assists in keeping the rope off the ground and clear of waterside obstructions. The illustration is from 1200 years after the end of Roman Britain, but the practice was also used in the Roman period.
Fig. II.2.1.3. Punting a river boat (RJOM from altar fragment from Colijinssplat, Netherlands, Leiden Museum, c. A.D. 200)

Fig. II.2.1.4. Leather sail on a river boat from the Moselle region
(Casson 1994:135, Fig. 100)
Fig. II.4.3.1. Possible Pre-Roman Iron Age sailing routes in the English Channel (McGrail 1983:309, Fig.4).
Fig. II.4.3.2. An example of the extensive river and stream network in Britain. Rivers and streams in Bedfordshire, Buckinghamshire, Hertfordshire, Essex and Middlesex, showing the sites of sixty-one villas (Green et al 1997:189, Fig. 1).

The authors note that “All except one of the villa sites lie close to a river or stream.”, and “Springs and wells may have supplemented the rivers and streams as sources of water for domestic and industrial purposes, but could not have replaced the waterways as convenient and economical means of transport. Despite some of the sites being fairly high up the river course, it is thought that the vast majority of villas would have been accessible by shallow craft.” (Green et al 1997:191)
Fig. II.6.1.1a. Principles of joining an ancient Mediterranean ship's planking with mortise and tenon joints, and an example from an underwater excavation (Casson 1994:34, Fig. 24)
Fig. II.6.1.1c. Mortise and tenon construction for the keel and garboard fastenings of the Madrague de Giens wreck, 1st century BC, near Toulon. Note double planking, sheathed with lead over tarrd fabric. (Casson 1994:34, Fig. 29)

Fig. II.6.1.1b. Changes in mortise and tenon planking over the centuries (Casson 1994:106, Fig. 79)
Fig. II.6.1.2a. Construction sequence of the Romano-British Blackfriars Ship 1 from London. A transition phase from shell first to frame or skeleton first construction (Marsden 1994:78, Fig. 70)
Fig. II.6.1.2b. Medieval skeleton first construction. Detail from The Building of St. Ursula’s Boat by Paolo da Venezia (1310-1358). One of the earliest representations of skeleton first construction. (Illustration from Unger 1991: Illustration 58.).

Notes:
1. Unger has a number of illustrations of skeleton first building from the Medieval to Renaissance periods.
2. The illustration also appears in Basch, L. Ancient Wrecks and the Archaeology of Ships. *IJNA* 1:1-58., and in Casson 1994:31, Fig. 23.
Fig. II.6.4.1. Strake diagram for the Blackfriars Ship 1 (Marsden 1994:93, Fig. 85)
Fig. II.6.4.2. Strake diagram for the late Saxon Graveney Boat
(Fenwick 1978:296, Fig. 10.1.2)
dumps c.AD 200 over silt filling of channel

pottery dated c200 AD in silt with timbers from boat

trench 2
trench 1

THE BOAT

0 5m

Fig 87  The position of the New Guy's House boat adjacent to the south-west wing of the hospital building.

Fig. II.6.7.1a. The New Guy's House Boat, location and parts excavated (Marsden 1994:97, Fig. 87)
Fig. 88  Plan, long-section, and cross-sections of the New Guy's House boat.

Fig. II.6.7.1b. The New Guy’s House Boat, as found plan and sections
(Marsden 1994:98, Fig. 88)
Fig. II.6.7.1c. The New Guy's House Boat, reconstruction plan, elevations and sections (Marsden 1994:103, Fig. 94).
Fig. II.6.7.2a. The New Guy's House Boat: construction of the north end. (Marsden 1994:102, Fig. 93)
Fig. II.6.7.2b. The New Guy’s House Boat: nailed frames in the north end (Marsden 1994:99, Fig.89)
Fig. II.6.7.2c. The New guy’s House Boat: nailed frames (Marsden 1994:100, Fig. 90)
Fig. II.6.8.1a. The Blackfriars Ship 1: plan from the first excavation (Marsden 1994:38, Fig.25)
Fig. II.6.8.1b. The Blackfriars Ship 1: Plan after second excavation
(Marsden 1994:39, Fig. 23)
Fig. II.6.8.2a. The Blackfriars Ship 1: the reconstruction of the complete vessel (Marsden 1994:77, Fig. 69)
Fig. II.6.8.2b. The Blackfriars Ship 1: Reconstruction of the hull interior (Marsden 1994:65, Fig. 58)

Fig. II.6.8.3a. The Blackfriars Ship 1: The nailing system (Marsden 1994:58, Fig. 48)
Fig. II.6.8.3b. Nails:
1. The New Guy's House Boat (top):
2 and 3. Blackfriars Ship 1: Side and bottom planking nails.
(Marsden 1994:56, Fig. 46)
Fig. II.6.8.3.c. The Blackfriars Ship 1: hooked nails from the side (A) and bottom (B) (Marsden 1994:57, Fig. 47)
Fig. II.6.8.4a. The Blackfriars Ship 1: Side frame and nails (Marsden 1994:52, Fig. 40)

Fig. II.6.8.4b. The Blackfriars Ship 1: a knee timber (Marsden 1994: 64, Fig. 57)
Fig. II.6.8.4c. The Blackfriars Ship 1: The Mast step
(Marsden 1994:53, Figs. 42, 43)
176. Small vessel with a spritsail, 2nd B.C.

Fig. II.6.8.5. A spritsail on a small vessel; relief is from the Archaeological Museum, Thasos. (Casson 1995:Fig. 176)
Fig. II.6.8.6. A side rudder from the Bruges Boat, from an archaeological site in Belgium. Now in the National Scheepvaartmuseum in Antwerp. Marsden notes "...the Bruges boat was of similar construction to the Blackfriars ship...both vessels similar in other respects, such as the mast and rudder." (Marsden 1994:74-5, Fig. 67).
Fig. 1. Maps showing the position of Barland’s Farm. (Glamorgan Gwent Archaeological Trust)

Fig. II.6.9.1. Barland’s Farm Boat: Location (McGrail and Roberts 1999:134, Fig. 1).
Fig. II.6.9.2a. Barland's Farm Boat: Remains of the boat as excavated (McGrail and Roberts 1999:135, Fig. 2)
Fig. II.6.9.2b. Barland’s Farm Boat: Scale model of remains  
(McGrail and Roberts 1999:136, Fig. 3)
Fig. 4. Reconstruction drawing of the boat. The frames were numbered from the bow which is to the right. F4 is the floor with side timbers just forward of section F; F10 is the pair of half-frames under the central crossbeam; F17 is midway between sections A and B – its floor timber locks the lower end of the sternpost to the plank-keel (F4 has a similar function). (Institute of Archaeology, Oxford)

Fig. II.6.9.3. Barland's Farm Boat: reconstruction drawing
(McGrail and Roberts 1999:137, Fig. 4)
Fig. II.6.9.4. Barland's Farm Boat: 1/10 scale model of the boat as reconstructed (McGrail and Roberts 1999:139, Fig. 5)
Beached coasters unloading directly to a cart, and on the beach (Greenhill 1988:25, Fig. 27; 114, Fig. 91)
Fig. II.6.10.1. St. Peter Port Ship: Surviving keel planks and floor timbers and reconstruction showing missing members (Rule and Monaghan 1993:13,14, Figs. 6 and 7)

Fig. 6. The surviving timbers, showing intersection between nail holes on inboard face of hull and outboard face of the frames. Nail holes on the frames are marked by crosses.
Fig. II.6.10.2. St. Peter Port Ship: keel planks, showing nail positions, setting out marks and plugged holes (Rule and Monaghan 1993: 30, Fig.15)
Fig. II.6.10.3. St. Peter Port Ship: Eroded corner of keel plank (Rule and Monaghan 1993: 16, Fig.9)

Fig. II.6.10.4a. St. Peter Port Ship: Caulking, recessed nail heads in keel: protruding head through planking (Rule and Monaghan 1993: 26, Fig.13)
Fig. II.6.10.4b. St. Peter Port Ship: Cross-section of wreck at floor timber 42: Note recessed nail heads in keel, protruding heads in planking, position of three limber holes and the hooked shaped clenched nails. (Rule and Monaghan 1993: 25, Fig.12)

Fig. II.6.10.5. St. Peter Port Ship: saw marks on hull planking. Note *teredo sp.* burrows in the face of the plank and on its bottom edge. (Rule and Monaghan 1993:19, Plate 3)
Fig. II.6.10.6a. St. Peter Port Ship: the stern post
(Rule and Monaghan 1993: 32, Fig. 18)

Fig. II.6.10.6b. St. Peter Port Ship: the stern post, isometric view from below, the port underside (Rule and Monaghan 1993:34, Fig. 20)
Fig. II.6.10.6c. St. Peter Port Ship: isometric view of the stern post and stealers, T5 and T6 showing the attachment (Rule and Monaghan 1993:35, Fig. 21)

Fig. II.6.10.6d. St. Peter Port Ship: plan of the stern post, junction with keel (Rule and Monaghan 1993: 32, Fig.19)
Fig. II.6.10.7a. St Peter Port Ship: tool marks on floor timbers, keel and frames. All marks are of axe and adze (Rule and Monaghan 1993:22, Plates 9, 10 and 11).
Fig. II.6.10.7b. St Peter Port Ship: tool marks on frames and stern post. All marks are of saw and adze (Rule and Monaghan 1993:23, Plates 12, 13 and 14).
Fig. II.6.10.8. St. Peter port Ship: mast step
(Rule and Monaghan 1993:40, Fig.27;19, Plate 4)
Fig. II.6.10.9. St. Peter Port Ship: Nail heads and caulking, nail clenching
(Rule and Monaghan 1993:80, Fig.60)
Fig. II.6.11.1a. County Hall Ship: 1910 A.D. drawing of the wreck.
(Marsden 1994:118, Fig. 105)
Fig. II.6.11.1b. County Hall Ship: Partly reassembled remains about 1912
(Marsden 1994:104, Fig.101)
Fig. II.6.11.2. County Hall Ship: current 1994 drawing from the 1910 drawings. This drawing shows all the recorded mortise and tenon joints (Marsden 1994:119, Fig. 106).
Fig. II.6.11.3. County Hall Ship: cross-section showing wale (Marsden 1994:125, Fig.113)
Fig. II.6.11.4. County Hall Ship: reconstruction: deck beams, stanchions and stringers
(Marsden 1994:127, Fig.115)
Fig. II.6.11.5. County Hall Ship: mortise and tenon joints (Marsden 1994:121, Fig. 109)
Fig. II.6.11.6. County Hall Ship: details of construction and position of mortise and tenon joints and limber holes.
(Marsden 1994:120, Fig. 107)
Fig. II.8.2.1. Sources for ornamental building stone used in Roman London
(Jones and Mattingly 1990:220, Map 6.38)
Fig. II.9.3.1a. Zwammerdam barge 2: Cross-section, construction details, and development from a simple dugout (de Weerd 1978:17)
Fig 22  Barge Zwammerdam 4: part of the bottom and port side. Knee-ended ribs are placed in pairs and in alternate positions. In addition to the knees some separate uprights (photo IPP. F Gijbels)

Fig. II.9.3.1b.  Zwammerdam barge 4: Part of bottom and port side. Note the paired L shaped one piece bottom and side frames, fitted alternately to port and starboard (de Weerd 1978:19, fig.22)
Fig 23  Ferry-like barge Zwammerdam 6: part of the bottom and a side. Knee-ended ribs are placed in alternate positions. A double-hooked plank is used to brace the rising end-sections (photo IPP: G Verkuijl)

Fig. II.9.3.1c. Zwammerdam barge 6: Part of bottom, side and end section. The frame arrangement is similar to that in Fig. II..9.3.1b (de Weerd 1978:19, Fig. 23)
Map 6:2  Roman exploitation of British minerals. Principal sites areas: 1 Charterhouse, 2 Halkyn Mt., 3 Parys Mt., 4 Gt Orm*, 5 Alston and the Pennines, 6 Dolaucothi, 7 Linley, 8 Draether 9 Weald, 10 Forest of Dean, 11 SE Midlands, 12 Co. Durham 13 Derbyshire, 14 Llanymynech, 15 Cornwall, 16 Yorkshire Dales, 17 Fridd, 18 Plylimon

Fig. App.E.1. Principal Roman mining sites in Britain.  
(Jones and Mattingly 1990:180, Map 6.2)
Fig. App. E.2. Underground Roman Lead Mines at Draethen, Gwent. 
(Jones and Mattingly 1990:187, Map 6.8)
Fig. App.E.3. Underground Roman copper mines at Llanymynech, Shropshire.
(Jones and Mattingly 1990:191, Map 6.11)
Fig. App.E.4. Distribution of lead pigs from various mining sites in relation to some of the major roads (Jones and Mattingly 1990:189, Map 6.10)
Fig. App.E.5. Distribution of lead pigs from the seven major lead mining areas: Charterhouse/Mendips (1); Draethen (2); Linley, Shropshire (3); Pentre, Clwyd (4); Derbyshire (5); Pennines (6); Wharfedale N. Yorks (7). See Annex for details.
Fig. App.F.1. Main Romano-British pottery kiln groups in the late first and early second centuries A.D. (Jones and Mattingly 1990:207, Map 6.25)
Fig. App.F.2. Generalized distribution of Romano-British pottery kilns  
(Jones and Mattingly 1990:206, Map 6.24)
Fig. App. G.1. Location of principal Romano-British salt production sites.
(Jones and Mattingly 1990:226, Map 6.43)
Brine springs • Areas with salterns using sea water *
Areas with numerous sites 

Fig. App. G.2. Location of principal Romano-British salt production sites. (Reported since 1970)
Fig. App. I.1. Grain orientation in tangentially split timber.
Fig. App. I.2. Grain orientation in radially split timber.
Fig. App. K.1. Location of principal tileworks in Roman Britain.
Lines: plan, elevation and cross-sections. The vessel is double-ended, and the cross-sections would be similar fore and aft of the centre of the hull.

Cross-section of the hull construction at sections 7 and 8

Fig. App.M.1. Hypothetical troop and stores transport for Caesar’s expedition to Britain in 54 B.C.
Barge 1: 15m long x 3.75 m beam x 1.2 m depth of hull. Elevation, plan and cross-section. Elevation shows the no load and full load waterlines.

Barge 2: 12 m long x 3.0 m beam x 0.96 m depth of hull. Elevation, plan and cross-section. Elevation shows the no load and full load waterlines.

Fig. App. N.1. Hypothetical Romano-British Barges 1 and 2
Barge 3: 10 m long x 2.5 m beam x 0.80 m depth of hull. Elevation, plan and cross-section. Elevations shows the no load and full load waterlines.

Barge 4: 7 m long x 1.75 m beam x 0.56 m depth of hull. Elevation, plan and cross-section. Elevations shows the no load and full load waterlines.

Barge 5: 5 m long x 1.25 m beam x 0.40 m depth of hull. Elevation, plan and cross-section. Elevations shows the no load and full load waterlines.

Fig. App. N.2. Hypothetical Romano-British Barges 3, 4 and 5
Fig. App. P.1: The steps in forging a 5 cm x 5 cm x 46.5 cm long 9 kg iron bloom into sixteen lengths of iron rod for making nails.

a. The 9 kg bloom is heated to bright red heat and hot cut into four pieces.

b. Each of the four pieces is forged into a 2.5 cm diameter round rod 59.2 cm long. The 2.5 cm diameter rod is hot cut into four pieces.

c. Each of the four pieces of 2.5 cm diameter rod is forged into nail making sizes: either 1.7 cm diameter by 32 cm long, or 1.0 cm diameter by 92.5 cm long.
Fig. App.P.2: Roman blacksmith’s tool for making hollow cone headed nails for ship building. The hollow under the head holds the caulking.

The shank is forged first, together with the tapered point. The top few cm of the shank is just too large to go through the hole in the tool, and is used to form the head. The blacksmith requires considerable skill to form the top of the shank so that it is neither too small (the whole piece falls through the hole), nor too large (too much is left protruding for the head). The tool and nail are placed on the anvil, with the nail shank through the hole in the anvil, and the tool resting on the top surface. The smith hammers the head into shape, and when the nail has cooled somewhat, flips the tool over and knocks the nail out.
Fig. App.P.3: Felling a tree with an axe. The angle in the felling slot must be somewhat larger than the angle formed by the tangential lines along the face of the axe; otherwise the axe will jam in the cut. The scale of the axe is about twenty times that of the tree.
Fig. App.P.4. Graph of time in minutes versus hole depth in cm to drill holes from 10mm to 25 mm diameter, using a Roman spoon type bit or equivalent. (Darrah 1980:220; and experiments by the author)
Fig. App.P.5. Graph of time in minutes versus nail length in cm to drive nails about 1.0 cm diameter, using a carpenter's 0.675 kg hammer and a 2.27 kg sledge hammer.
(From experiments by the author)
BIBLIOGRAPHY
BIBLIOGRAPHY

Abbreviations

AA  Archaeologia Aeliana
AJA  American Journal of Archaeology
Antiq. Journ.  Antiquaries Journal
ArchJ  Archaeological Journal
BAR  British Archaeological Reports
CA  Current Archaeology
CBA  Council for British Archaeology
HMSO  Her Majesty’s Stationery Office
IJNA  International Journal of Nautical Archaeology
JRS  Journal of Roman Studies
LA  London Archaeologist
LAMAS  London and Middlesex Archaeological Society
MM  Mariner’s Mirror
NMM  National Maritime Museum
OUCA  Oxford University Committee for Archaeology
PPS  Proceedings of the Prehistoric Society
RCAHM  Royal Commission on Ancient and Historical Monuments
RCHM  Royal Commission on Historical Monuments
RIB  Roman Inscriptions of Britain

Classical Authors

For classical authors the abbreviation convention of *The Oxford Classical Dictionary* has been used, and the abbreviations for classical authors have not been listed in this bibliography.

Classical Sources (Unless otherwise noted the sources are the Loeb Classical Library texts published by Harvard University Press, Cambridge, Ma, and William Heinemann, London).

Ammianus Marcellinus

Arrian

Caesar

Cato, Marcus Porcius

Cassius Dio
1961 *Dio’s Roman History*. ed. and trans. by Ernest Cary, on the basis of the version of Herbert Baldwin Foster.
Columella, Lucius Junius Moderatus

Herodotus

Hesiod

Julian

Libanius

Pliny (The Elder)

Pliny (The Younger)

Polybius

Strabo

Suetonius

Tacitus

Theophrastus

Thucydides

Varro, Marcus Terentius

Zosimus
Bibliographical Entries

Adam, Jean-Pierre

Adam, Paul

Adkins, Lesley, and Roy Adkins

Adler, Dana S.
1998  Roman Naval Ranks. *MM* 84.1:76-78.

Adshead, S.A.M.

Akeroyd, A.

Allason-Jones, L., and M.C. Bishop

Allen, D.F.

Allen, J.R.L., and M.G. Fulford

Allen, J.R.L., and S.J. Rippon

Allen, R.H., and R.G. Sturdy

Allen, T.G., T.C. Darvill, L.S. Green, and M.U. James
1993  *Excavations at Rough-ground Farm, Lechlade, Gloucestershire: a Prehistoric and Roman Landscape*. OUCA, Oxford.
Andersen Soren H.

Anderson, James D.

Andreau, Jean

Angus, N.S., G.T. Brown, and H.F. Cleere

Arnold, Béat
1974 La barque gallo-romaine de la baie de Bevaix. Cahiers d'Archéologie Subaquatique (Fréjus) III:133-50.
1999 Some Remarks on Romano-Celtic Boat Construction. IJNA 28.1:34-44

Arthur, Paul

Bailey, Donald M.

Bailey, Jocelyn
1998 The Village Wheelwright and Carpenter. Shire, Princes Risborough.

Barnes, J.H., C.F. Robson, S.S. Kazwowska and J.P. Doody (editors)
Barrett, Anthony A.

Basch, L.

Bass, George F., and Frederick H. van Doorninck Jr.
1978 An 11th Century Shipwreck at Serce Limani, Turkey. *IJNA* 7:119-32


Bean, Simon

Bednarik, Robert G.
1998 An Experiment in Pleistocene Seafaring. *IJNA* 27.2:139-149.

Bell, Antony, David Gurney, and Hilary Healey

Bellabarba, Sergio

Bender, Barbara
1986 The Archaeology of Brittany, Normandy and the Channel Islands. Faber and Faber, London.

Berti, F.

Besly, Edward

Bestwick, J.D.

Betts, Ian M., and Robert Foot

Beveridge, W.H.
Bidwell, Paul T.

Bidwell, P.T., and W. Griffiths

Bidwell, P.T., and N. Holbrook

Bill, Jan

Bill, Jan, B. Poulsen, F. Rieck, and O. Ventegodt

Bird, Joanna, Mark Hassall, and Harvey Sheldon (editors)

Birley, Anthony R.

Birley, Eric

Bishop, M.C.

Bishop, M.C., and J.N. Dore

Black, E.W.

Blackman, D.J. (Editor)

Blagg, T.F.C.

Blair, John, and Nigel Ramsay (editors)

Blockley, K., M. Blockley, S. S. Frere, and S. Stow

Bond, C.J.

Bonino, Marco

Boon, G.C.
1964 Roman Britain in 1963: Wales. Rescue-excavation of the legionary fortress at Caerleon. JRS 54:152-3

Bounegru, Octavian, and Mihail Zahariade

Bowen, E.G.
1972 Britain and the Western Seaways. Thames and Hudson, London.

Bowman, Alan K.

Bowman, Alan K., and J.D. Thomas
1974 The Vindolanda Writing Tablets. Frank Graham, Newcastle upon Tyne.
Bradley, R.
Bradley, R., and M. Edmonds
Branigan, K.
Branigan, K., and D. Miles (editors)
Braund, David
Breeze, David J.
Breeze, David J., and Brian Dobson
Bridbury, A.R.
Brigham, Trevor
Brigham, Trevor, and Bruce Watson
Brigham, Trevor, Bruce Watson, Ian Tyers and Ryszard Bartkowiak
Brodribb, Gerald
Bromwich, James
Brown, A.E. (editor)
Brown, A.G., and I. Meadows
2000 Roman Vineyards in Britain: finds from the Nene Valley and new research.
*Antiquity* 74:491-2.

Brown, David

Brown, Lisa

Brown, R. Allen

Bruce, J. Collingwood

Brunning, Richard

Bryant, S.R., and R. Niblett

Buckland, P.C.

Buckley, D.G. (editor)

Bunbury, E.H.

Burnham, B.C.

Burnham, B.C, (editor)

Burnham, Barry C., and John Wacher

Burnham, C. Paul
25, University of Exeter, Exeter.

Burford, A.

Campbell, Brian

Campbell, J.B.

Carr, Frank G.G.

Casey, P.J.

Casey, P.J., and B. Hoffham

Casson, Lionel

Chaplin, P.
1982 The Thames from Source to Tideway. London.

Chapman, Hugh

Chevallier, Raymond

Chitwood, Prince, and Lisa Donel
Christensen, Arne Emil

Clark, C., and M. Haswell

Clark, G.

Clarke, D.V., D.J. Breeze, and Ghillean MacKay

Clarke, R.R.

Cleere, Henry

Cleere, Henry, and David Crossley

Coates, J.F.
1985 "Hogging" or "Breaking" of Frame-Built Wooden Ships. MM 71:437-42

Coles, J.M.
Coles, J.M., S.V.E. Heal, and B.J. Orme
1978 The Use and Character of Wood in Prehistoric Britain and Ireland. *PPS* 44:1-45

Collingwood, R.G.
1929 Town and Country in Roman Britain. *Antiquity* 3:261-76.

Collingwood, R.G., and J.N.L. Myres

Collingwood, R.G., and R.P. Wright

Collis, John (editor)
1977 *The Iron Age in Britain: a Review*. University of Sheffield, Sheffield.

Collison, M.N.

Conlin, David L.

Cotterell, Brian, and Johan Kamminga

Cotterill, J.
1993 Saxon Raiding and the Role of the Late Roman Coastal Forts of Britain. *Britannia* 24:227-239.

Couper, A. (editor)

Cowie, Robert, and Deyman Eastmond

Craddock, P.T. (editor)

Craddock, P.T.

Craddock, P.T., and M.J. Hughes (editors)

Crawford, Michael

Crawford, M., and J. Reynolds
Creighton, John

Crone, Anne

Croome, Angela

Crumlin-Pedersen, Ole

Crumlin-Pedersen, Ole, with contributions by Christian Hørte, Kenn Jensen, and Susan Møller-Wiering

Crumlin-Pedersen, Ole, and Birgitte Munch Thye

Crummy, Philip

Cummins, W.A.

Cunliffe, B.W.
1977 The Evolution of Romney Marsh: A Preliminary Statement. In Archaeology

Cunliffe, B.W., and T. Rowley (editors)

D’Ambra, Eve

Daniels, Charles

Dark, K.R.

Dark, Ken, and Petra Dark
1997 The Landscape of Roman Britain. Sutton, Stroud.

Dark, Petra
D'Arms, John H.

Darrah, Richard

Darvill, Timothy

Davey, Norman, and Roger Ling

Davies, Roy W. (edited by David Breeze and Valerie Maxfield)

Dearne, Martin J., and Keith Branigan

De Boe, Guy

de Brisay, K.W.

De Graeve, Marie-Christine

de la Bédoïère, Guy

Delaine, Janet

Delbos, Geneviève, and Paul Jorion

Delgado, James P. (editor)

DeRoche, C.D.
Desbat, Armand
de Weerd, M.D.

Didsbury, P.

Dillon, J.

Dixon, Karen R. and Pat Southern

Dore, J.N., and J.P. Gillam
1979 *The Roman Fort at South Shields*. The Society of Antiquaries of Newcastle upon Tyne, Monograph Series No. 1, Newcastle.

Drury, P.J., and Warwick Rodwell

Dunbabin, K.M.B.
Duncan-Jones, Richard

Dymond, D.P.

Dyson, Tony (editor)

Eckoldt, M.
1984 Navigation on Small Rivers in Central Europe in Roman and Medieval Times. IJNA 13:3-10.

Eddison, Jill (editor)

Eddison Jill, and Christopher Green (editors)

Edwards, James Frederick, and Brian Paul Hindle

Eglinton, Edmond

Ehrenreich, Robert M.

Elkington, H.D.H.

Ellmers, D.

Elsted, W.P.

Engel, June

Erim Kenan T., and Joyce Reynolds

Esmoort Cleary, A.S.

Espenshade, Edward B. (editor)

Evelyn, John

Farr, Grahame


Fenwick, Valerie
1995 Review of Batellerie gallo-romaine sur la lac de Neuchâtel, by Béat Arnold. IJNA 24.2.167-170

Fincham, Garrick, Geoff Harrison, Rene Rodgers Holland, and Louise Revell (editors)

Fischer, Anders

Fitzpatrick, A.P.

Fitzpatrick, A.P., and Elaine L. Morris
1994 The Iron Age in Wessex: Recent Work. Trust for Wessex Archaeology and
English Heritage, London.

Fitzpatrick, A.P., and P.R. Scott

Foerster, Federico

Foster, Cecil

Fowler, P.J.

Fowler, P.J. (editor)

Frank, Tenney
1937 Notes on Roman Commerce. *JRS* 27:72-79.

Frere, S.S.

Frere, S.S., and J.K.S. St Joseph

Friel, Ian

Friendship-Taylor, D.E.
Fry, Malcolm F.
2000 *Coiti Logboats from Northern Ireland.* Northern Ireland Archaeological Monographs No. 4.

Fryer, J.

Fulford, Michael G.

Galliou, Patrick

Garnsey, Peter

Gauld, W.W.

Gerrard, Sandy
2000 *Early British Tin Industry.* Tempus, Stroud.

Giesecke, Heinz-Eberhard

Gifford, Edwin, and Joyce Gifford

Gilliver, C.M.
1999 *The Roman Art of War.* Tempus, Stroud.

Gilyard-Beer, R.
Goldsworthy, Adrian Keith

Goodman, W.

Göttlicher, Arvid

Gowland, William

Green, Don, Harvey Sheldon, Michael Hacker, Chris Woon, and Hilary Rowlinson

Greenaway, Jillian

Greene, Kevin

Greenhill, Basil

Greenhill, Basil, with John Morrison

Gurney, David

Gwilt, Adam, and Colin Haselgrove

Halkon, Peter, and Martin Millett

Hall, Jenny, and Ralph Merrifield


Hayes, J.W.

Hayfield, C.

Haywood, John

Heal, S.V.E.

Healey, Hilary

Healy, John F.

Hearne, Carrie M., and Peter W. Cox

Heighway, C.M., and A.J. Parker

Helm, P.J.

Henig, Martin

Henig, Martin, and Paul Booth
Hewett, Cecil A.  

Hill, C., M. Millett, and T. Blagg  

Hill, Donald  

Hindle, Paul  

Hingley, Richard  

Hiscock, Eric C.  

Hobley, Brian  

Höckmann, Olaf  
1993 Late Roman Rhine Vessels from Mainz, Germany. *IJNA* 22.2:125-135

Hodge, A. Trevor  

Hodges, Henry  

Hodges, Richard  

Hodgkinson, J.S., and C.F Tebbut  

Hornblower, Simon, and Antony Spawforth (editors)  
Oxford.
Hornell, James
Hughes, Paul
Humphrey, John W., John P. Oleson, and Andrew N. Sherwood
Hurst, Henry (editor)
1999 *The Coloniae of Roman Britain. New Studies and a Review.* Papers of the conference held at Gloucester on 5-6 July 1997. JRA Supplementary Series Number 36, Portsmouth, R.I.
Hurst, J.D.
Hurst, J.T.
1865 *A handbook of formulae, tables and memoranda for architectural surveyors and others engaged in building.* 15th edn. E. and F.N. Spon, London. non vidi
Hutchinson, J.N., C. Poole, N. Lambert, and E.N. Bromhead
Hyland, Ann
1993 *Training the Roman Cavalry: from Arrian’s Ars Tactica.* Grange, London.
Illsley, John Sherwood
1996 *An Indexed Bibliography of Underwater Archaeology and Related Topics.* Antony Nelson, Oswestry
Inman, R.
Ireland, S.
Jackson, John S.
James, Simon
James, Simon, and Martin Millett (editors)
2001 *Britains and Romans: Advances on the Archaeological Agenda.* CBA
Research Report No. 125, CBA, York.

Joffroy, René

Johnson, Stephen

Johnston, Paul F.

Johnstone, David E.
1979 *An Illustrated history of Roman Roads in Britain*. Spurbooks, Bourne End.

Johnstone, Paul

Jones, A.H.M.

Jones, Barri, and David Mattingly

Jones, G.D.B.

Katzev, M

Kendal, Roger

Keppie, Lawrence
1986 *Scotland’s Roman Remains: an introduction and a handbook*. John Donald, Edinburgh

Kienast, Dieter

King, Anthony

King, D.
1986 Petrology, dating and distribution of querns and millstones. The results of

Kron, Geoffrey

Kunzig, Robert

Lamb, Hubert, and Knud Frydendahl

Laing, Lloyd, and Jennifer Laing

Langdon, John

Langouët, Loïc

Leech, R.H.

Lehmann, L. Th.

Lepper, Frank, and Sheppard Frere

Lequêment, R.

Lewis, Archibald R., and Timothy J. Runyan

Lewis, David
Lewis, M.J.T.

Ling, Roger

Liversidge, Joan

Luff, Rosemary-Margaret

Lyne, M.A.B., and R.S. Jefferies

MacDonald, G., and A. Park
1906 *The Roman Forts on the Bar Hill*. Glasgow.

Macready, Sarah, and F.H. Thompson (editors)

Maloney, C., and Dominique de Moulins

Maltby, Mark

Manning, W.H.

Margary, Ivan D.

Markey, Mike

Marsden, Peter
Marsden, Peter, R.V.
1967  *A Ship of the Roman Period from Blackfriars, in the City of London.*
Guildhall Museum, London.

Marsden, Peter, and Barbara West

Mattingley, H., and E. Sydenham
1926  *Roman Imperial Coinage.*  London

Maxfield, Valerie A. (editor)

McCaughan, Michael

McGrail, Sean
1977b  *Sources and Techniques in Boat Archaeology.*  Edited by Sean McGrail.  BAR Supplementary Series 29, Oxford.


1984 *Aspects of Maritime Archaeology and Ethnography. Papers based on those presented to an international seminar held at the University of Bristol in March 1982.* Edited by Sean McGrail. Trustees of the National Maritime Museum, London.


McGrail, Sean, and Eric Kentley (editors)

McGrail, Sean, and Owain Roberts  
1999 A Romano-British Boat from the Shores of the Severn Estuary. MM  
85.2:133-146.  
McGrail, S., and R. Switsur  
1979 Medieval Logboats of the River Mersey- a Classification Study. In The  
Archaeology of Medieval Ships and Harbours in Northern Europe, edited by S.  
McGrail. pp.93-115. NMM Greenwich Archaeological Series No. 5, BAR  
1982 Woodworking Techniques before AD 1500. Papers presented to a  
symposium at Greenwich, September 1980, together with edited discussion. BAR  
McKee, Eric  
1983 Working Boats of Britain: Their Shape and Purpose. Conway Maritime  
McWhirr, Alan  
1982 Roman Crafts and Industries. Shire, Princes Risborough.  
McWhirr, Alan, and Linda Viner  
1978 The Production and Distribution of Tiles in Roman Britain with Particular  
McWhirr, Alan, Linda Viner, and Calvin Wells  
1982 Romano-British Cemeteries at Cirencester. Cirencester Excavations II.  
Cirencester Excavation Committee, Cirencester.  
Meiggs, Russell  
1982 Trees and Timber in the Ancient Mediterranean World. Oxford University  
Press, Oxford.  
Meijer, Fik.K.  
Meijer, Fik, and Ouno van Nijf  
Routledge, London.  
Mercer, Roger (editor)  
1980 Farming Practice in British Prehistory. Edinburgh University Press,  
Edinburgh.  
Merrifield, Ralph  
Meteorological Office  
1967 Meteorology for Mariners with a Section on Oceanography. 2nd. edition. Her  
Majesty’s Stationery Office, London.  
Millar, Roderick J.O.  
1991 The Pre-Conquest Roman Penetration of South-Eastern Britain.  
Miller, Louise, John Schofield and Michael Rhodes

Millett, Martin

Millett, Martin, and S. McGrail

Mills, John, and Ken Whittaker

Milne, Gustav
1996b Blackfriars Ship 1: Roman, Celtic, Gallo-Roman or Classis Britannica. LJNA 25.3:234-238.

Milne, G., and B. Hobley (editors)

Milne, G., and C. Milne

Milne, J.G.

Molin, Michel

Morris, Elaine L.
London.

Morris, G.C. (editor)

Morris, John

Morrison, J.S.

Morrison, J.S., J.F. Coates, and N.B. Rankov

Mowat, Robert J.C.

Muckelroy, Keith

Murphy, J.P.

Nash, Daphne

Nash-Williams, V.E.

National Maritime Museum

Nayling, Nigel

Nayling, Nigel, David Maynard, and Sean McGrail

Neal, David S.

Neal, S.V.E.

Nilen, Helen A.L.
1990 *A Vase à Anse from Guernsey in the Channel Islands.* *PPS* 56:291-4.

Northover, J.P.

O'Connor, B.
1980 *Cross-Channel Relations in the Later Bronze Age.* BAR International Series 91 (i) and (ii), Oxford.

O'Connor, C.

O'Leary, T.J., Kevin Blockley, and Chris Musson

Oleson, John Peter

Olier, B. d'

Olsen, O., and O. Crumlin-Pedersen

O'Neil, Helen E.
1945 *The Roman Villa at Park Street, near St. Albans, Hertfordshire.* *ArchJ* 102:21-110.

Ordnance Survey

Ottaway, Patrick
1995 *Romans on the Yorkshire Coast.* Yorkshire Archaeological Trust, York.
Owen, Elizabeth, and Mark Frost
1999 *The Dover Bronze Age Boat Gallery.* Dover Bronze Age Boat Trust, Dover.

Paget, R.F.

Pare, C.F.E. (Editor)

Parfitt, Keith
1993 *The Dover Boat.* Current Archaeology 133:4-8.

Parfitt, K., and V. Fenwick

Parker, A.J.

Parker, H.M.D.

Parry, Steven, and Sean McGrail

Partridge, Clive

Peacock, D.P.S.

Peacock, D.P.S., and D.F. Williams

Pegoretti, G.
1869 *Manuale pratico per l'estimazione dei lavori architettonici, stradali,*
idraulici e di fortificazione, per l'uso degli ingegneri ed architetti. 2 vols. revised by A. Cantalupi, Milan. non vidi.


Pitts, Mike 2001 Fiskerton. CA 25.8, no.176:327


Ramsey, D.C., and G.W. Taylor

Rea, J.T.
1902 How to Estimate Being the Analysis of Builders’ Prices. Batsford, London.

Reece, Richard

Rees, Sian E.

Reinders, Reinder, and Kees Paul (editors)

Reynolds, Peter J.

Reynolds, Peter J., and J.K. Langley

Riccardi, Edoardo

Richmond, I.A.
1943 Recent Discoveries in Roman Britain from the Air and in the Field. JRS 33:47. (Notes on the Hill of Gourdie and the Steed Stalls feature).

Richmond, I.A. (editor)
Ridley, Ronald T.

Rieck, Flemming

Rigold, S.

Rippon, Stephen

Rivet, A.L.F.
1970 *The British Section of the Antonine Itinerary.* *Britannia* 1:34-82.

Rival, M.

Roberts, Owen T.P.
1998 *An Exercise in Hull Reconstruction Arising from the Alderney Elizabeth Wreck.* *IJNA* 27.1:32-42

Robertson, Anne S.
1970 *Roman Finds from non-Roman Sites in Scotland: more Roman 'Drift in Caledonia.* *Britannia* 1:191-226.
1978 *Roman Imperial Coins in the Hunter Coin Cabinet, University of Glasgow, IV. Valerian I to Allectus.* Published for the University of Glasgow by the Oxford University Press, Oxford.

Robertson, Anne, Margaret Scott and L.J. Keppie
1975 *Bar Hill: a Roman fort and its Finds.* BAR 16, Oxford

Rodwell, W., and T. Rowley (editors)
1975 *The 'Small Towns' of Roman Britain.* BAR 15, Oxford.

Roman Inscriptions of Britain

Roseman, Christina Horst
Rossiter, J.J.

Rule, Margaret

Rule, Margaret, and Jason Monaghan

Saller, R.P., and B.D. Shaw

Saddington, D.B.

Salway, Peter

Sanctuary, Anthony

Schnitzler, Bernadette
1996 Cinq siècles de civilisation romaine en Alsace. Les Musées de la Ville de Strasbourg.

Scott, Eleanor
1993 A Gazetteer of Roman Villas in Britain. Leicester Archaeology Monographs No.1, University of Leicester, Leicester.

Scott, Sarah

Sealey, P.R., and P.A. Tyers

Selkirk, A.

Selkirk, Raymond

Severin, Tim
Shaw, Timothy (editor)  

Sheldon, Harvey, Gerry Corti, Don Green, and Paul Tyers  

Sherratt, Andrew  

Shirley, Elizabeth A.M.  
2001 Building a Roman Legionary Fortress. Tempus, Stroud.

Shotter, David  

Simmons, B.B.  

Slade, W.J., and B. Greenhill  

Smith, A.H.V.  

Smith, C.  

Smith, J.T.  

Speidel, Michael P.  

Stanford, Edward  

Starr, Chester G.  

Stead, I.M.  
Steers, J.A.

Steffy, J. Richard

Stephens, Nicholas

Sturt, George

Sunter, N., P.J.Woodward et al.

Swan, Vivien G.

Swan, Vivien G., and Robert A. Philpott

Swinnerton, H.H.

Symonds, R.P.

Symonds, Robin P., and Sue Wade

Tarr, Laszlo

Taylor, C.

Taylor, Jeremy
1997  *Space and Place: Some Thoughts on Iron Age and Romano-British*

Tchernia, A., P. Pomey, and A. Hesnard

Teigelake, U.

Temin, Peter

Thomas, C.

Thompson, F.H.
1965 *Roman Cheshire*. Cheshire Community Council, Chester.

Thompson, F.H. (editor)

Thomson, J. Oliver

Timber Development Association

Tingay, G.I.F., and J. Badcock
1972 *These were the Romans*. Hulton, Amersham.

Tipping, Richard

Tod, M.

Todd, Malcolm (editor)

Toynbee, Jocelyn M.C.

Turner, Judith

Turner, Ruth Dixon

Tyers, Paul

Tylecote, R.F.

Tylecote, R.F., and B.J.J. Gilmour

Unger, Richard

Van Arsdell, R.D.

Viall, H.R.

Viatores

Vinson, Steve

Wacher, J.S.

Wachsmann, Shelley

Waddelove, A.C., and E. Waddelove
1990 Archaeology and Research into Sea-Level during the Roman Era: Towards a Methodology Based on the Highest Astronomical Tide. Britannia 21:253-266.

Walker, Philip

Walsh, Michael
Ward, J.
Watson, Bruce (editor)
1998 Roman London: Recent Archaeological Work. JRA Supplementary Series no. 24, Portsmouth, R.I.
Watson, G.R.
Watts, O.M. (editor)
1965 Reed's Nautical Almanac. Thomas Reed, Sunderland.
Webster, G.
Weeks, Jane
Westerdahl, Christer (editor)
Wheeler, R.E.M.
1930 Mr. Collingwood and Mr. Randall: a note. Antiquity 4:91-5.
White, K.D.
Whittick, G. Clement
1931 Notes on some Romano-British Pigs of Lead. JRS 21:256-264.
1961 The Casting Technique of Romano-British Lead Ingots. JRS 51:105-111.
Whitwell, B.
Wild, John Peter
Williams, D.

Williams, David, and César Carreras

Williams, David, and David Peacock

Williams, J.H.

Williams, John

Williams, T.

Williamson, W.S.

Willis, Steven

Wilson, Davis Gordon

Wilson, D.R.

Wilson, P.R.

Winbolt, S.E., and G. Herbert
1934  *The Roman Villa at Bignor*.

Worcester, G.R.G.

Woodiwiss, Simon

Wright, E.V.

Young, Christopher


Young, Susan M.M., A. Mark Pollard, Paul Budd, and Robert A. Ixer


Zwicker U., H. Greimer, K-H Hofmann, and M. Reithinger