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Shipbuilding Practice and Ship Design Methods From the Renaissance to the 18th Century

A Workshop Report

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Editorial Preface

In November 2001 the Max Planck Institute for the History of Science in Berlin held a three-day Workshop on “Shipbuilding Practices and Ship Design Methods from the Renaissance to the 18th Century.” This Preprint documents some of the most significant results of this meeting, which were made available by the authors after the workshop as original written contributions. It also gives guidance on how to find other material associated with the workshop.

From the viewpoint of the workshop organizers at Max Planck Institute for the History of Science the theme of the workshop was chosen as an ideal application of one of its significant long-term research interests, viz., the genesis and migration of knowledge in science and technology. Maritime scientific and technological developments offer an abundance of evidence on knowledge genesis and migration, regionally widely dispersed and temporally spread over millennia. The topic of maritime knowledge history promises to be a fertile ground for science historians.

To the specialists in shipbuilding history the workshop also gave a welcome opportunity to review recent findings and to discuss novel methodologies in their subject area. This field has gained much new momentum in recent decades, not only by numerous new excavations by means of modern underwater archaeology, which has added significant substance to our knowledge on historical shipbuilding and ship design, but also by important improvements in their evaluation and information extraction processes. Thus the historical reconstruction of ships and shipbuilding practice, which in the past had to rely more heavily on literary and pictorial sources can now be subjected to a critical reexamination of earlier hypotheses and conclusions. This leads to interesting new insights and may also shed new light on shipbuilding knowledge genesis and migration.

The invitation to the workshop was extended to a group of selected international experts in the history of science, shipbuilding and ship design. Their contributions were solicited on a representative spectrum of topics in maritime science and technology, encompassing the full range of shipbuilding practices and ship design methods. A group of about 30 participants attended the workshop (Appendix I). The Workshop Programme (Appendix II) was structured into six sessions with 23 presentations. A majority of these primary inputs was later posted on the MPIWG Website for access through the internet. These subjects covered a broad spectrum of interests.

In the current Preprint we have restricted ourselves to 9 original articles submitted in writing by some of the authors corresponding to the main areas of interest addressed in the workshop. The material in this report is presented in two sections on “Ship Design and Hull Geometry” and on “Shipbuilding Practices,” the two focal areas of discussion. This split is of course a bit arbitrary, as the reader will appreciate, because design methods depend on building practice and vice versa. But in the two sections these fundamentally coherent subjects are approached from two different perspectives as the starting points. Yet the material presented here should be regarded as connected pieces of evidence on maritime knowledge history.

Only in one case have we also included an earlier paper, first published by Eric Rieth in NEPTUNIA of 2000, which was reproduced here because it provides valuable background to several articles in Section I and thus facilitates the understanding of other contributions by the same author and by others.

The workshop has concentrated on the period from the Renaissance to the 18th century. This was an eventful era in maritime history in Europe because many nations in Mediterranean and Atlantic Coast countries were building up large fleets of military and merchant vessels for various political and economic interests. It was also a period of rapid technological change in ship size, ship speed, propulsion systems and other outfitting. These advances were driven by commercial competition and military rivalry.

In this period - and hence in our workshop - the technology of building ships "skeleton first with carvel planking" plays a dominant role, at least for the larger ships built in the more advanced shipyards, even if simultaneously examples of shell-first and hybrid construction continue to exist. This technology imposes high accuracy requirements and reliable advance planning. Special design techniques for accurate, reproducible hull form definition became indispensable. New lofting practices for hull geometry and ship construction originated in Mediterranean countries, notably in the Venetian, Iberian and French traditions, all characterized by derivation from a single mould to define the entire hull form. Other practices and experience developed in the Atlantic Coast regions. This creates an interesting common platform of shipbuilding knowledge with some distinct and contrasting practices.

Section I of this Preprint discusses the origins and developments in these two traditions. Eric Rieth in his first article dates the first archaeological evidence on the Mediterranean method, the Culip VI wreck found off the coast of Catalonia, around 1300. This is well before the first written description of these methods beginning in the 15th c. in Venetian, Portuguese and French sources. All these Mediterranean design methods develop the hull shape from a single mould augmented by a few further shape control instruments and parameters. Rieth in his second article gives an overview and contrasts these Mediterranean methods with the later method of "whole-moulding," perhaps used for some time in England and maybe in other countries. Rieth suggests certain possible "ibero-Atlantic" migration paths. Richard Barker in his first contribution casts some doubts on these migration hypotheses, explains the limited evidence on the English use of whole-moulding and emphasizes that the classical English lofting method of "hauling up and down" has its own roots and does not belong to the single mould family. Barker in his second article also interprets an enigmatic Venetian drawing of 1610 in an intriguing analysis of a simple, pictorial document and addresses possible links in design methodology between Venice and England. In the last contribution of this Section Rieth documents an explicit case history of shipbuilding knowledge migration from the Mediterranean to the Atlantic Coast of France around 1700 when some master shipwrights moved across and took their traditions in shipbuilding practice along. This Section highlights the coherence in and contrasts between ship design knowledge and shipbuilding practice over a wide region and in a large time frame, showing certain common roots and many independent blossoms.

Section II describes instances of shipbuilding practices spanning a very long time frame. Rieth reports the excavation and reconstruction, performed from 1992 to 1997, of a small river and coastal freighter, whose wreck was found in the lower part of the river Charente, called the Port Berteau II wreck. This ship was built in about 600 AD.

The ship finds suggest a carvel, frame-first construction and imply a well planned and coordinated operation in the shipyard. Barker in “Cradles of Navigation” reviews the historical record of ship launching technology. This operation under the responsibility of the shipyard has always been one of the most critical events in a ship’s lifetime. Its technologies objectively reflect the technical experience with and physical analysis of the launching process in terms of its forces and dynamics. The article on this rarely studied subject gives a valuable sidelight on how shipbuilding practical knowledge and physical understanding developed concurrently. Gilberto Penzo wraps up this Section by presenting two articles on current shipbuilding and design practices in the Northern Adriatic region, where the heritage from the medieval Mediterranean tradition remains clearly visible.

The facts and hypotheses presented in this Preprint merit a deeper analysis by the interested readers and by the scientific community. The dialogue on open issues in maritime knowledge history in science and technology must continue. The Workshop and this Preprint are only intended as snapshot pictures of a dynamically advancing research field.

An important spin-off effect of the workshop was also the opening of a specialized website at the Max Planck Institute for the History of Science on the theme of:

“History of Science in Naval Architecture”.

This website currently contains information on this subject, composed of:

17 electronic prints (digital documents) of workshop contributions

144 full texts, i.e., scanned versions of relevant and in some cases rare historical literature

370 bibliographical entries as a roadmap to relevant material.

The scope of this database, which will serve as a collaborative network, is intended to be maintained and to be gradually extended, also with the assistance of the network users. The access to this website is under revision.

The editors, also on behalf of the Max Planck Institute express their sincere gratitude to all authors of this Preprint and to all participants in the Workshop.

Horst Nowacki and Matteo Valleriani

Section I

Ship Design and Hull Geometry

First Archaeological Evidence of the Mediterranean Whole Moulding Ship Design Method: The Example of the Culip VI Wreck, Spain (XIIIth-XIVth c.)

Eric Rieth

Introduction

The Culip VI wreck, lying at less than 10m. deep in the creek of Culip, located close to the cap Creus, in Catalonia, Spain, was excavated in 1990 under the general direction of Xavier Nieto, director of the Centre de Arqueologia Subaquatica de Catalunya. The excavation of the remains of the hull and the study of the data were my responsibility (1).

The structure, of which only 11m. in length and 3m. in breadth are preserved (fig. 1), corresponds to the bottom of the hull: keel, keelson, floor-timbers, planking, start of the stem and two mast-steps (main and fore masts). The artefacts in connection with the hull (ceramics produced in South Spain in particular) date the wreck to the end of the XIIIth-beginning of the XIVth century.

The hull is built "frame first" according to the techniques of the medieval Mediterranean shipyards. The Culip VI ship, whose shipyard could be located in North Catalonia, is a coaster. Its restored dimensions are: 16,35m. in length, 4,10m. in breadth at the master-frame, 1,94m. in depth of hold. The burden is estimated at around 40 tons.

The originality, and the scientific importance, of this small wreck lies in a particular organization of the frames in relation to surmarks and Roman numbers engraved in the floor-timbers. For the first time, these surmarks and numbers were observed and recorded during an archaeological excavation. For the first time, also, these surmarks and numbers were interpreted in correlation to a corpus of written sources from Venice, Spain, Portugal and France, dated between the XVth and the XVIIth century. For the first time, at last, this comparison between archaeological data and written evidences has given the possibility to restitute the precise process of design of the frames of a medieval coastal freigther.

First question

What are the main archaeological data? 38 floor-timbers are preserved; 35 are nailed in the keel and 3 are nailed in the start of the stem. The 35 floor-timbers situated on the keel (M 104 to M 138) have a scarf near their extremity. This scarf corresponds to the joint between the floor-timber and the first futtock. This particular scarf, named in the French sources of the XVIIth century "écart à croc ou à dent" (scarf with a hook), can be interpreted as an architectural sign of the Mediterranean tradition, different of the dovetail scarf of the Ibero-Atlantic tradition. The 3 floor-timbers localized on the stem do not have a scarf. The first-futtock is directly joint with the floor-timber.

One floor-timber (M 113) of the first group has one scarf on one side and another scarf on the reverse side. From this particular floor-timber with reversed scarfs, the position of the other scarfs is fixed according to a very precise plan. Towards the stem, the scarfs are localized on the fore side of the floor-timbers and towards the stern on the aft side of the floor-timbers.

These two symmetrical groups of floor-timbers have also three other characteristics (fig. 2). One central surmark is engraved on a level with the middle of the keel. This central surmark has always an invariant position. Two lateral surmarks are engraved on a level with the scarfs. These two lateral surmarks have a variable position according to the narrowing of the length of the floor-timber. One Roman number is engraved between the central and the lateral surmarks (Fig. 3). In the group of floor-timbers fully preserved (M 114 to M 138), the first floor-timber (M 114) is numbered I and the last one (M 138) is numbered XXV. In the second group of floor-timbers preserved in part (M 113 to M 104), the first floor-timber (M 113) is also numbered I and the last one preserved is numbered X.

These archaeological data recorded during the underwater excavation give the possibility to have a first comprehensive view of the organization of the frames. Two groups of floor-timbers can be surely identified: one group which corresponds to the central part of the hull; another which corresponds to the extremity of the hull. The first group, characterized by scarfs in the extremity of the floor-timbers, central and lateral surmarks, roman numerals, can be divided in two sub-groups from the two master-frames M 113 and M 114. The last floor-timber numbered XXV in the fore part of the hull is identified as the fore tail-frame.

Second question

How to interpret these archaeological data from the point of view of the ship design method?

To recognize the significance of the archaeological data recorded during the excavation of the Culip VI wreck, a corpus of medieval and modern written sources from Venice, Spain, Portugal and France were studied. One example of this research concerns the identification of the surmarks engraved in the floor-timbers.

In the *Libro* de Zorzi Trombetta de Modon, a Venetian manuscript (2) of the middle of the XVth century (c. 1445) which, probably, is a copy of an anonymous manuscript of the beginning of the XVth century, there are different rolls of proportions for galleys and *navi*. In relation with these written descriptions, there are schematic geometrical figures of master-moulds as, for example, the master-mould of a *nave* with a burden of 700 *botte* (around 350 tons). Two surmarks are pictured on the *fondi* which corresponds to the mould of the floor-timber: one central surmark in relation to the middle of the keel and one lateral surmark at the beginning of the bilge. In another Venetian document - the *Libro di marineria* also entitled *Fabrica di galere* (3) - another copy of an anonymous manuscript, probably of the beginning of the XVth century (C. 1410), the lateral surmark is not pictured but the text gives a numerical value of a particular point of the arc of the master-mould. This point is named in Venetian *poselese de fondi* or *della paraschuxula*. In the French mediterranean documents of the XVIIth century, it is entitled "point d'escoue" and in the Atlantic documents of the same period "point du plat de la varangue." This point of the arc is superimposed to the lateral surmark.

One of the first descriptions - with an illustration - of the making of these surmarks is given by the Portuguese João Baptista Lavanha in his *Livro primeiro da architectura naval* (4) dated to the beginning of the XVIIth century (c. 1610). Lavanha, after the description of the use of the mould of the floor-timber, explains that the shipbuilder engraves a first central surmark (letters MS) in the middle of the mould and a lateral surmark (letters OP) near the extremity of the mould.

Through the text and the drawing of Lavanha on the one hand, through the surmarks mentioned and pictured in the Venetian documents on the other hand, the surmarks archaeologically attested in the floor-timbers of the Culip VI wreck acquire an historical significance. These surmarks can be interpreted as the material signs of a particular process of moulding the floor-timbers and, more generally, the frames from the master-frame to the tail-frame. From that time, it is possible to associate the organization of the floor-timbers of the wreck according to the position of two master floor-timbers, the localization of the surmarks and, also, of the Roman numbers, with a precise ship design method. This moulding method is characterized by the use of the three traditional "instruments": the master-mould, the french "maître-gabarit," the rising square, the french "tablette d'acculement" and another wooden scale to obtain the narrowing of the breadth-line, the French "trébuchet."

Third and last question

How to check this interpetation? Because the first-futtocks are not preserved, only two levels of the process of moulding were checked: the narrowing and the rising of the 25 floor-timbers preserved between the main floor-timber (M 114) and the fore tail floor-timber (M 138).

What is the methodology used for the narrowing? The lateral surmarks of the master floor-timber and of the tail floor-timber give with precision the value of the narrowing. After some tests, the geometrical diagram named *mezza luna* (half-moon) in the Venetian manuscripts was selected to calculate graphically the intermediate values of the narrowing between the master floor-timber and the tail floor-timber. From the archaeological record in scale 1/1 of the master floor-timber, a theoretical mould was reconstructed in small scale. With this scaled mould of the floor-timber on which the different theoretical values of the narrowing are inscribed, the shape of the intermediate floor-timbers is moulded always in theory. The comparison between the theoretical shape and the recorded shape of the floor-timbers shows a good agreement for the 13 flat floor-timbers which validates the interpretation. But for the other 12 floor-timbers, there is no agreement because the floor-timbers are narrowed but, also, raised. Using the same methodology - reconstruction of a rising mould on which the calculated values of the rising are scribed - , the shape of the raised floor-timbers has been moulded. The comparison between the theoretical and the recorded shape of the raised floor-timbers shows a good agreement which validates the interpretation (fig. 4).

Conclusion

In conclusion, two aspects can be underlined. Firstly, an important part of the floor-timbers of the Culip VI wreck can be associated with a precise process of moulding (for the narrowing and the rising). This process is related to a ship design method defined in the French historical source as "le maître-gabarit, la tablette et le trébuchet" method. Secondly, the Culip VI wreck, dated to the end of the XIIIth-beginning of the XIVth century, is actually the oldest archaeological evidence of this method of moulding. In this perspective, it will be very interesting to compare the Culip VI wreck with the extraordinarily well preserved medieval galley excavated during the last months in the Venice lagoon.

References

1. E. Rieth, "L'arquitectura naval," in: X. Nieto, X. Raurich (ed.), Excavacions Arqueologiques Subaquatiques a Cala Culip, 2. Culip VI, Museu d'Arqueologia de Catalunya, Centre d'Arqueologia Subaquatica de Catalunya, Girona, 1998, p. 137-189; E. Rieth, R. Burlet, "Caracteristiques del vaixell," ibidem, p. 191-200.

2. London, British Library, Cotton, ms Titus A 26.

3. Florence, National Library, Magliabecchiano, ms D 7, XIX.

4. Madrid, Library of the Royal Academy of History, collec. Salazar, ms. 63; facsimile, new transcription and translation, Academia de Marinha, Lisbon, 1996.

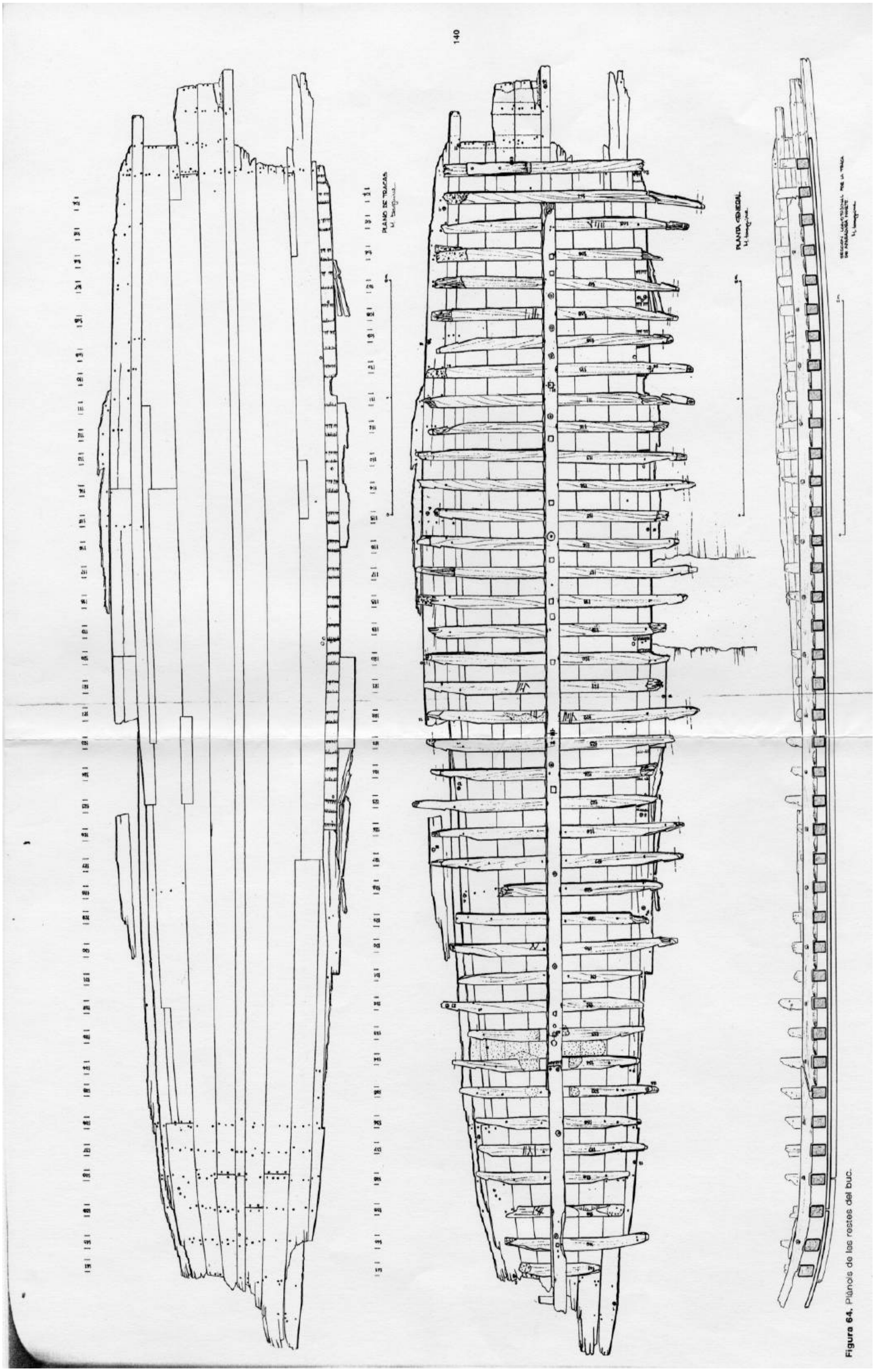

Fig. 1. Plan of the planking, general plan, longitudinal section (X. Nieto, X. Raurich (ed.), Excavacions..., fig. 64).

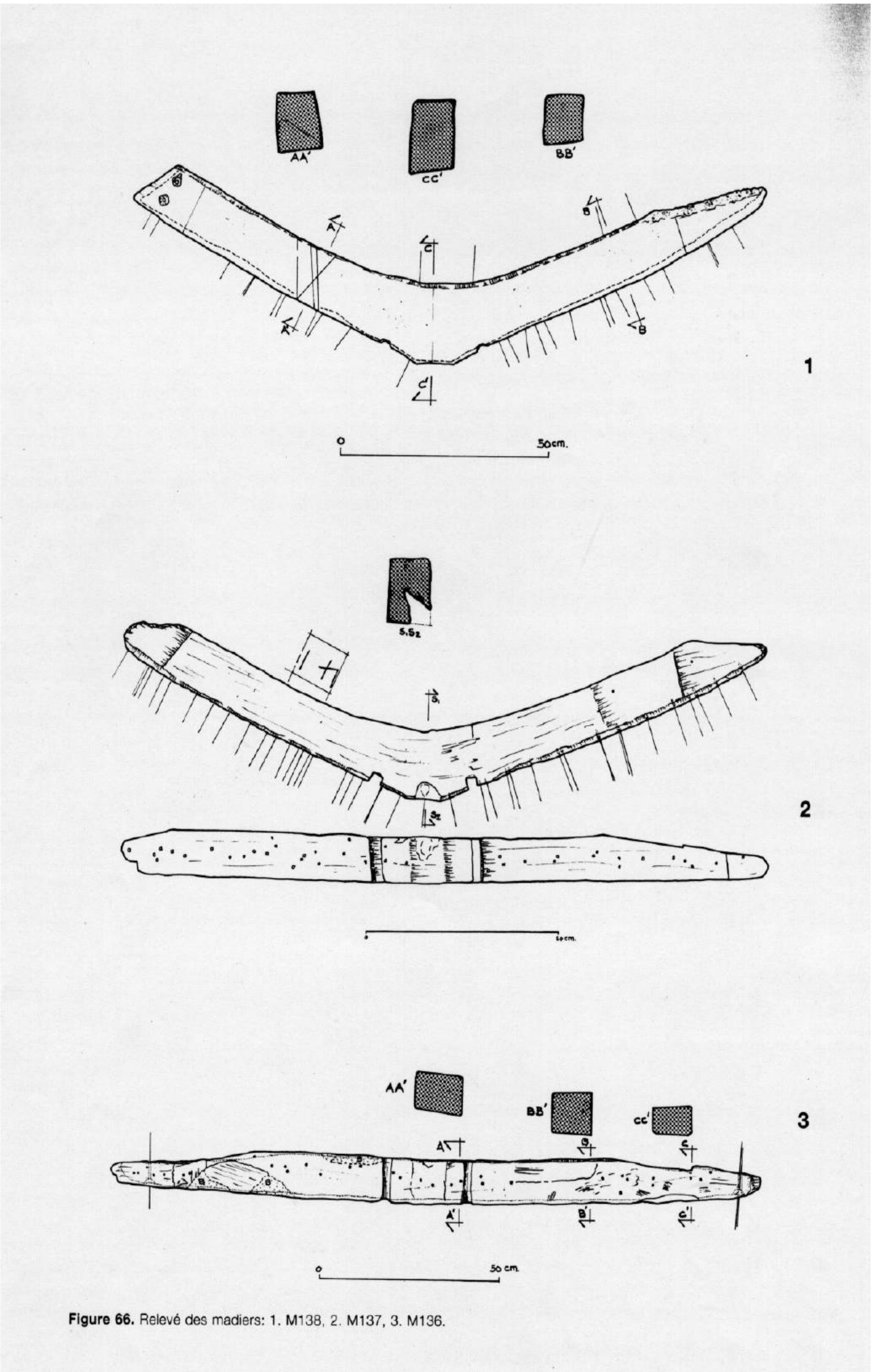

Fig. 2. Floor-timbers M 138 (1), M 137 (2), M 136 (3), (X. Nieto, X. Raurich (ed.), Excavacions..., fig. 66).

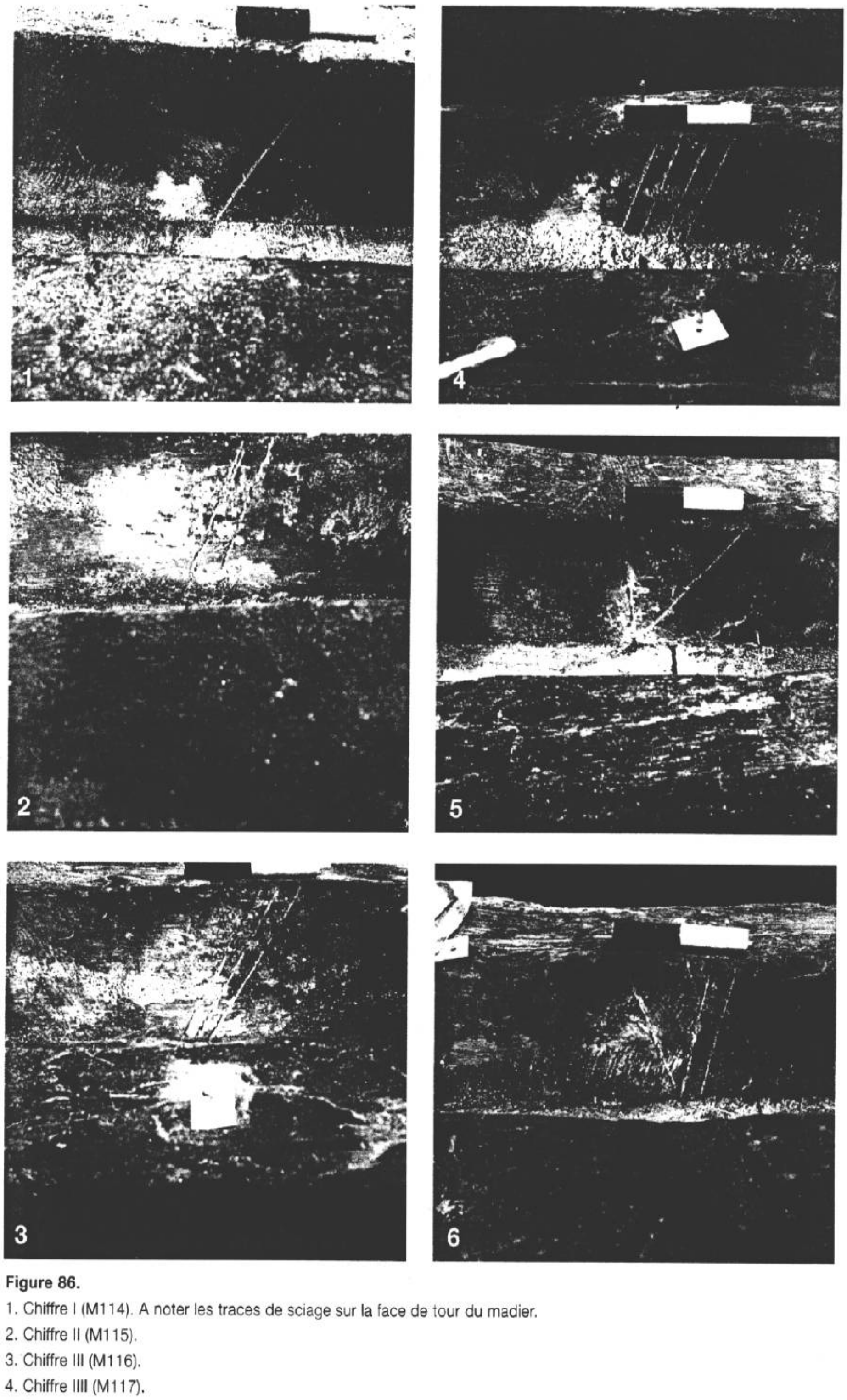

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Figure 86.

1. Chiffre I (M114). A noter les traces de sciage sur la face de tour du madier.
2. Chiffre II (M115).
3. Chiffre III (M116).
4. Chiffre IIII (M117).
5. Chiffre V (M118).
6. Chiffre VI (M119).

Fig. 3. Roman numbers engraved in the floor-timbers M 114 to M 119 (X. Nieto, X. Raurich (ed.), Excavacions..., Fig. 86).

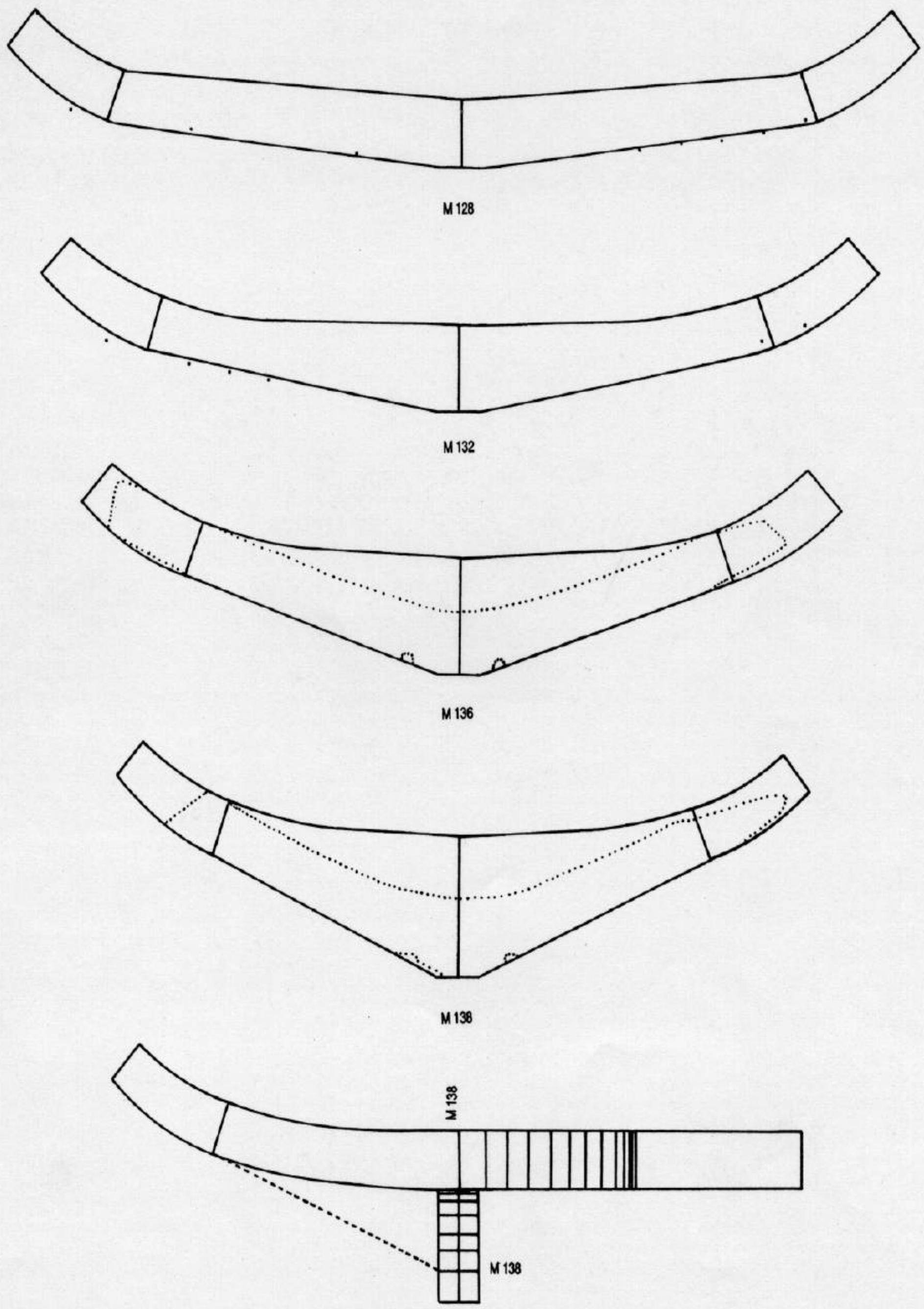

Figure 84.

1. Restitution du madier fond d'estelle M128 (trait plein). Les points correspondent aux valeurs directement relevées sur le madier qui ne s'inscrivent pas dans le tracé restitué. Le même principe de représentation se retrouve dans les autres figures.
2. Restitution du madier fond d'estelle M132.
3. Restitution du madier fond d'estelle M136.
4. Restitution du madier-radier M138.
5. Restitution du tracé du madier-radier M138 à l'aide du gabarit du madier-jumeau et de la tablette d'estelle ou d'acculement.

Fig. 4. Restitution of the floor-timbers M 128, M 132, M 136, M 138. Method of restitution of the floor-timber M 138 with the theoretical breadth mould and rising square (X. Nieto, X. Raurich (ed.), Excavacions..., fig. 84).

La méthode moderne de conception des carènes du "*whole-moulding*": une mémoire des chantiers navals méditerranéens du Moyen Age[1]

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L'une des grandes interrogations de l'histoire de l'architecture navale médiévale concerne les origines et le développement, dans le cadre de l'espace maritime atlantique, du système de construction à franc-bord "membrure première" qui, en référence aux sources écrites du XVe et du début du XVIe siècle, peut être aussi qualifié de système de construction à "carvel" (1). Comme l'a souligné avec beaucoup de justesse S. Bellabarba, le passage d'un système architectural à un autre (du clin "bordé premier" au franc-bord "membrure première") est un changement radical affectant le principe (conception des formes et des structures) et les procédés de construction: "..*a structural principle and...a construction procedure were replaced by completely different methods and principles*" (2).

En relation avec cette rupture architecturale au sein de l'espace atlantique de la fin du Moyen Age, deux interprétations principales s'opposent. La première tend à considérer que l'apport méditerranéen direct ou indirect, via la péninsule ibérique, et selon une chronologie et des procédures par bien des aspects encore obscures, aurait été déterminant dans ce qui s'apparenterait à un transfert de techniques des pays du sud vers ceux du nord (3). Cette empreinte culturelle des constructeurs méditerranéens se serait maintenue, par ailleurs, une fois le transfert achevé. La seconde, au contraire, atténue fortement, au sein de l'espace atlantique, l'influence des pratiques architecturales issues des chantiers navals de la Méditerranée et s'oriente vers la mise en évidence d'un phénomène spécifiquement ponantais qui, dès le XVIe siècle, s'exprimerait, d'une manière particulièrement lisible, au niveau des modalités de conception des carènes. C'est ainsi que s'appuyant d'une part sur les traités anglais d'architecture navale de la fin du XVIe siècle et du début du siècle suivant et, d'autre part, sur l'analyse de deux épaves du XVIe siècle (la *Mary Rose*, coulée en 1545 et le présumé *San Juan*, un baleinier basque perdu en 1565 dans le havre de Red Bay, au Labrador), B. Loewen aboutit à la conclusion que la méthode mise en oeuvre pour concevoir les formes des deux bâtiments, anglais et basque, relève de principes strictement similaires qu'il associe, à titre d'hypothèse, à une méthode de tradition proprement atlantique, différente de celle d'origine méditerranéenne attestée dans les sources du XVI siècle d'origine ibéro-atlantique (4). Il évoque d'une manière très nette l'existence, au XVIe siècle, de deux "écoles" de conception des formes - de tradition méditerranéenne pour l'une, de tradition atlantique pour l'autre - au sein du monde atlantique.

1. This paper has been published in *Neptunia*, 220, 2000, pp. 10-21.

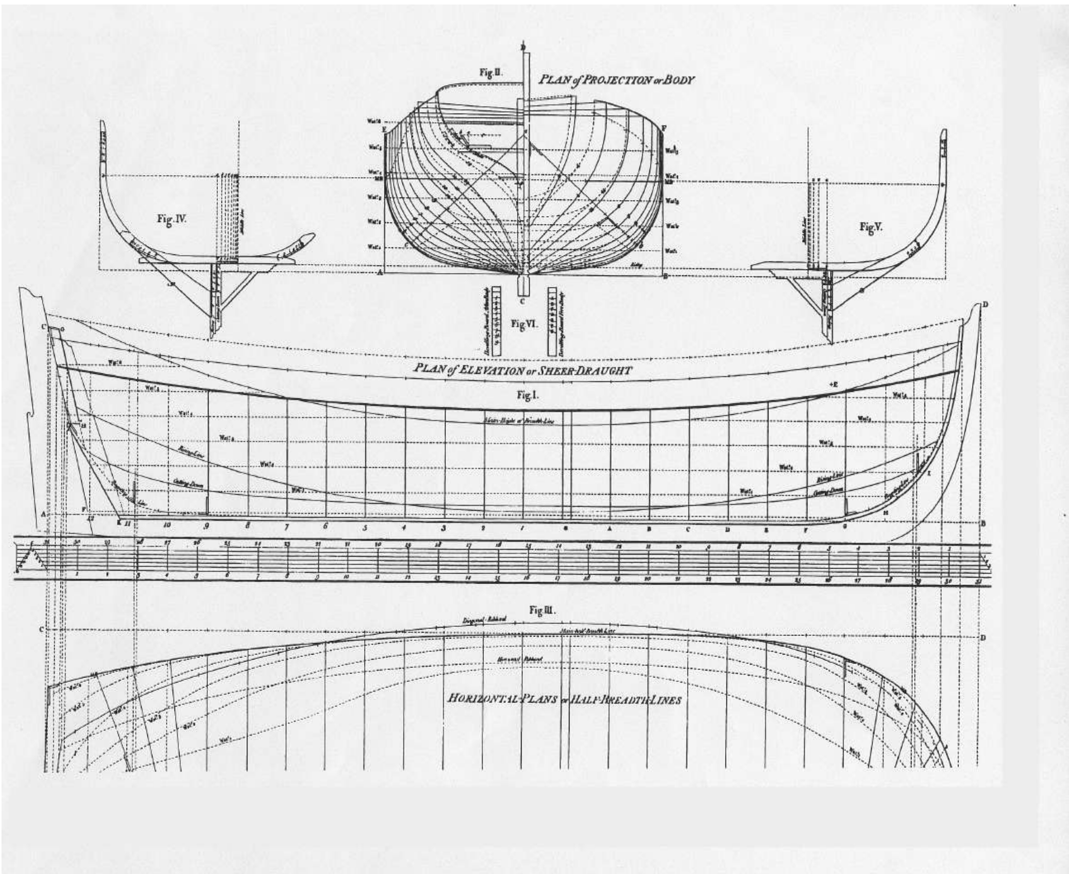

Fig. 1. Le principe du "*whole-moulding*" selon M. Stalkartt, ouv. cit., pl. 1. En II, le plan transversal de la chaloupe. En IV, le maître-gabarit et la tablette d'acculement sont disposés pour définir le tracé de la section arrière 9. En V, les deux "instruments" de conception sont combinés pour déterminer la figure de la section avant G. En VI sont figurées les tablettes d'équerrage des membrures.

Face à ces deux interprétations, la méthode de conception du "*whole-moulding*" apparaît, à notre avis, comme un élément majeur de discussion dont il importe, tout d'abord, de définir le principe.

##

Curieusement, il faut attendre les dernières décennies du XVIIIe siècle pour trouver la description la plus complète du "*whole-moulding*" dans un traité anglais d'architecture navale (*Naval Architecture or the Rudiments and Rules of Ship Building*) rédigé par Marmaduke Stalkartt et dont la première édition date de 1781 (5). Dans l'introduction du livre 1 consacré au "*whole-moulding*" (6), Stalkartt indique que "l'art" du "*whole-moulding*" permet de définir la partie principale du corps d'un navire ou d'une embarcation ("*forming the principal part of a ship*...") à partir d'un gabarit reproduisant la figure du maître-couple ("*by the use of a mould made to the midship-bend*..."). Ce gabarit est déplacé en avant et en arrière de la maîtresse-section en relation avec une tablette d'acculement dans le but de donner au corps de la carène des formes harmonieuses ("*in order to make the body fair*") (fig. 1). Stalkartt ajoute que par le passé, c'est-à-dire avant que "l'art" de la construction navale ait atteint son niveau de perfection actuelle, la méthode du "*whole-moulding*" était très réputée (*"the method of whole-moulding was in great repute*").

Il est bien vrai, en effet, qu'en 1781 la conception à partir de plans de projection était la seule méthode employée dans les arsenaux anglais et, sans doute aussi, dans certains grands chantiers navals privés. A cette date, seuls les petits chantiers navals construisant des embarcations et des bâtiments de faible tonnage faisaient appel à la méthode du "*whole-moulding*." Selon l'historien américain H. I. Chapelle (7), cette méthode était toutefois appliquée à la conception des unités de guerre de la marine anglaise jusque dans les années 1730. Malheureusement, il ne fournit aucune référence à l'appui de cet usage tardif du "*whole-moulding*" dans les arsenaux anglais. La donnée chronologique la plus précise est fournie par le constructeur Blaise Ollivier qui, au terme de sa mission effectuée dans les principaux arsenaux anglais en 1737, ne fait aucune allusion au "*whole-moulding*" dans son rapport (8).

S'appuyant sur l'exemple d'une chaloupe ("*long-boat")* pour un vaisseau du 3e rang, de 31 pieds de long, 9 pieds 3 pouces de large au maître-couple et 4 pieds 1 pouce de creux, Stalkartt décrit, à partir du chapitre XVI, livre 1, de son traité, la pratique de la méthode du "*whole-moulding*" basée sur l'emploi d'un maître-gabarit ("*mould to the midship-bend*"), d'une tablette d'acculement ("*rising square*"), et d'une "latte de talon" ("*straight bottom*") (9). Indice révélateur de la date de publication de l'ouvrage de Stalkarttt, les quinze premiers chapitres du livre 1 sont consacrés à la construction géométrique du plan de la chaloupe (10). Autre signe du contexte "savant" auquel se rattache Stalkartt: c'est à partir du plan à échelle réduite que les trois "intruments de conception" particuliers à la méthode du "*whole-moulding*" sont confectionnés en grandeur d'exécution.

Il serait hors de propos de reprendre dans le cadre de cet article chaque étape de la démonstration très complète de Stalkartt. Insistons simplement sur quatre aspects qui nous paraissent essentiels.

Premièrement, la conception des formes de la chaloupe est assurée sur le chantier, une fois les "instruments" réalisés en grandeur d'exécution, par la combinaison ordonnée du maître-gabarit, de la tablette d'acculement et de la "latte de talon" selon trois plans: horizontal pour le maître-gabarit en relation avec la diminution de la longueur du plat de la varangue, vertical pour la tablette d'acculement en fonction de l'augmentation de l'acculement, oblique pour la "latte de talon" servant à relier le pied de la varangue au départ de la courbe du bouchain. Ce déplacement tri-dimensionnel des trois "instruments de conception" permet de définir le volume de la coque à partir de l'ensemble du maître-gabarit dont - donnée fondamentale - la figure géométrique (un arc de cercle) demeure inchangée.

Deuxièmement, les mouvements synchroniques des trois "instruments" dans le plan horizontal, vertical et oblique, sont ordonnés entre eux selon des progressions dont les valeurs sont inscrites sur les "instruments."

Troisièmement, le maître-gabarit ne subit pas de trébuchement, c'est-à-dire qu'il n'est pas basculé latéralement pour modifier, en l'augmentant, la largeur. Cette absence de trébuchement aboutit à des formes de carène très caractéristisques dotées de sections transversales sensiblement parallèles les unes aux autres.

Quatrièmement, si le principe de la méthode du "*whole-moulding*" doit, théoriquement, permettre la définition de l'ensemble du volume de la coque, Stalkartt paraît limiter son usage aux membrures non dévoyées ("*square frames*") qu'il prend soin de distinguer des membrures dévoyées des extrémités ("*cant frames*"). En accord avec cette distinction, les marques inscrites sur les "intruments" concernent uniquement les sept membrures de l'avant (A à G) et les neuf de l'arrière (1 à 9), excluant les quatre membrures dévoyées de l'avant (H à K) et les trois de l'arrière (10 à 12).

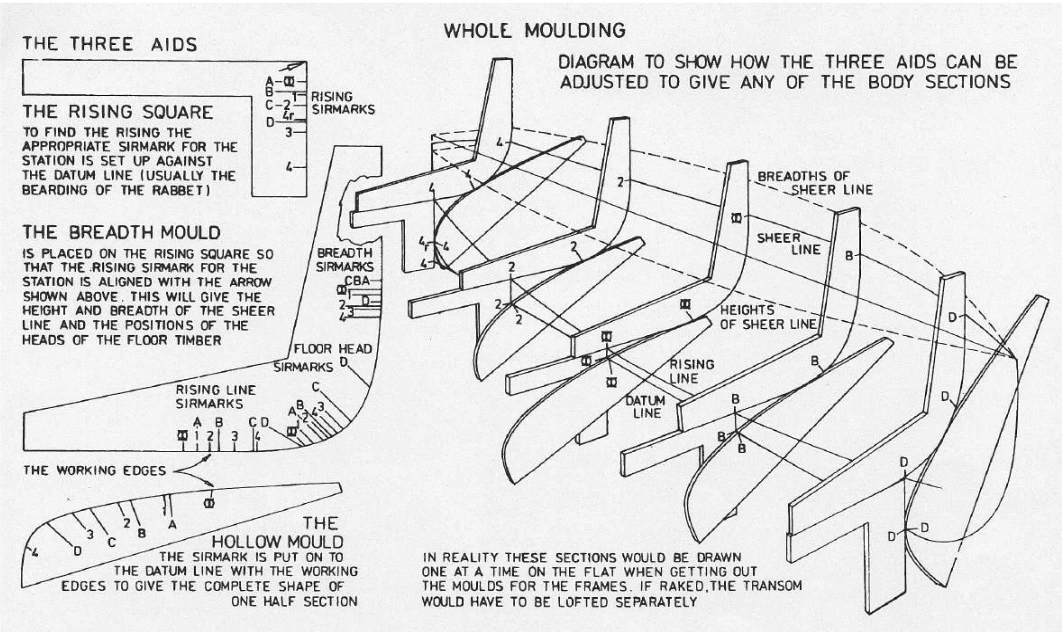

Fig. 2. Le principe du "*whole-moulding*" selon E. Mc Kee, ouv. cit, p. 122. La figure montre parfaitement de quelle manière le jeu entre les trois "aides" à la conception permet de définir l'ensemble des formes de carène de l'embarcation.

Une remarquable illustration contemporaine du principe de la méthode du "*whole-moulding*" est fournie par E. Mc Kee dans son ouvrage malheureuement trop peu connu intitulé *Working boats of Brittain* (12). Mc Kee montre parfaitement comment, avec le recours de ce qu'il nomme trois "aides" à la conception - le maître-gabarit, la tablette d'acculement, la "latte de talon" -, l'intégralité des formes d'une embarcation à tableau peut être harmonieusement définie (fig. 2). Il justifie en des termes particulièrement convaincants les raisons de l'emploi des trois "aides" à la conception. En ne faisant pas varier l'acculement, c'est-à- dire en n'employant que le seul maître-gabarit, les possibilités de variation des formes de carène sont très limitées. En donnant un acculement progressif aux varangues avec l'aide de la tablette d'acculement, utilisée conjointement au maître-gabarit, une plus grande variété de formes est possible. En ajoutant à l'emploi du maître-gabarit et de la tablette d'acculement celui de la "latte de talon ("*hollow mould*" selon l'expression de Mc Kee), une carène aux lignes beaucoup plus douces et harmonieuses peut être obtenue. Cet "instrument" permet, en effet, de joindre le talon de la varangue au départ du bouchain au moyen d'une courbe concave.

A l'appui du témoignage de Mc Kee sur les possibilités offertes par le "*whole-moulding*" est celui de l'architecte naval et historien W. A. Baker. Ayant lui-même expérimenté cette méthode, il considère que les embarcations construites en utilisant les gabarits associés au "*whole-moulding*" possédaient d'excellentes qualités nautiques et étaient rapides à la voile (13).

Si ce jugement de W. A. Baker, chercheur et architecte naval aux compétences reconnues, confirme la qualité des résultats obtenus en recourant à la méthode du "*whole-moulding,*" une question demeure: celle de l'application de la méthode à la conception d'unités de grandes dimensions et de tonnage élevé. Rappelons à ce sujet que Stalkartt affirme qu'avant de faire appel aux plans, les constructeurs anglais concevaient des navires ("*ships*") de cette manière. Une réponse à cette interrogation est fournie par G. Juan dans son excellent traité d'architecture navale publié en Espagne en 1771 et traduit en français en 1783 (14). Après avoir évoqué une première méthode conception basée sur l'emploi d'un maître-gabarit fixe et de lisses (15), G. Juan décrit une deuxième méthode où le maître-gabarit, désormais mobile "sert à déterminer la figure de tous les couples compris entre les deux couples de balancement" (16). La définition des formes de carène est obtenue au moyen du maître-gabarit, d'une tablette d'acculement et d'une règle (équivalent à une "latte de talon") dotée d'une courbure concave destinée à tracer le talon des varangues (fig. 3). Nous retrouvons là les trois "instruments," cités par Stalkartt, et révélateurs d'une méthode strictement similaire à celle de son traité publié, notons-le, dix ans après celui de G. Juan. Le témoignage de ce dernier ne peut donc avoir été inspiré par celui de Stalkartt. Autre donnée intéressante: G. Juan associe explicitement la deuxième méthode à celle "des constructeurs anglais, c'est ce qu'ils nomment *whole moulding"* (17). Il la distingue de celle des constructeurs français qu'il considère être celle du maître-gabarit, de la tablette et du trébuchet (fig. 4 et 5). Selon G. Juan, la différence entre les deux méthodes se situe donc uniquement au niveau de la correction de la largeur par le biais du trébuchement (fig. 6 et 7).

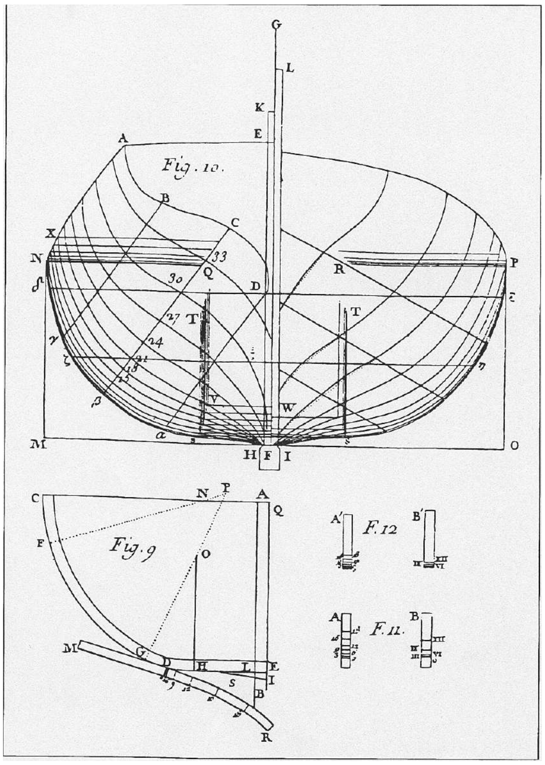

Fig. 3. Le principe du "*whole-moulding*" selon G. Juan, ouv. cit, vol. 2, pl. III. En 9 sont représentés le maître-gabarit et la "latte de talon." En 11 sont figurées les tablettes d'acculement et en 12 les tablettes de diminution de la largeur au fort dont les valeurs sont égales à celles de la réduction de la longueur du plat de la varangue.

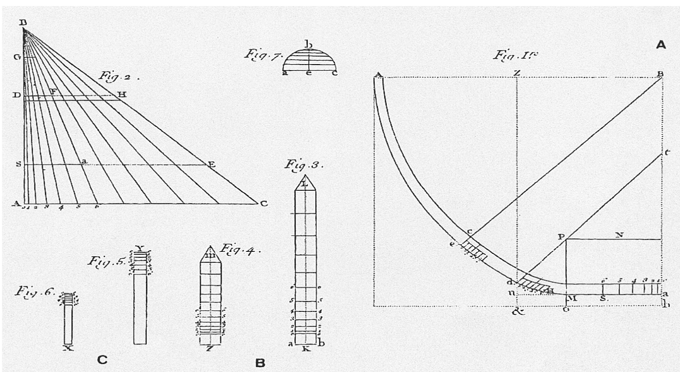

Fig. 4. En A, maître-gabarit; en B, tablettes d'acculement; en C, trébuchets. Duhamel du Monceau, *Elémens de l'architecture navale*, Paris, 1752, pl. XII.

Si l'on peut raisonnablement admettre que des navires marchands et des bâtiments de guerre ont été conçus à l'aide de la méhode du "*whole-moulding*," il est certain que l'absence de trébuchement - caractéristique fondamentale de cette méthode - présente, selon le juste commentaire de J. Boudriot, "l'inconvénient d'assimiler la carène d'un vaisseau à un corps de volume cylindrique" (18). L'une des conséquences de cette forme de carène est de réduire dans de trop fortes proportions les capacités du bâtiment au niveau de son fort et de diminuer le soutien latéral de la coque à la flottaison. Cette faiblesse de tenue à la gîte est particulièrement néfaste pour un vaisseau dont la batterie basse risque alors d'être noyée, interdisant toute possibilité de tir.

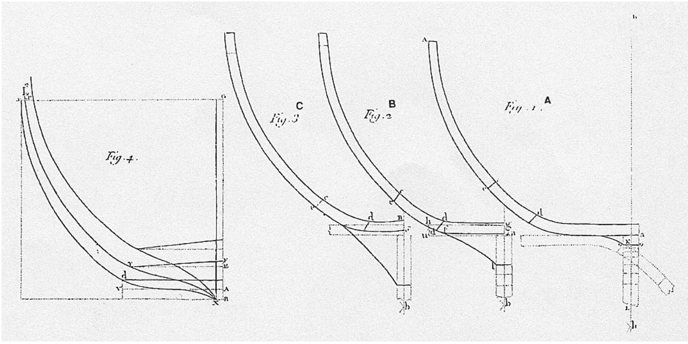

Fig. 5. En A, position des "instruments" de conception pour tracer la figure du maître-couple; en B et C, position des "instruments" de conception pour définir le contour du quatrième couple arrière et du sixième. Ces deux couples sont affectés d'une correction de la largeur au fort par le biais d'un trébuchement du maître-gabarit. Duhamel du Monceau, ouv. cit., pl. XIII.

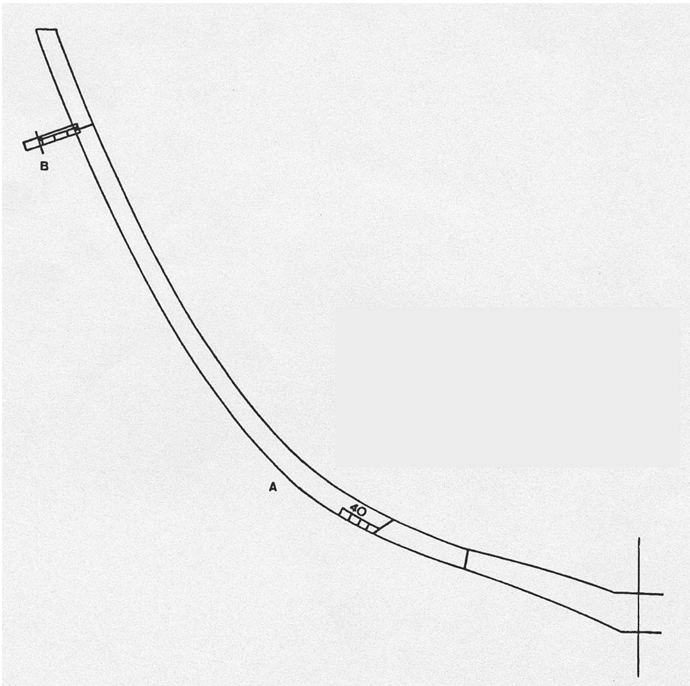

Fig. 6. En A, l'allonge; en B, le trébuchet. La marque correspond à la valeur du trébuchement. Dessin E. Rieth.

Une question à laquelle ne répond pas G. Juan est celle du cadre chronologique précis associé à l'emploi de la méthode du "*whole-moulding*." Il se contente d'indiquer que "les constructeurs ont travaillé d'après ces pratiques pendant beaucoup de siècles, et ce n'est que depuis peu de temps qu'ils se sont astreints...à former des plans" (19). En vérité, ce "peu de temps" correspondant à l'usage régulier du plan lors de la conception peut se situer entre la fin du XVIIe siècle, voire plus tôt dans le cas de l'Angleterre, et le début du XVIIIe siècle pour la plupart des grandes nations maritimes.

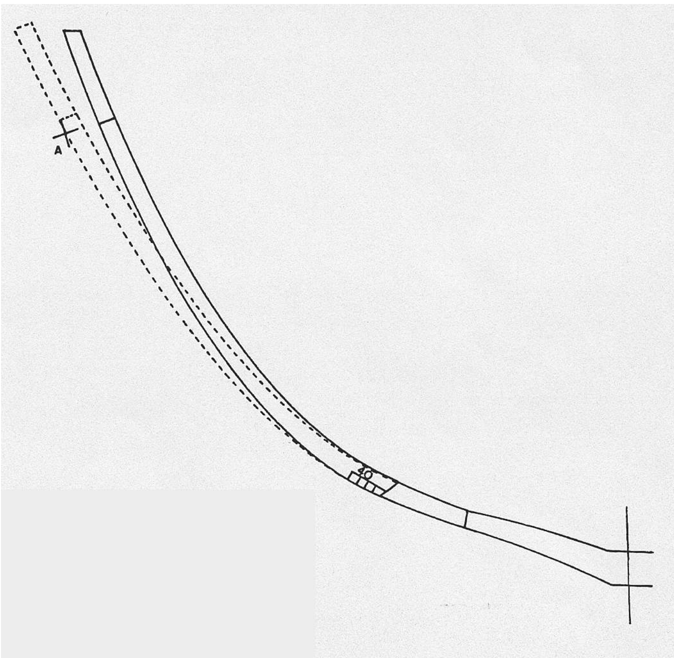

fig. 7. Trébuchement de l'allonge jusqu'au niveau de la marque A indiquée par le trébuchet. En pointillé, position de l'allonge après son trébuchement. Dessin E. Rieth.

##

Après avoir fixé, dans ses principes, le contenu de la méthode du "*whole-moulding*," il faut s'interroger à présent sur ses relations avec l'univers des chantiers navals méditerranéens.

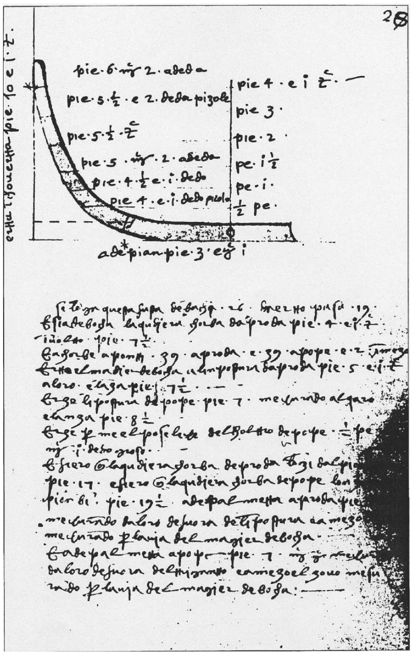

Fig. 8. Maître-gabarit d'une *fuste*. Z. Trombetta de Modon, *Libro*, c. 1445, Londres, British Library, Cotton, ms Titus A 26, fol. 28.

C'est dans les sources écrites vénitiennes du XVe siècle et, plus précisément, dans trois "livres de recettes techniques" d'architecture navale que se trouvent les plus anciennes mentions de ce que nous avons appelé la méthode du maître-gabarit, de la tablette et du trébuchet (20) et que S. Bellabarba nomme, en référence aux documents vénitiens, la méthode de la "*partisone*" (21). Cette méthode qui, au XVe siècle, n'est pas limitée au seul espace de Venise mais s'étend, en réalité, à une large partie des rivages méditerranéens, repose sur le principe d'une modification progressive d'un certain nombre de valeurs de la figure du maître-couple, modification qui, cependant, ne change pas son tracé géométrique. Les quatre variables affectant la maîtresse-section portent sur la diminution de la longueur du plat - "*fondo*" -, l'augmentation de l'acculement - "*stella*"-, le trébuchement - "*ramo*"- et le recalement - "*scorrer del sesto*." Ajoutons, d'une part, que ces modifications permettent de définir la figure de tous les couples compris entre les deux couples de balancement et que, d'autre part, la détermination des formes de cette partie de la coque est effectuée à l'aide du maître-gabarit et de tablettes - "*sesti*." Précisons, également, que la méthode de la "*partisone*" est employée pour concevoir des unités de tous types et tonnages (fig. 8 et 9).

Cette méthode de conception, dont le plus ancien témoignage archéologique remonte à la fin du XIIIe siècle-début du XIVe siècle (épave de Culip VI, Catalogne, Espagne) (22) présente, tant au niveau de son principe que de son application, de multiples points de similitude avec le "*whole-moulding*" décrit par Stalkartt.

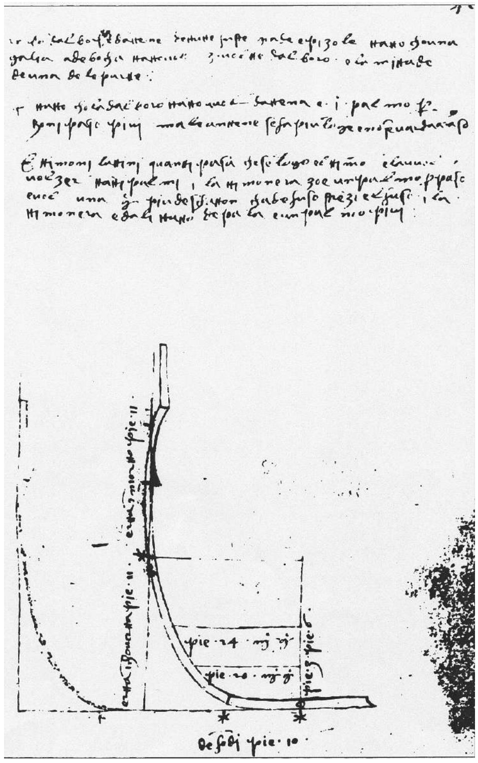

Fig. 9. Maître-gabarit d'une *nave* de 700 *botte*. Z. Trombetta de Modon, ms cit., fol. 48.

Principe: définition du tracé des membrures à partir de la figure du maître-couple en modifiant certaines de ses valeurs mais sans transformer sa construction géométrique.

Application: utilisation "d'instruments" dont le maître-gabarit et la tablette d'acculement; leur combinaison dans différents plans et leur déplacement le long de la quille aboutissent à la définition des formes de la coque.

Au regard de la méthode du "*whole-moulding*," trois différences principales sont identifiables:

existence de deux modifications supplémentaires: le trébuchement et le recalement;

absence d'emploi de la "latte de talon;"

limitation de la méthode aux membrures entre les deux couples de balancement.

Toutefois, ces différences doivent être relativisées. C'est ainsi que le trébuchement, effectivement attesté en Méditerranée au XVe siècle, semble apparaître plus tardivement - au début du XVIIe siècle - dans l'espace ibéro-atlantique, aspect sur lequel nous reviendrons. Par ailleurs, "l'enfermement" de la méthode à l'intérieur des deux couples de balancement varie selon les types de bâtiment. Dans le cas des galères, par exemple, les deux couples de balancement sont situés à proximité des extrémités de la coque et la méthode de la "*partisone*" est opératoire, de ce fait, sur une grande longueur de quille. En revanche, elle est d'une utilisation nettement plus réduite dans le cas des navires à voile.

Une autre illustration, contemporaine cette fois-ci, de parenté entre les deux méthodes est fournie par les pratiques des chantiers navals traditionnels grecs (23). Dans sa forme la plus élémentaire, les constructeurs de la mer Egée et de la mer Ionienne faisaient appel, il y a encore quelques années, à une méthode de conception appelée "*monochnaro*" ce qui signifie, littéralement, "un seul gabarit," en l'occurrence celui du maître-couple (fig. 10 et 11). Le principe de cette méthode est strictement comparable à celui de la méthode du "*whole-moulding*" anglais. Il s'agit dans les deux cas de partir de la figure de la maîtresse-section et de modifier deux de ces valeurs - la longueur du plat de la varangue et l'acculement - pour définir les membrures comprises entre les deux couples de balancement. L'application de la méthode du "*monochnaro*" est similaire, également, à celles du "*whole-moulding*." Elle repose sur un jeu de trois "instruments :" un maître-gabarit ("*mana*"), une tablette d'acculement ("*pinakidi*"), et une "latte de talon" ("*axinistrofo*"). Ces trois "instruments" ou "aides" à la conception sont si proches de ceux décrits par Stalkartt qu'il semble guère utile de souligner plus longuement les relations de parenté fonctionnelle entre les deux méthodes.

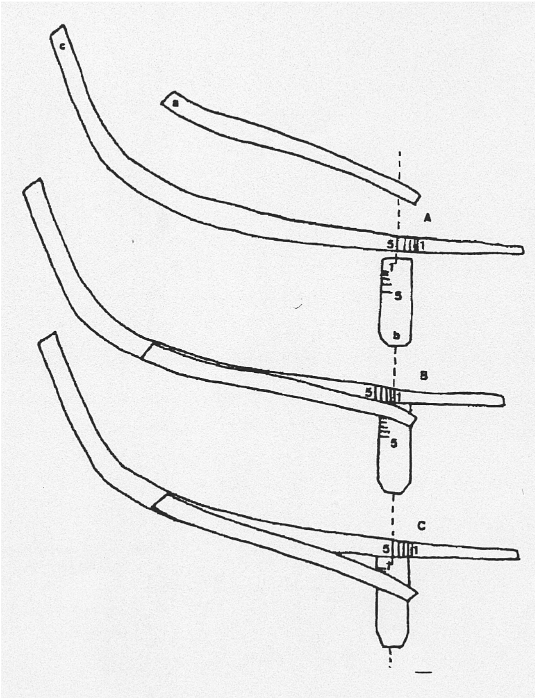

Fig. 10. En A, les trois "instruments" du "*monochnaro*;" en B, position des trois "instruments" pour tracer le maître-couple; en C, position des trois "instruments" pour définir le contour du cinquième couple. D'après K. Damianidis, 1986, ouv. cit., p. 52.

Un aspect particulièrement intéressant mis en évidence par K. Damianidis est celui de l'existence, au sein d'une même méthode, de variables qui se marquent à travers l'emploi d'une gamme "d'instruments," trois dans le cas de la forme la plus élémentaire du "*monochnaro*" et cinq dans celui de la forme la plus aboutie de la méthode. Les deux "aides" supplémentaires sont un gabarit d'allonge et un trébuchet permettant une augmentation, par le trébuchement du gabarit de l'allonge, de la largeur de la membrure. Pour autant, ces variables ne remettent nullement en question le principe de la méthode.

Avant de considérer de quelle manière peuvent être interprétées, en termes historiques, ces similitudes, il importe de rappeler en quelques phrases le poids des pratiques des chantiers navals méditerranéens dans le contexte ibéro-atlantique (24) et, plus largement, dans celui de l'arc atlantique des XVIe et XVIIe siècles.

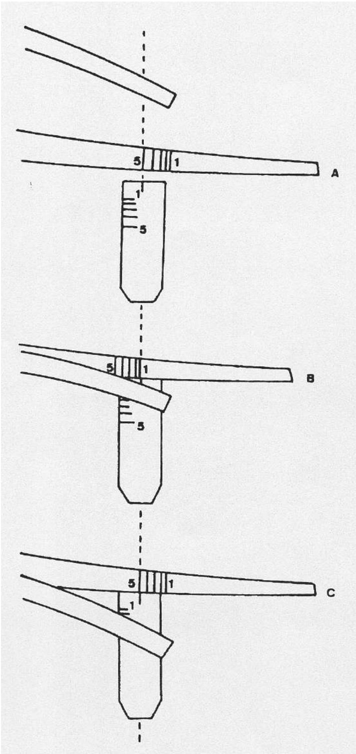

Fig. 11. Détail des trois "intruments" (A) et de leur position pour définir la figure du maître-couple (B) et du cinquième couple (C). D'après K. Damianidis, 1986, ouv. cit., p. 52.

Dans les dernières décennies du XVIe siècle, Oliveira, natif d'Aveiro, Portugal (25) et Palacio, originaire de Santander (Cantabrie) (26), deux hommes du nord de la péninsule ibérique, ont témoigné de l'usage d'une méthode de conception des carènes qui, sans guère d'ambiguïtés, se rattache à la tradition médiévale et méditerranéenne, dans sa forme élémentaire, du maître-gabarit et de la tablette d'acculement. Aucun indice, en effet, du recours au trébuchement n'est discernable dans les écrits des deux hommes qui pour le premier évoque les pratiques des chantiers navals portugais et pour le second celles probablement en usage dans ceux du pays basque (27).

Au cours du XVIIe siècle, les attestations d'une méthode de conception comparable à celle décrite par Oliveira et Palacio, mais présentant une forme plus aboutie, sont également présentes dans le contexte ibéro-atlantique. T. Cano (28) est ainsi le premier auteur à faire état de la pratique du trébuchement ("*joba*") qui apparaît officiellement dans l'ordonnance royale de 1613. A la fin du siècle, le grand constructeur basque Gaztaneta y Yturribalzaga rédige et illustre un remarquable traité d'architecture navale (29) qui est une parfaite illustration de la méthode médiévale et méditerranéenne du maître-gabarit, de la tablette et du trébuchet.

Cette référence à l'univers méditerranéen nécessite une remarque et une question.

Remarque: la relation d'équivalence observée entre les méthodes de conception des constructeurs des espaces ibéro-atlantique et méditerranéen est à replacer dans le cadre de l'introduction et du développement le long du littoral atlantique de la péninsule ibérique du système de construction à franc-bord "membrure première." L'une des "paternités historiques" de ce transfert de techniques serait-elle à accorder, au début du XIIe siècle, à des constructeurs génois et pisans (30) ou ne reviendrait-elle pas, plutôt, à l'influence, plus étendue dans l'espace et dans le temps, des constructeurs maures d'al-Andaluz? (31).

Question: les oeuvres d'Oliveira, Palacio et Gaztaneta, pour ne faire état que des trois auteurs cités originaires du nord de la péninsule ibérique, ne pourraient-elles pas être le seul reflet de la culture officielle et dominante propres aux grands chantiers navals royaux et occulter d'éventuelles méthodes régionales particulières aux petits chantiers navals privés? Faute de sources probantes, il demeure difficile de répondre à cette interrogation.

Quittons le domaine ibéro-atlantique pour celui du Ponant français des deux dernières décennies du XVIIe siècle. Plusieurs documents indiquent, sans aucun doute possible, que la méthode d'origine méditerranéenne du maître-gabarit, de la tablette et du trébuchet était pratiquée par les constructeurs et charpentiers de marine du littoral atlantique le long d'un secteur compris entre les arsenaux de Rochefort et de Brest (32). Certes, il s'agit à cette époque de pratiques en voie de disparition dans le cadre des chantiers royaux. Qu'en était-il auparavant? Que fut le devenir de cette méthode des "anciens constructeurs," selon l'expression de Duhamel du Monceau, dans le contexte des petits chantiers du littoral atlantique travaillant pour les armements au commerce et à la pêche? Nulle source ne nous a permis, pour le moment, de trouver un début de réponse.

Si l'on résume les remarques précédentes, on constate, en premier lieu, que dans l'espace ibéro-atlantique et atlantique des XVIe et XVIIe siècles, tous les documents semblent se conjuguer pour faire apparaître, sous des formes plus ou moins évoluées, une méthode de conception des carènes de même principe dont l'origine est à chercher au Moyen Age, en Méditerranée. On observe, en second lieu, que cette méthode d'essence méditerranéenne se superpose, de maints points de vue, à celle du "*whole-moulding*" décrite en 1781 par Stalkartt. Dès lors, comment peut-on interpréter dans une perspective historique la méthode du "*whole-moulding*" ?

##

Le premier aspect à envisager est celui de l'introduction et du développement du système de construction "membrure première" en Angleterre. Dans un contexte documentaire où les références directes à ce phénomène majeur de l'histoire de l'architecture navale médiévale sont des plus réduites, un fait central semble toutefois émerger: celui de l'intervention, sous le règne du roi Henri VIII (1509-1547), de constructeurs vénitiens dans les chantiers navals royaux qui, pour certains d'entre eux, firent un séjour de longue durée. Selon W. Abell, le roi confia à Sir Edward Howard la charge de développer, avec l'appui de ces "spécialistes" méditerranéens chargés, en particulier, de la conception des galées, une flotte de guerre et de former aussi un corps de constructeurs anglais afin que "la renommée de Gênes et de Venise, longtemps jalousée par les nations européennes, passa rapidement vers les rivages de l'Angleterre" (33).

Même s'il n'est pas aié de mesurer avec précision l'influence des constructeurs vénitiens, il semblerait qu'ils aient contribué, pour une part, à l'introduction et au développement en Angleterre de la construction à franc-bord "membrure première" et à la formation des charpentiers de marine anglais à cette nouvelle technique de construction (34). Celle-ci, rappelons-le, est à considérer dans ses dimensions conceptuelle - définir les formes de carène - et structurelle - bâtir une coque à franc-bord "membrure première." Dans ces conditions, il apparaît vraisemblable d'envisager que l'une des conséquences principales du séjour des constructeurs vénitiens dans les chantiers royaux a été l'adoption par les charpentiers de marine anglais de la méthode du maître-gabarit et de la tablette.

Plusieurs décennies après cette période de mutation architecturale, sous le règne d'Elizabeth Ière (1558-1603), le célèbre maître-constructeur anglais Mathew Baker (1530-1613), auteur, pour une large part, des non moins célèbres *Fragments of Ancient English Shipwrighty* (35), fait référence, dans la première partie du manuscrit datée des années 1570, aux usages des chantiers navals méditerranéens. Il trace ainsi, selon les pratiques des constructeurs vénitiens, la figure d'un maître-couple à partir de quatre arcs de cercle tangents de rayons différents (36). Il mentionne aussi certaines expressions propres à la méthode de la "*partisone*" qu'il écrit, en l'anglicisant, "*partysone*." Il évoque l'acculement ("*lastelly*" pour la "*stella*") (37), le couple de balancement ("*capo di* *sesto*") (38) et le trébuchement ("*linaramo del sesto*" pour "*legno in ramo*") (39). Avant de revenir sur le trébuchement, plusieurs points doivent être soulignés. Premièrement, la présence, dans les *Fragments,* de termes en rapport avec la méthode du maître-gabarit, de la tablette et du trébuchet n'est sans doute pas étrangère au voyage entrepris en Méditerranée par M Baker en 1552. Deuxièmement, aucun passage des *Fragments* n'indique que cette méthode méditerranéenne était pratiquée par les constructeurs anglais de la seconde moitié du XVIe siècle même si on est en droit de le supposer. Troisièmement, une méthode de conception des carènes différente de celle du maître-gabarit, de la tablette et du trébuchet émerge en Angleterre dans les années 1580 pour devenir, selon les termes de R. Baker "*the basic standard for two centuries"* (40). Dans cette méthode, dont les *Fragments* se font l'écho, la modification de la figure de la maîtresse-section s'opère par un glissement - "*hauling down/up*" - des gabarits du genoux et des allonges les uns sur les autres (41). Par ailleurs, la diminution de la longueur du plat de la varangue s'effectue séparément de la réduction de la largeur au fort. Ce sont donc deux systèmes géométriques de modification de la figure du maître-couple qui, désormais, se distinguent.

C'est dans ce contexte que se pose la question de l'interprétation de la méthode du "*whole-moulding*" décrite par Stalkartt en 1781. Trois niveaux de réponse peuvent être considérés.

Premier niveau: le "*whole-moulding*," encore utilisé à la fin du XVIIIe siècle pour la définition des formes de carène des embarcations pourrait constituer la mémoire, plus ou moins appauvrie par une simplification des procédures, des pratiques introduites au début du XVIe siècle dans les chantiers navals royaux anglais par des constructeurs méditerranéen pour la conception de galées et autres types de bâtiments. Ce premier niveau de réponse rejoindrait, en l'occurrence, le point de vue exprimé par R. Baker lorsqu'il écrit que la méthode décrite par Stalkartt "est une version dégradée, simplifiée, de celle pratiquée avec une plus grande complexité dans les arsenaux anglais du XVIe siècle" (42).

Deuxième niveau: la méthode du "*whole-moulding*," en tant que mémoire d'une culture technique d'origine médiévale et méditerranéenne, semblerait présenter maints points de convergence avec la méthode attestée aux XVIe et XVIIe siècles dans l'architecture navale de tradition ibéro-atlantique et atlantique.

Troisième niveau: ces similitudes, en relation avec l'introduction et le développement de la construction à franc-bord "membrure première" dans les espaces ibéro-atlantique et atlantique, pourraient traduire l'existence d'une culture technique, dotée d'éventuelles variables régionales, commune à l'ensemble des constructeurs de l'arc atlantique. Dans cette hypothèse d'une même tradition atlantique d'origine méditerranéenne, la "nouvelle" méthode de conception des carènes élaborée en Angleterre dans les derniers temps du XVIe siècle et faisant appel à la modification de la figure du maître-couple par le biais du "*hauling down/up*," serait la seule à pouvoir être qualifiée de méthode spécifiquement anglaise. Cette méthode, appliquée à la conception des bâtiments de guerre et des navires de commerce, se serait ainsi développée parallèlement à celle qualifiée de "*whole-moulding"* par Stalkartt à la fin du XVIIIe siècle. Moins adaptée à la conception des formes de carène des unités de guerre tout particulièrement, le "*whole-moulding*" aurait été progressivement limité à la conception des petits bâtiments puis à celle des seules embarcations.

Deux arguments peuvent être opposés à cette interprétation. Le premier est celui de la mise en évidence, dans les épaves de la *Mary Rose* (1545) et du présumé *San Juan*, baleinier basque coulé à Red Bay au Labrador en 1565, de l'emploi de la méthode, de tradition anglaise selon notre interprétation, du "*hauling down/up*" pour concevoir les formes de carène des deux bâtiments. Comment interpréter dans le cas de la *Mary Rose* l'usage précoce de cette méthode? Pour quelles raisons le baleinier basque de Red Bay aurait-il été conçu, dans un contexte historique ibéro-atlantique, selon une méthode de tradition anglaise? La publication complète de l'étude des deux épaves fournira, sans nul doute, des réponses à ces deux interrogations dont les implications historiques, notamment pour le cas du présumé *San Juan*, vont bien au-delà du seul domaine de l'architecture navale.

Le second argument venant à l'encontre de notre interprétation est un extrait des *Fragments of Ancient English Shipwrightry* de Mathew Baker. A propos du trébuchement ("*linaramo del sesto*"), Baker souligne qu'aucun constructeur anglais n'en comprend parfaitement la signification (43). De notre point de vue, cette constatation ne signifie pas que la méthode méditerranéenne du maître-gabarit, de la tablette et du trébuchet n'était pas employée par les constructeurs anglais mais qu'elle pouvait être pratiquée dans sa forme rudimentaire, sans trébuchement, similaire, dans son principe et son application, à la méthode du "*whole-moulding*." Cette absence d'usage du trébuchement n'apparaît pas exceptionnelle dans les années 1570-1580. Rappelons que dans le contexte ibéro-atlantique, le trébuchement ("*joba"),* ce "coup de maistre dont les constructeurs font le plus de mystère" (44), n'est attesté dans les sources écrites qu'à partir du XVIIe siècle.

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Au terme de cette réflexion, de nombreux aspects liés à l'étude de la méthode du "*whole-moulding"* et à ses relations avec la méthode méditerranéenne du maître-gabarit restent encore à expliquer. Sans doute, certaines interprétations devront-elles être corrigées à la suite de l'analyse d'autres documents. Mais au-delà des questions laissées provisoirement sans réponse et des hésitations concernant certaines conclusions, reste le caractère passionnant, par ses implications historiques, de la méthode de conception des carènes décrite en 1781 par Stalkartt qui repose sur trois simples "instruments": un maître-gabarit ("*midship-bend*"), une tablette d'acculement ("*rising square*") et une "latte de talon" ("*straight bottom*").

Notes

Je remercie Monsieur Walter Gaspard qui a mis à ma disposition, avec sa gentillesse habituelle, le texte et la planche de l'ouvrage de Stalkartt concernant le "*whole-moulding*."

1. Nous nous permettons de renvoyer à notre article: "La question de la construction navale à franc-bord au Ponant," *Neptunia*, 1985, 153, p. 21-31.

2. S. Bellabarba, "The ancient methods of designing hulls," *The Mariner's Mirror*, 1993, 79, 3, p. 274-292, p. 286.

3. A ce sujet, S. Bellabarba note: "*In the litterature on this subject a distinction is drawn between the procedure used on the Altantic seabord, termed 'whole moulding'...and alleged 'Meditteranean moulding', claimed to be the method described by Mediterranean seafaring documents. In fact, the two methods are one and the same thing, or at least where when the Mediterranean method was adopted in the North*" ("The origins of the ancient method of designing hulls: a hypothesis," *The Mariner's Mirror*, 1996, 82, 3, p. 259-268, p. 268, note 12).

4. Communication lors du 33e colloque d'archéologie historique et subaquatique, Québec, 4-9 janvier 2000. Cf. le volume des résumés: B. Loewen, "Red Bay: English hull design concepts in a Basque Shipwreck," p. 123. Selon B. Loewen, la différence la plus sensible se situerait dans les procédés de modification des membrures disposées en avant et en arrière du maître-couple, tout particulièrement au niveau de leurs genoux: "*hauling down the futtock*" dans la méhode atlantique et "*joba, espalhamento* ou trébuchement" dans la méthode ibérique et méditerranéenne. Cf. aussi: B. Loewen, "The Red Bay vessel. An example of a 16th-century Biscayan ship," *Itsas Memoria. Revista de Estudios Maritimos del Pais Vascos*, 1998, 2, p. 193-199. Les travaux de B. Loewen sont à compléter par ceux de R. Barker, le meilleur historien de l'architecture navale anglaise des XVIe et XVIIe siècles, grand spécialiste également des sources portugaises de cette même période. Cf. en particulier: "Fragments from the Pepysian library," *Revista da Universidade de Coimbra*, 1986, XXXII, p. 161-178;"'Many may peruse us': ribbands, moulds and models in the dockyards," *Revista da Universidade de Coimbra*, 1988, XXXIV, p. 539-559; "Design in the dockyards about 1600," dans Reinders R., K. Paul (dir.), *Carvel construction technique*, Oxbow Monograph, 1991, 12, p. 61-69; "A manuscript on shipbuilding, circa 1600, copied by Newton," *The Mariner's Mirror*, 1994, 80, 1,; p. 16-29; "English shipbuilding in the sixteenth century: evidence for the processes of conception and construction," dans E. Rieth (dir.), *Concevoir et construire les navires. De la trière au picoteux*, Technologies, Idéologies, Pratiques, 1998, XIII, 1, p. 109-126.

5. Nous avons utilisé la deuxième édition publiée à Londres en 1787.

6. M. Stalkartt, ouv. cit., livre 1, p. 1.

7. H. I. Chapelle, *American small sailing craft*, New York, 1951, p. 11.

8. *18th-century shipbuilding. Remarks on the Navies of the English and the Dutch by Blaise Ollivier (1737)*, ed. and transl. by D. H. Roberts, Rotherfield, 1992.

9. M. Stalkartt, ouv. cit., livre 1, p. 21-28. La "latte de talon" semble être la traduction la plus proche, d'un point de vue fonctionnel, de l'expression "*straight bottom* ."

10. M. Stalkartt, ouv. cit., livre 1, p. 2-21.

11. M. Stalkartt, ouv. cit., livre 1, p. 21.

12. E. Mc Kee, *Working boats of Brittain*, Londres, 1983, p. 122-124.

13. W. A. Baker, *The Mayflower and other colonial vessels*, Londres, 1983, p. 17. Il est à noter que, curieusement, Baker (p. 16) ne mentionne que deu gabarits ("*body mold*" et "*hollow mold*"), ne faisant aucune référence à la tablette d'acculement dont la fonction est pourtant essentielle.

14. G. Juan, *Examen maritime théorique et pratique, ou traité de méchanique appliqué à la construction et à la manoeuvre des vaisseaux et autres bâtiments*, traduit de l'espagnol, avec des additions, par M. Levêque, Nantes, 1783, 2 vol.

15. G. Juan, ouv. cit., vol. 2, p. 15-17.

16. G. Juan, ouv. cit., vol. 2, p. 17-18. Les couples localisés "entre le couple de balancement de l'arrière et l'estain, et entre le couple de lof et l'étrave" (p. 18) sont définis au moyen de quatre lisses.

17. G. Juan, ouv. cit., vol. 2, p. 19.
18. J. Boudriot, "La conception des vaisseaux royaux," *Neptunia*, 1988, 169, p. 9-24, p. 10.

19. G. Juan, ouv. cit., vol. 2, p. 19.

20. Nous nous permettons de renvoyer à notre ouvrage: *Le maître-gabarit, la tablette et le trébuchet. Essai sur la conception non-graphique des carènes du Moyen Age au XXe siècle*, Paris, 1996.

21. S. Bellabarba, "The ancient methods...," art. cit., p. 275-276.

22. Pour une première analyse, cf. E. Rieth, *Le maître-gabarit...*, ouv. cit., p. 149-164, and in this Preprint.

23. Cf.: K. Damianidis, "The diachronic 'Road of Dialogue' of mediterranean shipbuilding; some methods for controlling the form of a vessel," dans *Cultural and commercial exchanges between the Orient and the Greek world*, Athènes, 1991, p. 97-108; "Methods for controlling the form of vessel during shipbuilding in the Eastern mediterranean during the 18th and 19th centuries," dans *The evolution of wooden shipbuilding in the Eastern Mediterranean during the 18th and 19th centuries*, Athènes, 1993, p. 97-105; "Methods used to control the form of the vessels in the Greek traditional boatyards," dans E. Rieth (dir.), *Concevoir et construire les navires. De la trière au picoteux,* Technologies, Idéologies, Pratiques, 1998, XIII, 1, p. 217-244; cf. aussi: C. Prifti, T. A. Loukakis, "Technical contributions to the study of traditional greek vessels," dans *The evolution of wooden shipbuilding in the Eastern Mediterranean during the 18th and 19th centuries,* Athènes, 1993, p. 141-149.

24. Sur cette question, cf. les actes à paraître du colloque international *Arqueologia dos navios medievais e modernos de tradiçao Ibero-Atlântica,* Lisbonne, 7-9 septembre 1998.

25. F. Oliveira, *Livro da fabrica das naos*, c. 1570-1580, Lisbonne, Bibliothèque nationale, ms rés. 3702, édition par F. Contente Domingues, R. Barker, *Fernando Oliveira. O livro da fabrica das naos,* Lisbonne, 1991. Pour une approche du *Livro*, nous nous permettons de renvoyer à nos articles: "Les écrits de Fernando Oliveira," *Neptunia,* 1987, 165, p. 18-25; "Un système de conception des carènes de la seconde moitié du XVIe siècle," *Neptunia*, 1987, 166, p. 16-31.

26. D. G. de Palacio, *Instrucion nauthica*, Mexico, 1587 (rééd. Madrid, 1944).

27. R. Barker, "'Many may peruse us'...," art. cit., p. 551.

28. T. Cano, *Arte para fabricar y aparejar naos*, Séville, 1611 (éd. par E. Marco Dorta, Instituto de Estudios Canarios, La Laguna, 1944, p. 108).

29. A. de Gaztaneta y Iturribalzaga, *Arte de Fabricar Reales*, 1687-1691, Motrico, Archives de la Cas de Arrietakua, édition par F. Fernandez Gonzalez (dir.), Barcelone, 1992, 2 vol.

30. Cf. par exemple: O. L. Filgueiras, "Gelmirez e a reconversao da construçao naval tradicional do NW Séco. XI-XII," *Actas do Congresso Internacional Bartolomeu Dias e a sua Epoca,* Porto, 1989, 2, p. 539-576. `

31. Cf. le remarquable ouvrage de C. Picard, *L'océan Atlantique Musulman. De la conquête Arabe à l'époque Almohade*, Paris, 1997.

32. Cf. notre article à paraître dans les actes du colloque international *Arqueologia dos navios medievais e modernos de tradiçao Ibero-Atlântica*: "Le cas de la France à la fin du XVIIe siècle: une même méthode de conception des navires au Ponant et au Levant."

33. W. Abell, Th*e shipwright's trade*, Londres, 1981, p. 26-28.

34. Cette influence des constructeurs vénitiens est admise, non sans une juste réserve en raison de la pauvreté des sources, par R. Barker. Cf.:"'Many may peruse us'...," art. cit., p. 542; "A manuscript...," art. cit., p. 17. Il est à noter que R. Barker mentionne aussi le rôle possible tenu par des constructeurs

portugais au cours du XVe siècle. Mais faute de documents précis, il est tout aussi difficile d'évaluer leur influence sur les usages des chantiers navals anglais.

35. M. Baker, *Fragments of Ancient English Shipwrightry,* c. 1570-1580 (début du ms), Cambridge, Pepysian Library, ms 2820. Pour une approche générale du document, cf.: R. Barker, "Fragments...," art. cit.

36. M. Baker, *Fragments...*, ms cit., f• 11.

37. M. Baker, *Fragments...*, ms cit., f• 16.

38. M. Baker, *Fragments...*, ms cit., f• 23.

39. M. Baker, *Fragments...*, ms cit., f• 16.

40. R. Barker, "English shipbuilding...," art. cit., p. 112. Sur la description de cette méthode, cf.: W. A. Baker, "Early Seventeenth Century Ship Design," *The American Neptune*, 1954, 14, 4, p. 262-277.

41. Le mouvement du "*hauling down* "ressemble à celui du recalement mais, différence majeure, le premier est à la base de la modification de la figure du couple alors que le second est un ajustement ou une correction du trébuchement qui assure la modification du contour du couple.

42. R. Barker, "Design in the dockyards...," art. cit., p. 66.

43. M. Baker, *Fragments...*, ms cit., f• 16. La phrase complète est ."..*a thing without the which it is impossebell to make a perfect ship by ane plot, which order at present ther is no inglish man perfetly understandeth*."

44. *Traité de la construction des galères,* c. 1691, Vincennes, Service historique de la Marine, ms SH 134, 1ère partie, f• 23, édition par J. Fennis, *Un manuel de construction des galères,* 1691, Amsterdam et Maarssen, 1983.

Whole-moulding: a preliminary study of early English and other sources

© Richard Barker, February 2001

Introduction

Fournier's *Hydrographie* of 1643 has long been noted as containing a geometrical midship section (**Fig. 1**) which he termed the ancient method,[1] unfortunately without specifying how ancient, or where it was practised. It has an archaic appearance about it: a simple quadrant arc is raised on a flat floor, with a longer radius arc extending the side upwards above that. The majority of known frame shapes from the period around 1570 onwards, when they come to be recorded widely, are much more angular in the bilges and at the maximum breadth, resulting from the use, typically, of three arcs in place of the single quadrant.

If as seems likely, this method was part of a wider shipbuilding tradition employed (but not necessarily originating) on the Atlantic coast of northern Europe, we might especially note the possible link to the somewhat mysterious "whole-moulding" that first appears only in texts of the eighteenth century, and in several of which the midship section is based on that same simple quadrant linking a flat floor and a vertical side, albeit only representing small open boats at that stage.

It is a moot point whether "whole-moulding" takes its name from forming the whole hull from a single mould (which is never actually achieved in full), or from the more restricted fact that the whole midship section is created from a single mould. The rest of the hull is formed with rising and narrowing scales (sometimes marked on *staffs*) for that mould, without any rotation and consequently with a generally constant angle of the side; and that same mould is inverted to form the hollowing curve between bilge and keel. The degree of rising and narrowing is relatively empirical, either from a drawing, or by copying previous examples with the same markings (the surmarks) for the consecutive, adjusted positions of the mould(s) and rising square.

Though Fournier gives no supporting text, it seems quite possible that what he is describing is actually a form of "whole-moulding." This is in fact as close to the "Mediterranean" method as it is to the method of all English treatises from 1570 to 1711, when Sutherland first mentions whole-moulding as one method of design; and for ships, not just for the small boats which are the case from Murray (1765) onwards. That is, the key difference between whole-moulding and the fully developed Mediterranean method is that the *legno in ramo* or *trébuchement* is nil: the mould is not rotated about the bilge. By contrast, the English treatisers' method from the end of the sixteenth century does not use a single mould for the side, and is based on adjusting a series of tangent arcs within a grid that itself has narrowings and risings applied to it. This gives great flexibility in forming the hull shape, since the side is not formed by a single rigid mould, while still using only a small set of moulds for an entire ship. (Indeed it is not unknown for the term whole-moulding to be applied loosely or anachronistically for the treatisers' method, on that basis).[2]

1. G. Fournier, *Hydrographie*, Paris 1643, Book I, Chapter VIII, p. 23.

This paper will consider the implications of these observations, taken together with a wider range of evidence for occurrences in documents and archaeology of similar characteristics, to explore the possible origins of what is known as whole-moulding, and thence perhaps of European moulding more generally. To that end it also considers some of the lesser known English sources. It arises from a combination of circumstances, including the Workshop on *History of shipbuilding and ship design* at Max Planck Institut, Berlin in November 2001, and compilation of the report of the work by Barker and Loewen on the *Mary Rose*. The evidence, both documentary and archaeological, available for this subject is rapidly expanding, and inevitably requires continuous review of earlier theories. Lest some of the remarks below appear unduly critical of other researchers, it is perfectly apparent that some of this writer's earlier texts contain errors and misunderstandings too, not to mention omissions. Indeed sources only scanned for other purposes in the past have yielded significant surprises. This paper is merely a contribution to a long-term debate. It will be apparent from this text that there is a fatal dearth of evidence to resolve the many hypotheses.

History of whole-moulding in the North

We are not currently able to say where this eighteenth century English whole-moulding method came from, or whether it was earlier than the more sophisticated methods fully formed in England by 1509 at the latest. This writer first discussed the issue long ago,[3] and Rieth has elaborated that discussion in a recent article in *Neptunia*.[4] We should preface this section with Rieth's sub-title: "a memory of the Mediterranean shipyards of the Middle Ages," which seems to be undeniable; bar only any evidence of continuity, if we read memory for *mémoire*, rather than simply a reminiscence.

The history of the English methods is obscure. Until around 1460 there is no record of frame-first shipbuilding at all, and it is not known what the earliest influences were. Genoese and Venetian traders conspicuously visited English ports from the fourteenth century, and of course English ships with their carpenters went to the Crusades from the twelfth century. Many large foreign ships, especially Genoese, were purchased or cap-

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2. In this context we might note that Bellabarba is partly at fault here, using the term whole-moulding for a general "Atlantic" method (S. Bellabarba, "The origins of the ancient methods of designing hulls," in *Mariner's Mirror*, Vol. 82, 1996, pp 259-268, note 12 especially). "…whole-moulding… deriving the shape of all the frames from the mainframe, *varying the curves* at some points" also gives a false impression. He does then make a point that whole-moulding could have been identical to the partial "Mediterranean" method when that was first adopted in the North - without *trébuchement*, but does not distinguish between that and the treatisers' methods, never called whole-moulding by contemporary writers; recognise the absence of evidence for the term; or note that there were many methods developed on the Atlantic coasts, just as there had been a development in the Mediterranean method that renders it different from "whole-moulding" in most recorded examples. See also further comments below. Chapelle's omission of a source for his *whole-moulding* of English warships *up to* the 1730's (Rieth, 2000, p. 12/n7) may reflect the same point: he actually meant the treatisers' method?
3. R. A. Barker, "'Many may peruse us': ribbands, moulds and models in the dockyards," in *Revista da Universidade de Coimbra*, Vol. XXXIV, 1988, pp. 539-559, esp. pp. 557-9, notes the possible interest of Fournier, and the Serçe Liman wreck, for whole-moulding, for example, and the distinct possibility that continuity of geometrical method might eventually be traced back to antiquity.
4. É. Rieth, "La méthode moderne de conception des carènes du whole-moulding," in *Neptunia* No. 220, Paris 2000, pp. 10-21.

tured and used in English fleets over a long period. Bayonne had close links, and built very large English ships around 1419, albeit ostensibly shell-built clinker hulls at that stage. Bayonne may indeed be the continuing geographic link that explains the similarity of the moulding systems of the *Mary Rose* of 1509 and the Basque Red Bay whaler of 1565, though we have no knowledge of which way the system travelled. Northern French shipbuilders adopted frame-first building at about the same time as the earliest English records (excepting only that the Clos des Galées at Rouen was building French vessels - galleys essentially - in the Mediterranean style much earlier, apparently in isolation).

The earliest "carvels" known in the north were built by Portuguese shipwrights for the Duke of Burgundy about 1439; but we should note that that followed his marriage to Isabella of Portugal, who had spent many weeks in England at the end of 1429 with her close Royal relatives, on the way to Flanders, with a large Portuguese armada.[5] (Not for nothing is it called the Old Alliance, though while there is evidence for a flourishing trade,[6] and indeed for mutual support in naval operations,[7] none seems to have survived for shipbuilding in this period). Whatever the first occurrences may have been, the first large English warship so built was reputedly the *Regent* of 1489.[8]

It is well known that by the time of Henry VIII, Venetian shipbuilders in particular were employed in the English dockyards, but not what their specific role was - it may have been confined to galley construction. The first instance of which this writer is aware is 1541,[9] and then 1570, and both these can be inferred as for galleys.

The first recorded midship sections from English methods are only from the 1570's (though they include a late record of four ships of 1546), and they do not use the Mediterranean method at all, but a system of tangent arcs - though the evidence for these examples is for the midship section only, not its variation. Just such a system has been found by Barker and Loewen in the framing of the *Mary Rose*, built in 1509. There is no trace of the eighteenth century whole-moulding by name in any of these documents, until William Sutherland's *The Shipbuilders Assistant*, of 1711,[10] at least to this writer's knowledge. This is followed in 1765 by Mungo Murray's *A treatise on shipbuilding and navigation*, and Marmaduke Stalkartt's *Naval Architecture, or the rudiments and rules of shipbuilding*, of 1781. These are both for small open boats, and unlike treatises for the design of large ships, they hardly differ. They do refer to the use of a similar system

5. T. W. E. Roche, *Philippa….*, Chichester 1971, pp. 92-3; *Chronique d'Antonio Morosini*, Vol. III, Paris 1901, p. 242.
6. V. M. Shillington & A. B. Wallis Chapman, *The commercial relations of England and Portugal*, New York 1907, esp. p. 19.
7. Almost a forgotten chapter: research is in hand.
8. This rests on the supply of carvel nails for the construction of the *Regent*; the *Sovereign* of 1488 (believed to be the "Woolwich ship") was definitely built clench, and rebuilt carvel in 1509.
9. M. Oppenheim, *History of the administration of the Royal Navy, 1509-1660*, London 1896, p. 59. Abell (cited by Rieth) gives no source for a remark that Edward Howard brought shipwrights from abroad, chiefly Italy, but he only received his instructions as Admiral in 1512, and was killed just one year later.
10. There is a facsimile edition, Rothersfield 1989. We should perhaps note a comment by the late Frank Howard (*Sailing ships of war, 1400-1860*, 1979, p. 256) to the effect that later editions of Sutherland contain information (specifically for fitting out) that was increasingly out of date, some of it going back to around 1650.

for relatively large ships until recent times; the method appears regularly in encyclopaedias for many more decades - it is in the third edition of Steel's *Elements and Practice of Naval Architecture* in 1822, for example.[11] It still exists in use in small boats, as in Trinity Bay, Newfoundland.[12]

It is worth noting that at an early stage of frame-first construction in the north, the French and Scots (and others too) were in possession of large ships, such as the *Great Michael* of 1511, built by a French shipwright. Unfortunately there seems to be negligible information about methods of either ally for long afterwards. However, soon after the accession of James I (VI of Scotland) in England in 1603, Scottish shipbuilders were working in Denmark producing plans that are remarkably like Baker's in style and content (Baker was by then in his 70's and not active [*see Postscript*]). The search has to be wider than England and France, the Mediterranean and Iberia.

William Sutherland

William Sutherland's *Shipbuilders Assistant* of 1711 presents a number of problems of interpretation. It is a brief, perplexing and inconsistent work. As noted, it does refer to whole-moulding by name, once. The main figure has three scales for surmarks included on it, the rising staff, the half breadth staff and because it is for a large ship not a boat, a half breadth of top-timber staff. The first two correspond to staffs still found in current methods. However, Sutherland also compares whole-moulding with a "more exact way, and yet as easy"; and generally he has risings and narrowings for both the floor and breadth - which is not whole-moulding. He also uses some quadrant arcs. That is, although his reference to whole-moulding is almost in passing, in this context the work does require some consideration. What it describes is in part certainly a case of whole-moulding large ships (p. 80):

> "…when two such sets of moulds are formed very exact, and fitted in every respect, a preparation is made to lay down every timber, which may be done divers ways. As, by fastening (term'd tacking) all the mould together as high as the breadth, and lifting them according to the rising lines and narrowing them by the narrowing of the breadths, so that all the body or ribs of the ship may be marked out. [The text at this point refers to labels on a drawing for the narrowings and risings]. This fashion is called whole-moulding. But I shall lay down a more exact way, and yet as easy. For when all the rising lines are laid down, and narrowings or tapering parallels of the lower part, then the lines [again referred to a drawing] will afford general centres at any of these intersections, either to the fore or after body…..."

In some instances Sutherland unquestionably uses simple quadrant arcs in midship moulds, and uses moulds for the hollowing curves. He traces a history of attempts to produce mathematically perfect hulls, solids of least resistance, from Pett, Wallis, Newton. Some phrases are worth noting:

11. D. Steel, 1822, Plate XXIX, "Longboat for an 80-gun ship showing the nature of construction by whole-moulding." (First edition 1805).
12. D. A. Taylor, *A survey of traditional systems of boat design used in the vicinity of Trinity Bay….*, PhD thesis, Memorial University of Newfoundland, 1989, pp. 100-2 and notes. Taylor uses the term whole-moulding rather loosely in his historical discussion (even using it to include Portuguese and Italian methods), following other authors.

> "Perfect circular bodies have been universally condemned, and yet at length found to be the most suitable in every respect. For although the middle part of a ship should be shaped by perfect circles, the extremes turn themselves into quite different shapes………. All the ribs or timbers being perfectly circular, only observing, that the level line of floor lies directly with the upper edge of the keel dividing forward and aftward, according to the tapering of the ship's body. (p. 4). …… Also every timber has a point of inflexion, or the curve reverted, which will be very useful in square sterned ships, and may be applicable in forming the largest of our shipping" (p. 6).

Let us now describe what is actually drawn for his first examples. Sutherland's Fig. B (Plate fp. 4) (**Fig. 2**) shows views of a ship (at very small scale) with sections along most of the length, which appear to have identical shapes with a narrow flat floor. The main mould is a quadrant (the text has "perfectly circular"), there is no hollowing mould. This is superposed on a drawing showing four different narrowing and rising lines that run the full length of keel and posts in just the form used by for example Mathew Baker. This figure then purports to mimick the solid of least resistance with a quadrant arc, but is not whole-moulding. It also has a top-timber narrowing line.

Immediately below this a similar "blunter bowed" figure, D (**Fig. 2**), has hollowing moulds added, which appear to be the same arc as the main mould; in the woodcut at least it has lost the line for the narrowing of the floor, and has two lower rising lines, unexplained. The mould appears to be a similar quadrant, except for the last two sections aft, which are also unexplained.

Fig. C (p. 6) (**Fig. 3**) has a quadrant at the midship in a sketchy body-plan to accompany Figs B *and* D, with four sections drawn fore and aft that might use the same mould, but with no hollowing mould.

However this cannot all be true as a pure quadrant mould would require equal risings and equal narrowings at the floor and breadth. The sections appear to end on the upper rising line, but we then notice that the intersections must be offset longitudinally by the half breadth - it is a false line, and the centres of some of the quadrants apparently lie above it; or it may in fact be a line of wale? As far as one can tell from the woodcut, the sections follow the upper breadth line, and the lower narrowing line is false. It could thus be a case of whole-moulding, undeclared, and confused in the woodcut. The text then moves to other issues. A subsequent work by Sutherland may throw light on this (see below).

When moulding resumes, Fig. A (Plate fp. 58) (**Fig. 4**) shows the two longitudinal sections, with distinct narrowings and risings for the floor, the breadth, and the top-timbers, formed as ellipses. The text mentions only four of these lines clearly: the narrowing of the breadth and the rising of the floor are mentioned more elliptically, but can be read into the text. In the figure, all four main lines now run the full length between posts. It seems impossible to be sure what was intended here too. The next step describes with a small figure (Fig. B, Plate fp. 58) (**Fig. 5**) a stretched midship section: starting with a quadrant, the result is again an ellipse. Above that a second "height of breadth" is marked, giving a short length of vertical side, which "causes it to carry sail, and renders the top-timbers beautiful and more gibous" (p. 59). The elliptical section thereafter seems to disappear from the text, though the vertical side remains (and is indeed as seen in ships such as the *Victory*).

Moulding is described (pp. 77-84) as the process of using a pattern to mark and measure. Sutherland describes the mould-loft floor, spacious, well-lit, very even, black-sized for the chalk to show; the dry seasoned split-deal that is planed for the moulds themselves; and the *sweeps*, instruments to mark out the curves. This latter might include laths, especially for the longitudinal curves, but it certainly sounds as though they originated with circular arcs. The process of marking up the floor is called "crossing the moulds" (pp. 82-3), and care has to be taken to mark the surmark between the main side mould and the hollowing curve. This indeed is marked on the plate (fp. 82) (**Fig. 6**) accompanying the description, but we have another puzzle here: while the midship section reverts to a simple quadrant up to the lower height of breadth, most or all of the sections fore and aft use a sharper arc: they apparently do not match the mould of the midship section as would be expected, yet this is not referred to in the text.[13] The hollowing mould to the keel however does seem to use a constant arc, equal to the midship mould, and with a flat attached. Similar patterns appear in the arcs used above the breadth, termed working the hollow out (aft) and in (forward on). He proceeds to take bevels at the surmarks from the mould loft.
Interestingly, "it would also be very proper to try the line of ribbons, whether they are truly circular…" (p. 83), that is, he prefers to fair out his diagonal rather than make the water-lines fair. This would of course destroy the drawn ellipses: perhaps he is checking that those lines have been correctly generated in the mould loft from what are only three intermediate points fore and aft in the drawings. The objective of using the diagonal is explicit: to have a fair surface for the line of both plank and water flow. In his work of 1717 the benefit has become swift-sailing (see below).

In short, Sutherland is certainly describing aspects of whole-moulding as in use for ships, but it is not his primary method. The origin of his longitudinal rising and narrowing is in drawing, in which he follows the treatisers, yet he has none of their geometric sophistication in the section. Indeed he has a phrase "… strike the circle which will describe a midship bend more agreeable, and *less perplexing*, than if you was to chalk out *one hundred* segments of circles. 'Tis said indeed that the catanera (*sic*: catenary?) line will describe a shape of the greatest gravity [for the section ostensibly, but in fact for longitudinal curves?]; but I shall leave such nice demonstrations for the present, and proceed to shew an intelligible method to suit and forward young beginners" (p. 79). That is his only reference to the more elaborate geometric and arithmetic methods described by the earlier treatisers, except for the use of longitudinal curves which are in fact (though not so named) ellipses. (It is virtually certain that the final intervals at stem and stern were smoothed out with laths, and did not end perpendicular to the axis as an ellipse does).

13. Lavery discusses similar developments in Deane's work (only one of several areas where his *Doctrine* does not really reveal as much about his methods as Pepys supposed): B. Lavery, *Deane's Doctrine of Naval Architecture, 1670,* London 1981, esp. pp. 25-6. While ostensibly following the earlier treatisers' methods using constant arcs in his text, in fact he varies the radii of those arcs along the hull. This causes a step-change in the effort of making moulds, and is certainly no longer *whole*-moulding.

One curious aspect of all this is that it is as though Sutherland was arguing for a new introduction in many of his phrases: was he advocating a system of moulding to suit the fine theories, or pointing out tartly that the older methods had been best all along? We are left unable to determine whether Sutherland's method is older than the treatisers; parallel to it; or a simplification of it, wishing to use the quadrant arc. What is striking is precisely that quadrant arc, just as used by Fournier. At the same time, the method described by Sutherland in most of the longitudinal plans is not whole-moulding, nor the same as Fournier's (see below), because Sutherland uses two distinct and independent narrowing lines (and two rising lines) in most of his figures, where Fournier appears to have identical narrowings alow and aloft.

Sutherland's other work, *Britain's glory; or shipbuilding unvail'd*, of 1717, has only a single page on moulding (pp. 1-2), and one plate (fp. 4) (**Fig. 7**), which shows a quadrant section. Curiously it has a dedication to King George and table of contents all written in French. It calls the rising line of the floor timbers the "lipping"; otherwise it is more concerned with forming ships as conoids. Therein may lie the clue to what Sutherland is doing?

> "The cono-cuneus has been highly recommended by some to be very proper in shaping ships bodies, and yet it's not made a general method; neither doth it stand good with the opinion of divers famous writers; nor can it be naturally applied in the same.
>
> But such digressions I allow rather as Pro & Con for table-talk, than a general benefit, and proceed with a small instance, that the solid of least resistance, which has been so highly recommended, may be with vast advantage applied in building any ship.
>
> And since projections in general, tho' grounded on ever so good a basis, are nullified by those that should forward them, that same genuine solid may continue unapplied, as long as it has been a discovering" (p. xxv).

This appears to mean that he actually wishes to introduce circular sections more widely. Whether he is really following the mathematicians' approach to least resistance is of no interest here; but he certainly realises that it is not achievable in a real ship.

> "And after such a fashion may any ship's body be turn'd out by one rotation, according to the demonstration of the solid of least resistance; only instead of making use of a straight axis, it must be a crooked one, as DBC [in the drawing] corresponding to the rising line.
>
> However, the transverse lines will be parallel one to another, and in a direct current the water will pass in such a body, where the whole weight of water will equally affect the ship, according to the distance from the extream part of the ship's body.
>
> And this part here mention'd, may be term'd the middle part of a ship, since rightly considering her, she consists of three principal ones, which middle part naturally form'd is a hanging conoid, the only part that helps or hinders the motion of her, it being also the part that holds the lading, and also bears the ship, and her utensils, and lading: so that it really ought to be principally considered, since by the well or

> ill disposition thereof, depends the advantage or disadvantage, which will undeniably accrew to the use of either ship, bark or boat" (pp. 1-2).

And

> "The opinion of a great proficient in liberal sciences is, that a ship ought to be considered three principal ways. First, says he, to try her body below the deepest draught of water, whether the shape be truly circular, according to the course of the water, (and not by horizontal parallels) which will enable you to give true judgement whether she shall sail swift, or otherwise" (p. xxvi).

Now the figure shows longitudinal narrowing and rising lines that are not simple arcs, nor from their acute ends, ellipses - there is no construction shown or described in the text. All run to the posts, not the ends of the keel, there is apparently a significant dead-flat amidships. The section shows the midship, undeniably a quadrant, and one section in each extremity fore and aft, also apparently including quadrants, but of much reduced radii. (A hollowing mould and upperworks are superposed to that quadrant). There is no text, but relying on the small figure, and the simple fact that a quadrant in this system must have the same offset between breadth and floor both as narrowing and rising, we may observe that most of the run of his ship has a quadrant of close to its radius amidships, but that it reduces rapidly, as the rising of the floor kicks in, and that the resulting radius is much as shown in the sections. For this to be the case, the two rising lines, and the two breadth lines, have to be reconciled so that the distances between them are equal at any section. They cannot all be formal geometric curves; and this may in turn be the origin of a need to fair the diagonal?

Furthermore, this could explain why the later and most complete figure (fp. 82) (**Fig. 6**) in his 1711 text has no line for narrowing of the floor drawn in: it is left to follow the quadrant defined by the two risings and the breadth line. This explanation does not appear to work for all the earlier figures in 1711.

Sutherland has another delightful phrase, after recounting that many major warships required girdling, or suffered other "dismal miscarriages." At first sight, it implicitly refers to the treatisers' method of multiple arcs:

> "And not to rake in the ashes of some preceeding builders that has verified the old proverb, in making the addice the reconciling mould [the third and middle arc in the treatisers' method], there be several at this day that will engage to build a ship with little assistance of such an instrument" (p. 1).

The meaning changes when one realises that addice is adze, not a subtle instrument required in geometrical methods. It perhaps suggests, again, that Sutherland did not approve of multiple arcs, compared with his quadrants. He is not, however, describing whole-moulding as known to Murray or Stalkartt. The features in common are the quadrant arc, and the fact that the simple rising and narrowing are controlled by two lines extending the whole length of the hull, at the breadth. However, there is no single mould, except for a central portion that is, or is close to, a dead-flat - at all other sections the quadrant mould has a radius controlled by the rising line of the floor. This method appears to be Sutherland's "more exact way, yet as easy"; and he appears to recognise a pre-existing version which he calls whole-moulding. But while he has no name for the treatisers' method but a disparaging reference in each book, to a hundred segments of circles, and to reconciling moulds, discussion of the different methods becomes difficult. Perhaps we might borrow a phrase from Sutherland to describe his more exact, easy way: that of the hanging conoid.

The manifestation of whole-moulding as in Murray could have been a degenerate form that spread outwards from the main dockyards, for smaller vessels that did not need the full elaboration of the treatises to produce a satisfactory hull shape. A feasible mechanism would have been the impressment of shipwrights from around the country to work on major Royal projects during the sixteenth century, when they would have observed at least components of the full methods. Lavery on the other hand suggests that the earliest way to create the complex shape of a hull was to use the same shape for all the frames, moving it inwards and upwards, "probably the original meaning of whole-moulding, for a single mould or template could be used to cut out the whole frame"; and adds that this had been transformed by 1586 at latest (that is, by the first evidence in Baker's work of the treatisers' methods). In the light of new evidence from the *Mary Rose* this must have been a short-lived phase, though the older method could have continued in parallel. Sutherland's evidence is that whole-moulding pre-dated the method he describes as aiming at solids of least resistance, but cannot therefore explain the origin of whole-moulding.

It may be worth noting what is in other English material prior to Sutherland, though there seems to be nothing earlier that touches directly on whole-moulding. Bond, and Miller (*The compleat modellist*, first edition 1660) are concerned entirely with masts, rigging and similar issues. Deane's MS *Doctrine* of about 1670 is mentioned above (fn. 13).

Bushnell (*The complete ship-wright*, 1664) is far more relevant. Possibly uniquely amongst English sources it uses a midship mould (**Fig. 8**) with two arcs that are not (necessarily) tangent. One runs up from the wronghead and the other down from the breadth, meeting on a diagonal of breadth and depth. The top-timber is a straight line tangent to the extended futtock arc. He "could have cited other ways, but I judge this way sufficient" (p. 9). His four main narrowing and rising lines (**Fig. 9**) are all arcs of circles, with a dead-flat amidships, and the measures are to be calculated arithmetically. Moulding then proceeds in a mould loft, or floor. Three moulds are made, with the radii matching the floor and futtock sweeps, and with their initial surmarks. The narrowing of the floor and hauling down of the futtock and top-timber are then marked on the moulds on the mould loft floor, after aligning the surmarks with their adjusted positions at successive frames. Nowhere is the knuckle between the arcs referred to. (It is plausible that Bushnell is the target of Sutherland's jibe about the adze as reconciling mould). The method is otherwise a variation on the treatisers' method, and certainly not whole-moulding. There are extensive tables to assist the repetitive calculations of risings and narrowings. This book was re-issued many times, and as late as 1748.

It is worth a brief discussion of the problem of tangency in two-arc methods. The 1546 galleasses of Baker's *Fragments* have a valid solution for a pair of tangent arcs, the upper of which is part of a quadrant, constrained to have its upper surmark and its centre both at the height of the breadth. There is little flexibility in the choice of the pair of radii for any given proportion of breadth, depth and floor (and ignoring the problem that the breadth and depth are outside the apparent initial grid for the design); and in practice there is little difference between the shape resulting and a quadrant. There is a choice for the first radius, for the wronghead, however. Baker's construction may perhaps reveal the truth of avoiding a messy process of trial and error: the precise breadth (or depth) achieved is the result of specifiying the depth (or breadth) and the two radii first. This is not a system that was likely to survive.

The more usual system of this kind in *Fragments* is to end the second arc with its surmark on the upper corner of a predetermined grid of breadth and depth, but without other constraint. This is actually flexible and direct, allowing any choice of floor, and two radii; but the true breadth and depth exceed the grid values. The breadth is formed by the third arc - it is not a two-arc system in that sense.

In Bushnell's method, he adds a requirement that both arcs must pass through a geometrically defined point in the bilge area. The result is that while his two arc centres are on defined lines over the end of the floor and along the height of breadth, there is only a single solution to the radius of each. In general, at least, these two cannot also be tangent to each other, whence the problem. It is not a question of trial and error, because each radius is an explicit function of breadth, depth, floor, and in Bushnell's case dead rising too. Whether or not the curves are tangent is thus related to a happy choice of those four parameters, and there is certainly no quick analytical solution available to find it; Bushnell defines breadth and depth before the arcs, removing any flexibility. Some degree of knuckle is almost certain, as indeed his figure (p. 8) suggests.

Wallis' *Cono-Cuneus: or the shipwright's circular wedge* of 1684, which Sutherland refers to, is part of the search for solids of least resistance, but of no practical interest. Fagge (see *Mariner's Mirror*, Vol. 40, 1954, p. 156) and Hardingham have not been seen by this writer.

Some details of the other English sources

Rieth introduces the Venetian connection to English shipbuilding, but only in terms of a development by Henry VIII. The weaknesses with that are numerous. There is no explicit evidence for when Venetians were first formally employed (1541 is noted as one occasion), or that they were doing more than work on galleys. Linked to the *Mary Rose*, begun in 1509, shipbuilding initiatives are in all probability the legacy of Henry VII, not Henry VIII (especially bearing in mind the time it would have taken to summon shipwrights from Venice on Henry VIII's accession, in 1509). But the *Mary Rose* is only the first ship for which we have much evidence, not the first large ship built in frame-first mode in England. Again, if Venetian methods had been so significant during the growth of Henry VIII's navy, it is strange that no record, either text or technical, can be found. (We must however note the still unresolved curiosity that Baker does label some of his draughts as being the Venetian method - for the midship frame at least - and some of the few explicitly identified ships, built around 1570, are amongst them). In parallel with that, we might observe that the massive, irregular timbering of the *Mary Rose* has absolutely nothing to do with Mediterranean styles - if Venetians had been involved with the geometry, they assuredly were not with the actual timbers - a strange split if the Venetians were there to teach the methods from scratch.

Rieth then notes a brief and cryptic remark by Mathew Baker to the effect that no Englishman knew the full details of the *linaramo del sesto* method,[14] using it to suggest that Baker is saying that at that point (perhaps 1580's in the case of that isolated note on a twice re-used page) Englishmen must have been building most vessels using the method, without *trébuchement*, that later came to be called whole-moulding. The general weakness of this notion is that Baker never refers to this in his own elaborate material of the 1570's, even though he includes material that he labels as Venetian; and specifically there is another interpretation of the remarks, discussed below. Neither is there any trace in other treatises of the next generation. Most telling, though, is that the *Mary Rose* includes not whole-moulding, nor *trébuchement*, but virtually the system as used by Baker three generations later. There simply is no evidence yet identified for whole-moulding as a term until 1711, though Fournier may be referring to something of the sort.

In fact Rieth's footnote (following Bellabarba) citing *Fragments* f16 gives only part of a very cryptic text, whose meaning and context is far from clear. The whole passage, which bears no relation to the pages on either side, nor possibly to the underlying drawing of a typical early Baker midship section (with breadth arc starting at the grid-point of breadth and depth, and whose earlier function in the manuscript had been calculation of area) is:

> "Although at this day there be many that do use plots, yet the best understand not the true making thereof, neither the truth of any circular line therein contained."

That is, many English builders were using drawings in their design, a feature of adjusted tangent arc systems, not of *trébuchement* methods; they were perhaps still building on three frames and ribbands since they do not understand the circular lines, which in context this writer believes is more likely to be a reference to the longitudinal curves of narrowing and rising that much of Baker's work illustrates.

> "The Venetians for their *partysanes* and *lastely* [*la stella*, the rising] as they term it (which we do call the rising and narrowing) they attain in this manner. They imagine (?) a part and work by a certain progression of so many lines as they have rising or narrowing timbers. If it fall just with the height of the tuck or narrowing of the transom then they have done well. If not they begin again."

That is, they take a measure for the maximum value of the rising and narrowing (at the quarter frames), and if those used aft of midship lead to fair curves to end on the tuck and transom, that is the desired result; though the finer points of the remark remain unclear. The Venetians would set a *meia-lua* at the quarter frame, and a breadth at the transom; beyond the quarter frame here, a ribband will probably be fitted by eye.

> "Forasmuch as I mean to treat of their *linaramo del sesto* (a thing without which it is impossible to make a perfect ship by any plot) which order at this present there is no Englishman perfectly understandeth [Baker included, but comparing Mediterranean methods without the *linaramo* with his own systems, which have hauling down as a consequence of a similar search for perfection?], I will leave what may

14. Rieth, 2000, pp. 19-20, note 43.

be objected against these words, and for my answer thereunto refer unto some other places in this book."

Now Rieth[15] equates *linaramo del sesto* with *trébuchement*, the measure of frame rotation. (In this he is actually following Bellabarba's earlier article, to be discussed again below). In Baker's example that follows the text cited, related to labelled modifications added to his base drawing, it is quite clear from the labelling of the figure that Baker meant by *ramo del sesto* a scale of "hauling down" applied at the bilge, not the rotation measured at the breadth. So there is some question that Baker may just have been referring vaguely to his own method of moulding in its fullest development. (On the other hand Baker could just have confused the labelling for the method, which after all is not the system that his manuscript is concerned with in practice). There is also some ambiguity as to which words are objected to, and what his answer was to be is not known.

Could this also just mean that English builders did not use the geometric system of *meia-lua* for the *partison*? This would correspond with the fact that Baker nowhere uses it either - a conspicuous feature of *Fragments*, in that sense. It does not occur in English treatises until the seventeenth century - it appears in the 1620-5 *Treatise on shipbuilding*,[16] but only for the hollowing of the upperworks. Baker was using string lines or arithmetic for the purpose (in so far as he discusses the issue in what is effectively a note-book, not a coherent treatise), but the commonest approach seems by default to be a circular arc; which is described more elaborately in subsequent treatises as late as Deane (1670) for example. How literally a pure circular arc in a drawing of a large scale, or in a ship built without full lofting, is unclear, but bows or splines are a close approximation and certainly serve the same function of ensuring a fair curve. (Use of bow or spline has not actually been determined so early as this, but a trammel is impracticable and a stretched cord not very accurate. What is certain is that Baker had a mechanical aid to create his immaculate curved lines. Even so, Baker's main concern was the problem of accuracy in scaling up measurements from a notionally precise drawing to full size).

Bellabarba mentions the Baker manuscript reference to *linaramo del sesto* in an earlier paper.[17] He makes the equation of the full *partison* method including *legno in ramo* (*trébuchement*) and *scorer del sesto (recalement)*, with the English methods described by Baker and Wells. He also states that the function of the *scorer del sesto* in the Mediterranean system was to perfect the alignment of the arcs of the timbers at the bilge, following the rotation of the side frame: this is simply not correct, as the centre of rotation is not the centre of either arc, and what it actually does is to lower the whole side, so that the gunwale has a lesser sheer than the curve of risings of the floor.[18] But he extends that statement, by explicitly equating it with the English "hauling down" of the futtock. Since the English system of Baker's texts (and all other contemporary treatises) fixes the height of the side frame in the process of design completely independently of

15. Rieth, 2000, p. 19.
16. Ed. W. Salisbury and R. C. Anderson, SNR Occ. Pub. No. 6, London 1958, p. 38.
17. S. Bellabarba, "The ancient method of designing hulls," in *Mariner's Mirror*, Vol. 79, 1993, pp. 274-292, especially p. 288. (This is the first part of the article of note 2 above).
18. It is true that the side could be rotated outwards by sliding the futtock timber over the floor, using their common centre and arc, but if that were the intention there would be no need for separate measures for the sliding and for the outwards movement at the top of the frame.

the hauling down, they are not equivalent at all, other than visually. In English whole-moulding, by contrast, there is no hauling down at all, so there is again no equivalence. (It is however true that a surmark exists for the hollowing curve to the keel, but this is not usually included in discussions of hauling down of the futtocks; in whole-moulding, the futtock mould is integral with the floor timber mould, and is not adjusted from station to station).

We might insert some further observations on the implications of the *Fragments* at this point. Firstly, Rieth suggests (p. 19) that the presence of these Italian terms is *without doubt* due to Baker's voyage to Chios in 1552. However, this is not necessarily so: Rieth also suggests that Venetians were heavily involved from the time of Henry VIII on in creating frame-first carvel building in England - long before 1552, as above; and Baker worked alongside one Levello at roughly the time he was compiling his notes. The Greek mould alone is perhaps most likely to have been collected in Chios; otherwise some doubt remains about where the Venetian information came from.

It is true that Baker collects material identified as Venetian, dated roughly 1550-70, but we might note that to refer to it we have to cite a string of page numbers - it is scattered and incomplete, with no evidence that Baker was using it himself. He does however label as Venetian a four-arc midship mould system which is clearly in use in named ships around 1570. Unfortunately it does not correspond with extant Italian records, based on offsets, though this writer believes that that is because those records are not design documents but a means of conveniently transmitting the results, perhaps for contract purposes. At the same time we ought not to confuse the shape of the master frame with the method of varying it along the hull.

According to G. Juan in 1771,[19] as Rieth tells us, whole-moulding was an alternative to building on a master frame and ribbands, for large vessels. It is not immediately clear whether it was used in Spain, as Juan associates it directly with English whole-moulding. This had been used for several centuries until recently displaced by methods based on plans. Rieth remarks that in 1771 Juan could not have been inspired by Stalkartt (1781), but in fact he could have found the method in Murray's work, published six years earlier in England (or even in Sutherland's). In fact the method itself is beginning to look so widespread that it seems unnecessary to demonstrate a link between the authors.

Fournier's method

Returning to Fournier, at the end of his work he has a table of dimensions for the lengths of the main beams of a ship,[20] from the maximum section to the sternframe, and for the width of the floors. Ignoring for the moment the problem that he has narrowings for the floor at the same station as the transom of the sternframe, where there is no keel, let alone floor, it is conspicuous that the narrowing is identical at the floor and at the main beam. The curve is arrived at from a quasi-geometric device, calculated using sines.[21] In other words, the method is "whole-moulding," not *trébuchement*. That is, the French were also using whole-moulding at some point before 1643. It is not explicit, but the

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19. G. Juan, *Examen maritime théorique et pratique*…, French translation, Nantes 1783.
20. 1643, Book XVIII, Chapter XVII, pp. 782-3.

table may be linked directly to the *ancienne méthode*, as the maximum breadth of the ship is identical, at 27-1/3 *pieds* in both the *ancienne méthode* and the table, while his example of the "modern" style[22] is for 44 *pieds* breadth. (Against that it might be argued that there is also a standard 300 ton ship of 27-1/3 *pieds* and the same 10-1/2 depth in a table in Book I, Chapter VII, to which the text for the modern method refers; but only if we then accept that Fournier must be describing whole-moulding in his modern method). Does that, interestingly, suggest that the ancient method was still in use, to offer the example of narrowings? Such might be supposed from the opening remark of Chapter IX, on the modern method, which also links the change to English and Dutch builders. (Ships built on the older method were too round and rolled too much, Fournier says; though actually there is no inherent link between midship frame shape and method). Other examples in that part of the book relate to the port of Havre, and a northern French context is thus probable; though more generally Fournier compares terminology of Marseilles and Italy too.

Intuitively, while Fournier's midship section (**Fig. 1**) employs a simple quadrant, there would indeed be little point in rotating the side timber mould in the "Mediterranean" system of *trébuchement*, or *espalhamento*. Not least, since *trébuchement* is outwards (creating the flare of a seaworthy hull, while allowing the fine entry and run required at a lower level), there would be a tendency for the bilge to fall below the point of the turn of the bilge, unless the rising of the floor is pronounced. *Trébuchement*, we might observe, is commonly applied in hulls where there is a sharp transition from a flattish floor to a steeply rising side, only faired out locally, which is the key weakness of that method.

But consider Baker's final method, that of the subsequent treatisers. Two narrowings and two risings are independent, and carried close to the ends of the ship (though actual moulding with the midships templates was only carried that far as an ideal, as it was not fully achievable, and certainly beyond the ends of the keel, with its discontinuity of boundary conditions). The basis of this method almost calls for a moulding floor (not necessarily a permanent structure, for which there is no contemporary evidence), from which templates could be made for each piece of each frame. Or rather, where the set of standard templates for the major arcs could be adjusted against each other. The surmarks could be marked at overlaps - a fixed point at one end of a template, and at the other end a new mark for each frame position along the hull.

This leads to the expression "hauling down" of the futtock, though this writer will insist that hauling down - a term widely seen in English texts, is not the title of a method, but the consequence of adjusting tangent arcs with predetermined narrowings and risings - a form of moulding the vessel whole (to avoid the term whole-moulding here). Hauling down is one practical component of the method, not the method itself. We might further note that in the shipyard it is very visible to all the ship-carpenters, and difficult for the

21. We might also note that the calculation is carried to for example 2-198/300 feet, as well as its use of sines: while it is English shipbuilding that is noted for its use of sometimes advanced arithmetic methods up to this period, shipbuilding design is clearly not an activity for the numerically illiterate. The same is true of fifteenth century Italian methods, which need to calculate proportional dimensions, and indeed manuscripts then compiled for merchants and seamen concern themselves with the calculation of the cube root.

22. 1643, Book I, Chapter IX, p. 24.

masters to hide from those doing the manual work, in the contexts of both supposed secrecy and possible dissemination.

If each timber has its own pair of surmarks - points of overlap and alignment of the arcs, assembly is assisted; whether on the ground, or within the growing ship. Together with a separate temporary control of breadth of the frame, plumb-bob, horning of the timbers, etc, the final shape is assured to within practicable limits.

On balance, since the perimeter of a vessel is less at the ends than at the midship, there will tend to be a hauling down, but it does not follow that a particular shape of hull might not require a local "putting up" of the futtock in a corresponding position; and within the vessel as a whole both can be expected to arise.

But in this system we have something different from the Mediterranean method. The progressive adjustment of frames along the hull is no longer by a geometric device such as the *meia-lua* (which is more or less guaranteed to produce a fair surface, but only over the central section of the hull; and strictly it may not be fair for real planking runs or water flows). Each frame has its own variations from the midship section, which, though the results using Baker's methods or similar will remain fair over a greater length, are unpredictable. They can be calculated as chords between surmarks, direct from the narrowings and risings defined, as was done in Baker's time (though only really practicable after the development of logarithms).[23] They can also be marked directly on the template on the moulding floor - which Sutherland effectively does in his text of 1711, taking great care to mark the curve of surmarks on his body plan.

This is also what eighteenth century whole-moulding does: it has no inherent system of geometry, but records a prior operation, whether a plan (originally, perhaps), or a previous vessel. It remains valid while the curves of narrowings and risings are fair curves, either calculated, lofted, or copied with or without incremental alterations.

But this has said nothing of which version was the older, or where either came from. One of the few things we do now know, from preliminary work on the *Mary Rose*, is that this ship was not whole-moulded in the English dockyards in 1509 (very early in the frame-first system in England), but for much of her length she has repeating tangent arcs adjusted in the treatisers' method, or something like it, with some hauling down of the futtock apparent, and upper and lower narrowings and risings differentiated.

Older traces of framed construction in the north

A further possibility for the origins of northern moulding is that there was a completely independent system in the Channel-Biscay area, even perhaps pre-Roman, from the Veneti, whose heavy ships are described by Julius Caesar. This, supposing it might have been the origin of whole-moulding, might have omitted geometry in the narrowings and risings and frame shape, and have used no rotation of the side. That in turn could have

23. Recalling that John Wells, Baker's protégé at Deptford (though not himself a shipbuilder) was actually involved in helping to create the first set of log tables in 1617, after Napier's work of 1614. Pages to prove that exist in the *Fragments of Ancient English Shipwrightry*, with the comments that logarithmic calculation was much easier than traditional methods for some of Baker's calculations. (Bushnell's printed tables represent an alternative approach).

produced elaborations when larger frame-built ships were required - more arcs, if not the geometric risings and narrowings. That could have led to the stage discussed below, when the tumblehome was added.

Frame-first construction, which is considered to be inextricably linked to the ability to mould the shape of at least critical parts of a ship in advance, is known archaeologically from the third century, in a "Gallo-Roman" wreck found off Guernsey.[24] The report clearly states that heavy floor timbers were erected at previously marked positions on keel planks, and postulates a sequence of shaping those timbers (which this writer finds implausible, without questioning that the construction was frame-first: the broader question is why the report does not even consider the question of how the floor timber shapes were determined, but resorts to a three-stage process to arrive at the lands for planking of very variable width). The survival of timbers is not sufficient to judge the form of any moulding used.

A further frame-first vessel from the area of interest is the Port Berteau II wreck,[25] from around 600 AD. Unfortunately the critical areas for any moulding that may have been present at the bilge are lost in this case, as the hull survived upside-down (what survives is round-bilge carvel without edge-joining), but the sides show no rotation and frame-first construction implies the selection and shaping of some floor timbers at least to a pre-determined shape.

These examples are however only representative of a much larger and steadily expanding group of "Romano-Celtic" vessels from north-west Europe, including Blackfriars II, Barlands Farm and vessels on the Rhine. These all have the characteristic of frame-first construction, to a greater or lesser degree, though geometry is not their most conspicuous characteristic - many are flat-floored types too. There has been the same lack of continuity through to the written sources, however: the methods employed seemed to disappear at roughly the end of the Roman period (though they probably pre-dated the Romans, on Caesar's evidence, so the disappearance may be coincidental). Clearly Port Berteau II starts to fill the gap in those terms, but it does not solve the problem. We also note in passing that these frame-first vessels are older than almost all Mediterranean examples found to date. Numerous small boat types exist in England which could have preserved components of frame-first techniques from antiquity.

Tonnage measurement aspects of enlarged hulls

One aspect of this whole debate, which is also linked closely to early methods of tonnage measurement by formula, is worth considering in some detail. It is the step from ships of a single weather deck, to ships with two or more decks, whether they were conceived as merchantmen or warships, or just ships. Single deck for this purpose includes open boats and ignores any orlop deep in the hold in larger vessels: one key characteristic is that many such vessels will have sides that are still flared outwards at their gunwales, simply to be ship-shape and survive in rough waters.

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24. M. Rule & J. Monaghan, *A Gallo-Roman trading vessel from Guernsey (3rd C)*, Guernsey Museum Monograph 5, 1993.
25. É. Rieth et al, *L'épave de Port Berteau II (Charente-Maritime)*, Documents d'archéologie française 86, Paris 2001.

For such a vessel, the method of *trébuchement* is quite appropriate, as it characteristically does create or increase that flare by rotation of the side outwards, fore and aft. It is not essential however, as the side may be angled at midships, as it is in most small Mediterranean boats, and as occurs for example in the Serçe Liman wreck from the eleventh century, with little or no outwards rotation, but a clear suggestion of the graduated risings and narrowings (as fn. 3 above). In the smallest vessels, with flat bottoms, the constant side angle is even determined by the characteristic growth pattern of the tree species providing the knee at the bilge.[26] The early Punic ship is an exception - see below.

In that sense, the upright side of the eighteenth century whole-moulding of English texts is something of a mystery: possibly a sign of a degenerate method, rather than something that has evolved. The method as such, presumably even in those specific early examples of warships' boats (which may atypically have been intended for rowing, for stowage inboard, etc), was however perfectly capable of producing successful boats, and W. A. Baker (a naval architect as well as an early researcher in this field) reports so using it in small boats.[27]

There is good circumstantial evidence, from terminology and rationale, that early methods of calculating tonnage by rule[28] were based on hulls of this single-deck kind. The methods specify *bocha*, maximum breadth (probably excluding the bulwarks in a decked hull), and when second decks occur they are initially treated as additions. Depths related to the *bocha* too, but this creates problems when ships acquire more decks - the block coefficients of the original hull (or of its usable spaces) and of the higher deck are not the same, but the equations employed do not distinguish. By the late sixteenth century the methods tended to be based on two or three deck ships, but were consequently not so satisfactory for smaller vessels.

For reasons of stability, if nothing else (timber supply, defensive shape come to mind),[29] additional decks above the waterline were generally narrower than the main deck: ships were given tumblehome. To some extent that was true in earlier ships too[30] - probably reflecting the basic truth that stability relates to breadth at the waterline, or more immediately practical issues such as robustness of ships heeling at berths and against each other. Early Portuguese moulds clearly show tumblehome, but that results from using a single arc for the whole side frame. When ships acquired additional decks for artillery and accommodation tumblehome became pronounced, and required a short radius arc at or close above the maximum breadth, itself just above the waterline. Some

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26. H. Poilroux, "La nacelle des étangs du Languedoc," in *Le petit perroquet*, No. 16, nd - 1975?, pp. 15-26. The side angle of the nacelle is said to be constant at about 120 degrees (p. 16), "determined by those which occur naturally between the trunk and branches of pines used for the ribs." Perhaps not *very* constant, as he proceeds to relate that the developed form, the *bette*, has angles of about 110-115 degrees.
27. eg W. A. Baker, *The* Mayflower *and other colonial vessels*, London 1983, p. 17.
28. Distinct from methods of hoop-gauging, reported from documents of about 1500 onwards by Leonor Freire Costa in *Naus e galeões na Ribeira de Lisboa*…., Patrimonia, Cascais 1997, pp. 59ff.
29. R. A. Barker, "Why tumblehome?," in *Mariner's Mirror*, Vol. 84, 1998, pp. 95-7.
30. Perhaps we could cite the remarkable bronze ex-voto from Beth-Maré, dated to around 121AD, Plate XI in H. Seyrig, "Antiquités Syriennes," in *Syria*, Vol. XXVIII, Paris 1951, pp. 101-113+plates.

of the early sections in Baker's *Fragments* show features that suggest that what happened was literally an extension of the old single deck form. At a point corresponding to the top of the old flared side, another arc was added, tangential to it, and correspondingly that included the real maximum breadth of the new hull. (We might observe that that is effectively what Fournier's method does). Construction of the old hull was defined around the maximum beam, the *bocha*, at the top of the old side; and the extended hull also, for a while, retained a "breadth" measured at that point. Baker's grid lines in a few early cases make that possibility very clear. In Baker's case that system did not last long: the majority of designs in *Fragments* have a grid that corresponds to the true maximum breadth. Correspondingly, in the interim, there would be a problem of recording tonnage dimensions. The shipwright, if asked, might furnish his design breadth, probably a nice round number of feet, at the old *bocha*. If the ship was physically measured, a larger, and fractional number would result. The same ship might have more than one calculated tonnage; the old divisor would not suit the new system. (In the case of the *Mary Rose*, it seems that the true moulded breadth was not a round number of English feet, but neither did this problem arise, as perversely it appears to use the "later" system). The Red Bay ship, much later, is said to have a true moulded breadth as a round number of *codos*.

But what of the implications for the Mediterranean system? There is nothing to prevent the midship section associated with *trébuchement* incorporating an additional arc, and tumblehome.[31] If however, we add the tumblehome to the side and apply *trébuchement*, we may be creating a very unsatisfactory shape in the upperworks, as the rotation at the bilge cancels out the very tumblehome introduced at the midship, and in proportion to the height above the bilge. With no other corrections, the system requires an excessive tumblehome at the midship, to retain sufficient tumblehome nearer the ends. We might notice Sutherland's additional whole-moulding control for a ship: the "half breadth of top-timber staff."

At an intuitive level, then (and the evidence is and will be so sparse and contradictory that little more is achievable in this whole debate) the *trébuchement* method originated with small vessels, but was not as satisfactory in larger vessels. (Notwithstanding that, it was evident more widely in France at the end of the seventeenth century).[32] It presumably developed as an enhancement of the still earlier system in which there was narrowing and rising of the bilge, but no rotation of the side. (It is still extant, if not necessarily with geometric risings and narrowings). Possibly the English whole-moulding reflects something similar. It is only known for small craft, it has no rotation of the side. Perhaps the quadrant bilge reflects a different timber supply, and different conditions of sea, use and capacity.

31. In that sense, the midship section alone cannot necessarily distinguish between the two processes for adjusting it along the ship's length. In practice, the evidence of for example the Portuguese manuscript drawings where *espalhamento* was to be used, is that the side was most often a single arc, carried to the level of the floor in design, and faired in with a very short radius arc (Oliveira, conspicuously, did not even draw in the fairing arc, leaving an apparent hard chine). In Italian systems the side is now commonly said to be close to a parabola - perhaps originally a compound arc, as elsewhere - but the same feature occurs - a relatively sharp transition in the midship frame at the bilge. What evidence we have suggests that the northern methods used a much more rounded form, with more distinct arcs. The *Mary Rose* is one example, the four galleasses of 1546, built by James Baker for Henry VIII and recorded by Mathew, are another.

32. Rieth, 2000, *op.cit*., p. 18.

Discussion of the origins of whole-moulding

The complete absence of any clear early documentary evidence for whole-moulding remains a mystery. We have seen that it only appears by name in the eighteenth century, but that Fournier may imply its use in England and Holland as well as France, long before 1643, and possibly for almost two centuries before that, if it were linked to the advent of frame-first construction. Sutherland appears to be describing a form of whole-moulding for ships in 1711, and without a real context. The method was also known to a Spanish writer, and while his source is not known, one possible inference is that the method was practised in Spain in the late eighteenth century.

Archaeological evidence may place a comparable system in the Mediterranean no later than the eleventh century, in the Serçe Liman wreck of around 1025 (which has no *trébuchement*); similarities can be found even in some modern small craft. There were too systems of heavy hull construction indigenous to northern Europe - western France, Channel, southern North Sea - from a period before Roman occupation, even if our knowledge of them is still slender. Yet Bellabarba[33] actually provides a near-perfect archaeological example in the Marsala Punic ship, excavated by Honor Frost and published in Italy as long ago as 1981. The reconstruction given by Bellabarba even has a frame shape that is so close to a quadrant as to leave little real doubt that that is what was intended in the vessel itself. It is adjusted along the hull by rising and narrowing,[34] and has no rotation. Even if the vessel is shell-built, that implies some close control of form with moulds, and at least three of them. (More than that would beg a question about shell-building).[35] Bellabarba does not use the term, or comment on the similarity, but that is whole-moulding in all but name. It is also much closer to the system of moulding the entasis in classical columns of that very period, for which we have the very direct evidence of Didyma, around 334BC.[36] Again, archaeology is slowly filling the gaps, with a range of evidence emerging for the sixth and seventh centuries to suggest frame-first building in the Mediterranean.

A further early example is the Venetian *Roccafortis* of 1268, where dimensions are recorded in documents, but no drawing. Jal knew of the evidence, but Carr Laughton reinterpreted it as essentially Fournier's old method.[37]

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33. *Op.cit.*, 1996, Figs.4-6

34. Bellabarba says (*op.cit.*, 1996, p. 264) that he has not identified the pattern of risings and narrowings. Based (perilously, perhaps) on an enlargement of the published drawing, Fig. 5, it seems probable that both narrowing and rising follow a *meia-lua* or equivalent at least from the central station 16 to station 10. Stations 12 to 10 have a constant ratio of narrowing and rising, with apparent rogue data for the risings at stations 14 and 13. The rising certainly cannot go much further on that pattern, but the narrowing is a remarkably good fit as far as station 4. Of eleven intermediate values, one is not given, but there are just two rogues at stations 13 and 6. It is not possible to distinguish between most of the known geometric systems at this level, as they all approximate to square laws.

35. Bellabarba suggests (1996, p. 264) that most of the floor timbers may have been cut with moulds ("prefabricated") in this and in the atypical Nemi ship, and that does indeed seem very likely. In the Marsala Punic ship, with its rising floor and hollowing curve to the keel, that sits very uneasily with shell-building; suggesting some very "active" moulds, in fact.

36. L. Haselberger, "The construction plans for the Temple of Apollo at Didyma" in *Scientific American*, Dec.1985, pp. 114-122.

37. L. G. Carr Laughton, "The *Roccafortis* of Venice, 1268," in *Mariner's Mirror*, Vol. 42, 1956, pp. 267-278. (Subsequent work by Dotson, and Pryor, adds nothing for our purposes).

Bellabarba collects evidence of mostly Italian documents that clearly use the terminology of the *partison* methods no later than 1275. *Legno in ramo* appears in the *Fabrica di galere*, which he describes as a copy of a document of 1410, but is now believed to be copied from a manuscript by Michael of Rhodes, and begun as a collection in 1434.[38] That is, the full Mediterranean *partison* method, with *trébuchement*, was developed long before there is any question that the method came north for early frame-first ships in the second half of the fifteenth century.

There is other Mediterranean evidence, in contemporary small boats. Damianidis describes[39] a wide variety of systems termed *monochnaro* (literally, single mould),[40] one of which is hardly different from Stalkartt - differing essentially in the flare given to the side. There is every reason to suppose that the method is old in its Greek context; Greek builders have also retained forms of *partison* that differ from other common systems such as the *meia-lua*.

What we do not have for any of these isolated records is the slightest evidence for continuity or transmission. As noted above, a further possibility suggested long ago by this writer is that whole-moulding actually represents a degraded version (sufficient for small ships and boats), of a sophisticated geometrical system that was imported, adapted, or developed locally in the north, at the end of the fifteenth century with the advent of large frame-built ships, and spread on the England-France-Biscay axis in ways unknown. In the light of the Punic ship, and indeed some of the more recent Eastern Mediterranean sources, that may be less tenable, but continuity cannot be demonstrated.

Granted the relatively short interval between the introduction of frame-first methods in England and the fully developed form of adjusted tangent arcs as seen in the *Mary Rose*, the absence of records for whole-moulding, if it had a separate existence amongst technically-literate shipbuilders at that time, is not too surprising. The indigenous vessels were either clinker-built, or small boats, so long established that they needed no record, or even elaborate moulding at all. Larger frame-built vessels when they appeared in England could have been variously purchased abroad, built by foreigners, simply copied piecemeal (using methods hinted at by William Bourne), or a genuine new development. The very style of building was changing in other ways too, at the same time: the first square-stern ships are known from the 1470's, and spread rapidly, ostensibly from Spanish Atlantic origins. That is perhaps significant in the sense that many sources seem to relate moulding methods to the use of a template for the sternframe that might

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38. Sotheby's Sale Catalogue, Western MSS, London, 5 December 2000, pp. 60-72, which is a text by Andreas Mayor, originally for a sale in 1966.
39. K. Damianidis, *TO TRECHANTERI STEN HELLENIKE NAUPEGIKE TECHNE*, Athens 1986, with extensive illustrations; or a summary version in English in "The diachronic 'Road of dialogue' of Mediterranean shipbuilding," in *Cultural and commercial exchanges between the Orient and the Greek world*, Athens 1991, pp. 97-108. The first item is the source of Rieth's figures 10, 11, inadvertently omitted from his note 23.
40. It is perhaps worth noting that Damianidis states on various occasions (eg *op.cit.*, 1991, p. 102 or *TIP*, XIII, 1998, p. 219) that the term covers all forms of working with one mould, including those with and without *trébuchement*. Rieth, page 16 appears to imply that the term covers only the simplest form, equivalent to English whole-moulding, but that is actually a minority example of the term in Damianidis' examples. Otherwise it does not affect Rieth's argument.

also be used for the hollowing curve to the keel. The *Mary Rose* appears to have this feature by 1509.

The issue of timber supply in the Basque area may be relevant, given the two or three generations it takes to grow trained frame timbers, but is not likely to be conclusive here, partly because shell-built vessels of comparable size also require heavy frame timbers of much the same shapes, and partly because we have no knowledge of methods in Biscay at the critical period, except that Bayonne was still building its biggest ships by shell techniques around 1419.[41]

Conclusion

Can we find any pattern amongst the many disparate records, short of actual origins or continuity? It is clear that forms of whole-moulding existed in the Mediterranean in antiquity, but we cannot say categorically that they used formal geometry (rather than say a catenary, or slowly evolved empirical measures) for the rising and narrowing of the floor - only that there was suitable geometry in place in classical architecture; and that the first examples occur without any apparent rotation of the side frame. The earliest (the Punic ship) happens to use a quadrant, but the other (Serçe Liman) does not - there is no pattern in that; either could be argued as the more sophisticated, depending on whether geometry or potential performance at sea is the criterion.

It seems that between say 1100 and 1400, the use of rotation and then sliding of the side began to appear. That corresponds to the period of powerful city states, and Byzantine rather than high Renaissance. This is the origin of the developed form of "Mediterranean" moulding, still widely in use, but increasingly replaced for large vessels after say 1800 by the use of plans. How the Mediterranean handled the transition to multi-deck vessels is rather uncertain, but tonnage measurement methods may be an indicator of how and when it became a significant issue. We still have the example of Greek small boats using precisely "whole-moulding," with geometrical methods, but without the quadrant side (and Bellabarba reports other examples). What we do observe is that the records of "offsets" to define frame shape in Venetian documents are an unsatisfactory explanation of method, and probably mask an origin in systems of arcs.[42] There is another enigma for the Mediterranean: what happened to the no-rotation system of moulding, applied to larger vessels, after the advent of rotation, which was in place before the north adopted carvels? Only if it remained generally in use for large vessels could it have later travelled north to yield whole-moulding.

41. G. E. Manwaring, "A ship of 1419," in *Mariner's Mirror*, Vol. 8, 1922, p. 376 (and L. G. Carr Laughton, "The great ship of 1419," in Vol. 9, 1923, pp. 83-7). Brad Loewen has written on the occurrence of terms (*hameron* = hammerhead, as in Baker's *Fragments*) that suggest some moulding of this large clinker hull, in "Bayonne 1419. Lapstraking and moulded frames in the same hull?," in *Mariner's Mirror*, Vol. 83, pp. 328-331. The link to hameron = *amura*, tack, had been noted by R. C. Anderson in "The *Mary Gonson*," in *Mariner's Mirror*, Vol. 46, 1960, pp. 199-204. The *Mary Gonson*, despite its early date (variously ca 1512-20) is little help here, as the text records only dimensions, not shape, which is subject to some interpretation. What it does reveal is tumblehome, however, with a significantly greater breadth between its two decks than at the actual beams - a feature that also occurs in Portuguese methods, for example.

42. Touched on in R. A. Barker, "English shipbuilding….," in É. Rieth, ed, *Concevoir et Construire les Navires*, Technologies, Idéologies, Pratiques, Vol. XIII, 1998, pp. 109-126, esp. p. 119; and in a forthcoming paper.

What of the north? We apparently have structural methods using frame-first construction, earlier than in the Mediterranean (Blackfriars II, Guernsey, Port Berteau II and many others), but so far there is nothing to indicate how the frames were shaped and the hull form controlled. None shows any clear sign of quadrant or of geometry. However, if such methods survived until the fifteenth century, while the dominant methods were shell-based, they did so in small vessels, with no need of further development. There is certainly no actual evidence of transmission from the Mediterranean, least of all for the geometric aspects; but then Gothic masonry construction arose in the north apparently unaided (and indeed was so named by Italians who did not like this independent development). Nonetheless, Phoenicians and others travelled the western sea-lanes, however rarely, and have left their cultural marks in other respects - but before the development of the frame-rotation method.

Very soon after the re-introduction of frame-first building in the north in the fifteenth century, which we have generally supposed was entirely based on importing the system from Portugal, or using designers directly from Mediterranean areas, builders were called on to create large vessels in this system, and furthermore to support heavy artillery. The puzzle is that it now seems that a new departure took place, abandoning rotation of the side frame (if indeed it was ever used by northern builders), though one element in a new guise (sliding of the moulds, the "hauling down") reappears in the treatises (or survives, since it is already implicit in the *Mary Rose*). The floor seems to have continued to be built as it was in Mediterranean methods, with a controlled narrowing and rising (though large shell vessels would have used some system to control shape in that critical area too); except that timbering in the *Mary Rose* has nothing of the Mediterranean about it. Multiple tangent arcs were used, capable of handling any desired hull shape; and all this was in place, categorically, before 1509 (*Mary Rose*), and probably over a wider area of the Atlantic coasts of northern Europe. (Red Bay indicates well established systems before 1565; and *Mary Rose* the re-use of side moulds for the sternframe soon after its introduction). The method uses the same idea of *partison* as both Mediterranean systems, but there is no direct link, or commonality of methods to achieve it. Neither is there any evidence for rotation of the side in any English document. Whatever the origin of the new method in England, we do know that Henry VIII chose to employ Venetians (possibly only for galleys), and that Baker took some interest in Mediterranean methods, and it is not least from his records that suspicions arise about the secondary nature of the Venetian offsets. Alternatively, perhaps the use of multiple arcs arose in Venice or another city state precisely to handle multiple decks, which led to a recognition that the side could be divided at the breadth, even if the old rotation methods were retained below the breadth?

However, in parallel with these sophisticated methods of tangent arcs,[43] we have in Fournier (1643), and in other texts of the eighteenth century (Juan and Stalkartt), statements that something actually termed whole-moulding (first by Sutherland in 1711, as a pre-existing method) was a widely used method until "recently," and had been for several centuries. Yet there is no actual evidence in the English case (which has the most early relevant records) for anything of the sort before 1711, and by 1765 its use is actually confined to small boats employing quadrants (and again the method survives, if not with pure quadrants). It is this enigma that we seem to be no nearer solving.

43. Noting however that "whole-moulding" is also a system of tangent arcs, but perhaps using only one arc, reversed for the hollowing curve.

To explain the northern texts, we almost have to find an early survival of whole-moulding that owes no traceable origin to the Mediterranean (or, indeed, a hanging conoid); and to explain some of the southern wrecks, a method of forming the frames by frame-first methods in the shell-building era. If northern whole-moulding was indeed adopted from the Mediterranean, we still need to explain how and why, when frame-first construction came north around 1460-1500, the version of moulding that came north was of the older Mediterranean form, when the Mediterranean itself had already developed the *trébuchement* refinement long before. Though Rieth notes that the full method with *trébuchement* could still be written of as a mystery at the end of the seventeenth century, Bellabarba states (1996, p. 284) that it existed in the Mediterranean by the early fifteenth century, though it was certainly not widespread in extant texts from before 1489. Yet it was presumably developed for significant ships, not boats, and it was precisely for those ships that it supposedly came north.

As a parting shot, let us introduce two stray pieces of evidence. Firstly, that John Dee (magus, mathematician, courtier), had in his library about 1583 a *Naupegia Itali, cujusdam, cum figuris, papyro, 4^{o}*, that is, a manuscript on Italian shipbuilding, not otherwise identified. We may wonder whether that was in fact the manuscript now known in the British Library, currently identified as by Giorgio Trombetta. That too is paper, 4^{o}, and the first 60 leaves of the present manuscript are mostly in Italian from one source, and the whole collection of 293 leaves was bound and listed around 1600, according to Anderson.[44] It does seem quite likely.

Secondly, from around 1270, Roger Bacon's *Communia Mathematica*[45] has sections on practical and theoretical geometry, which includes, for practical geometry, an intriguing phrase: "Et pars quarta est in fabricacione canalium et conductuum aquarum, et pontium ingeniosorum, et navium, et instrumentorum natandi, et permanendi sub aquis." It has uses in the building of ships. What uses, we may wonder. At that period English shipbuilding was clinker-shell construction, usually deemed (erroneously in this writer's view) to have nothing to do with geometry. Is this, then, for creating moulds, for setting out keel and posts and achieving symmetry, for tonnage measures? Euclid, a wide range of geometric methods, even the extraction of the cube root, were all available at that time, and much of it in daily use in construction. Why do we know so little about its early application to ships?

While addressing mathematical sources, we might also correct a false impression given in earlier papers about the origin of the term *naval architecture*. While Dee and Harriot both used the root *naupeg-*, and Dee included architecture more generally in his scheme of mathematics in 1570, they do not seem to have gone further. However, it emerges that Thomas Digges in his military manual *Stratioticos* of 1579, promises a future "brief treatise of architecture nautical," which does not in fact seem to have been written. It is

44. J. O. Halliwell, ed, *The private diary of Dr John Dee and the catalogue of his library of manuscripts*, Camden Society 1842, p. 72. R. C. Anderson, "Italian naval architecture about 1445," in *Mariner's Mirror*, Vol. 11, 1925, pp. 135-163. The manuscript is British Library (not British Museum, as recently printed) Cotton MSS, Titus A XXVI, (not, note, 26 as given by Anderson), item 3, ff27b-60.

45. British Library Sloane MS 2156 and Bodleian Library MS Digby 76, edited by R. Steele, *Communia Mathematica Fratris Rogeri*, Opera hactenus inedita Rogeri Baconi, Fasc XVI, Oxford 1940, p. 43.

also the case that Robert Dudley, author of *Dell'Arcano del Mare*, habitually used the term naval architecture, certainly from not much later than his arrival in Italy about 1605; and he was of course a former pupil of Mathew Baker. It is thus no longer possible to regard Lavanha's *Livro primeiro da architectura naval* of about 1614 as even the first printed use of the term naval architecture. The term had been circulating for more than a generation before that amongst the English mathematical practitioners.

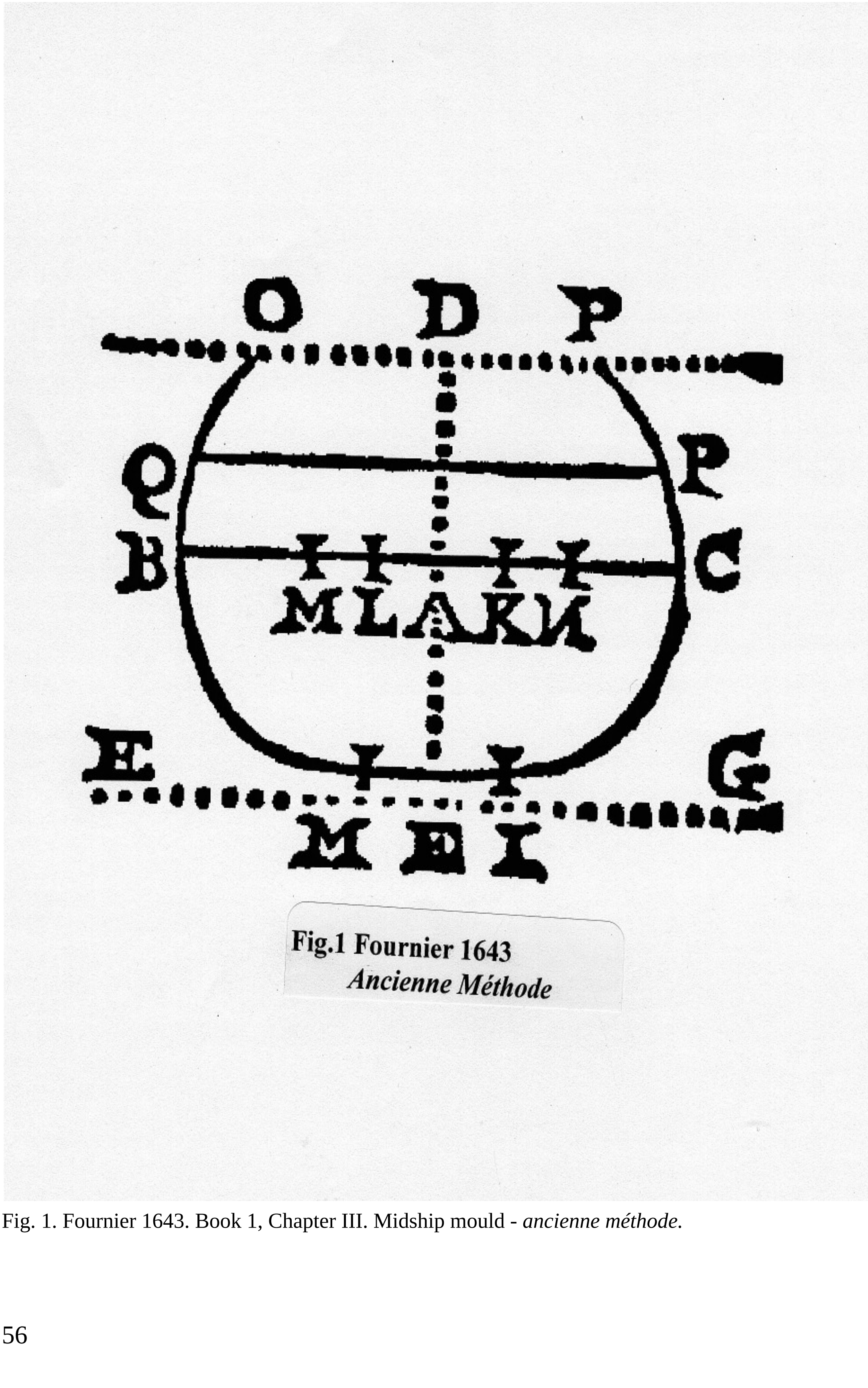

Fig. 1. Fournier 1643. Book 1, Chapter III. Midship mould - *ancienne méthode*.

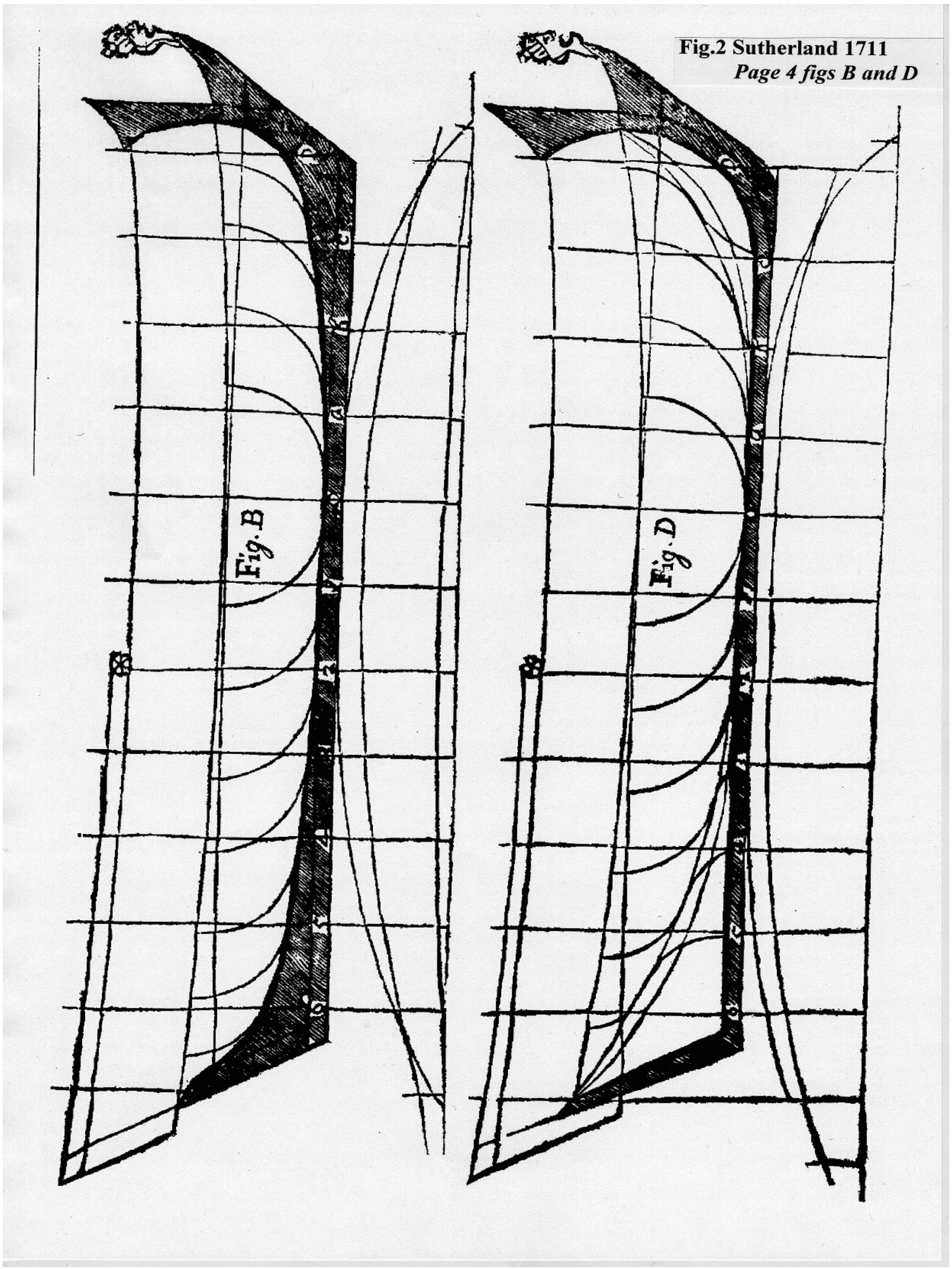

Fig. 2. Sutherland 1711. Facing page 4, figs B and D. Longitudinal.

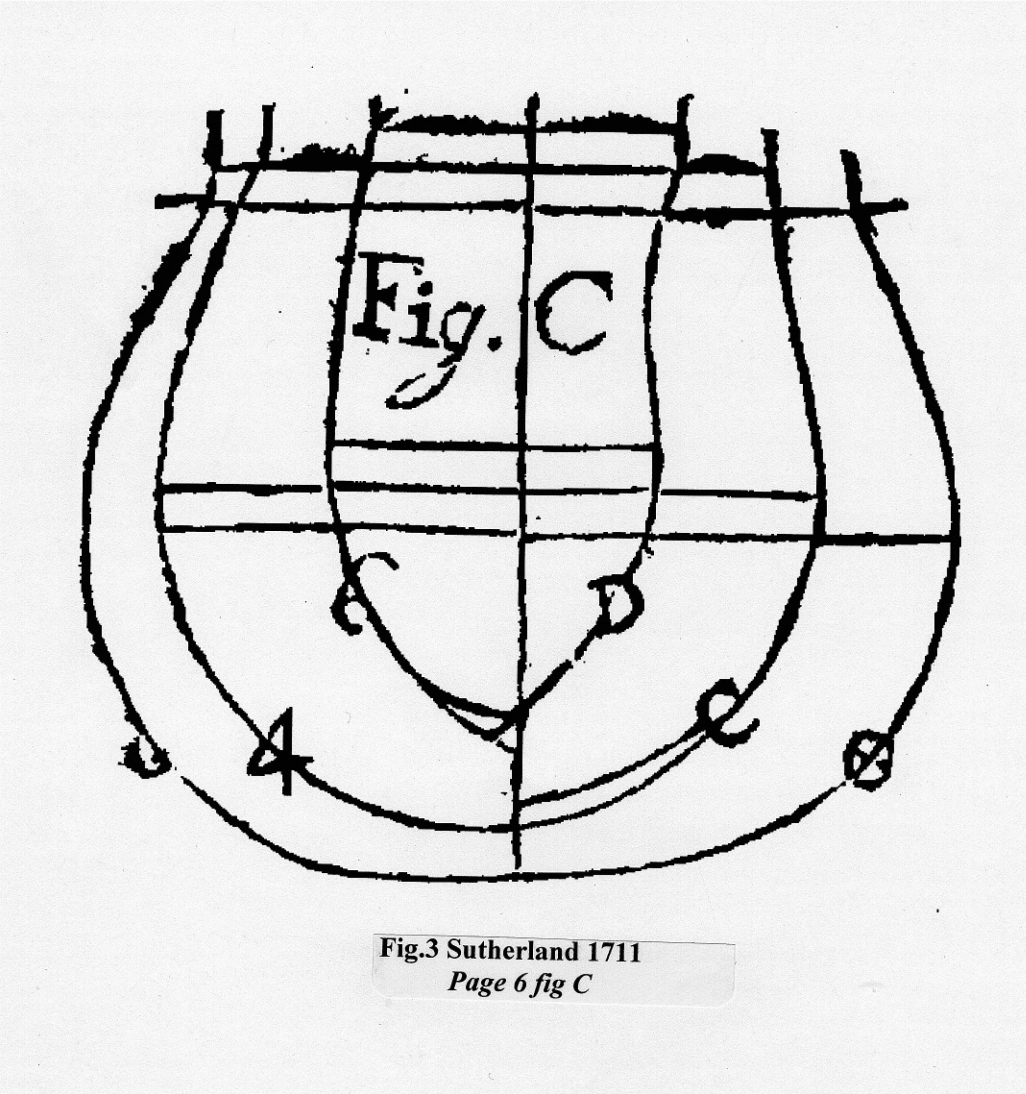

Fig. 3. Sutherland 1711. Page 6, fig C. Sections.

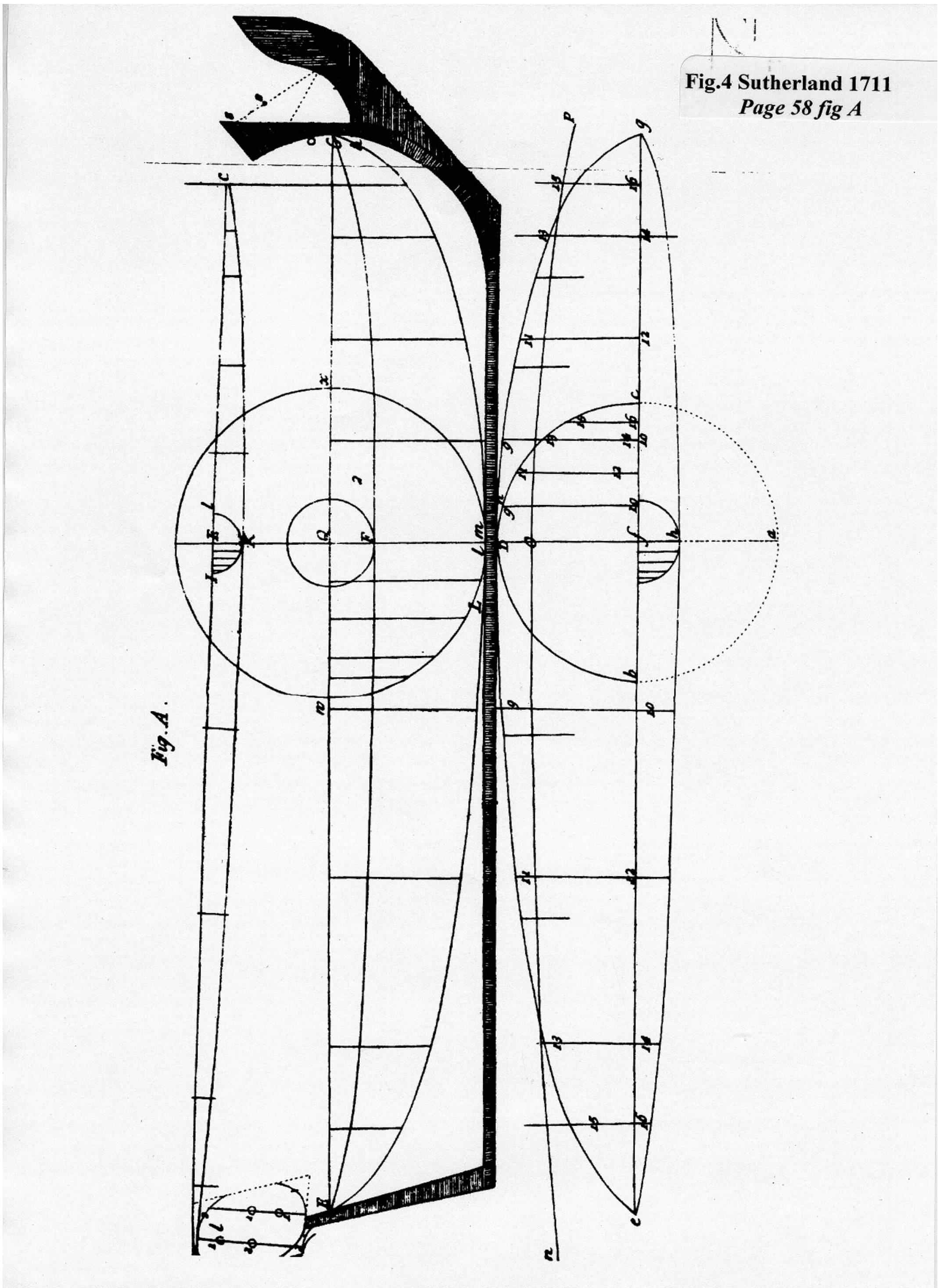

Fig. 4. Sutherland 1711. Facing page 58, fig A. Longitudinal.

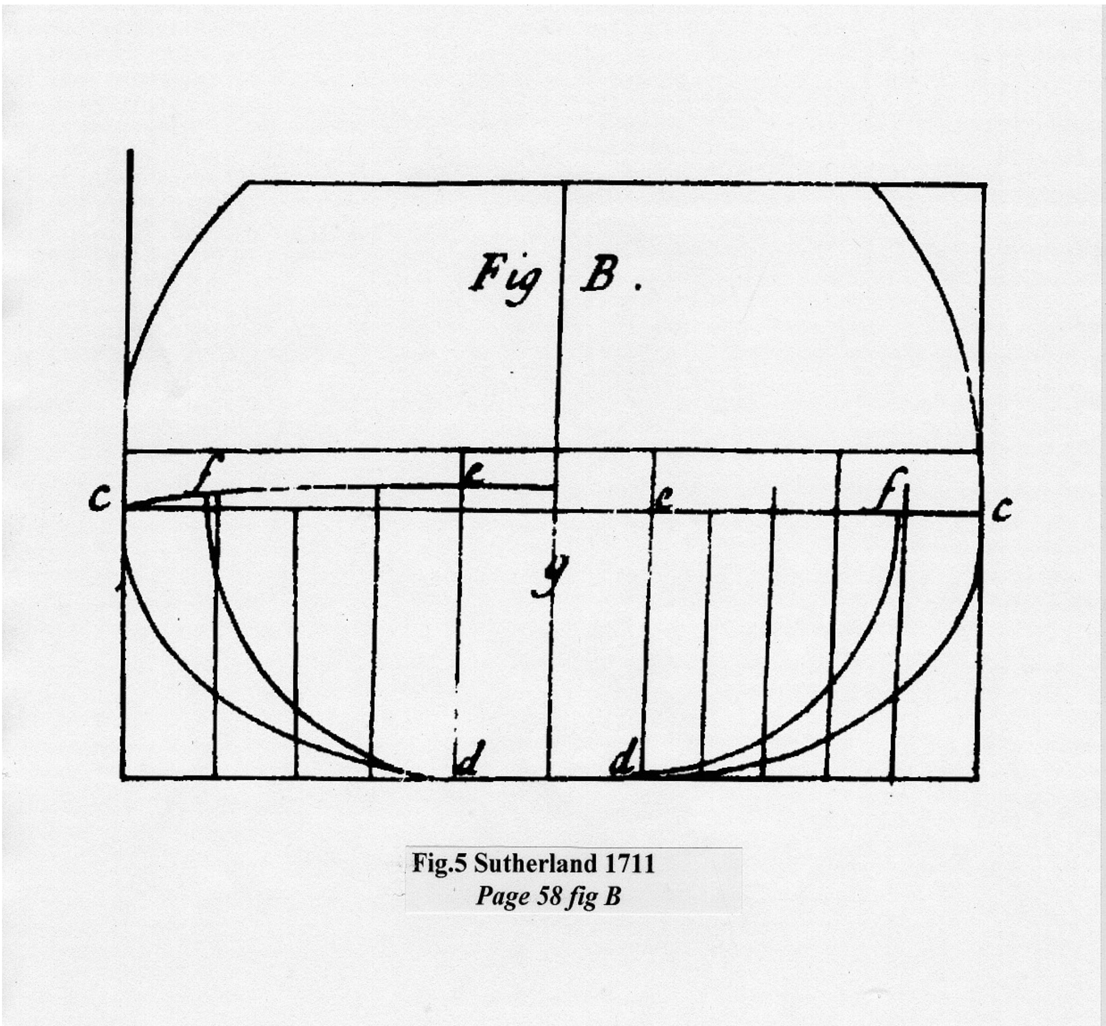

Fig. 5. Sutherland 1711. Facing page 58, fig B. Section.

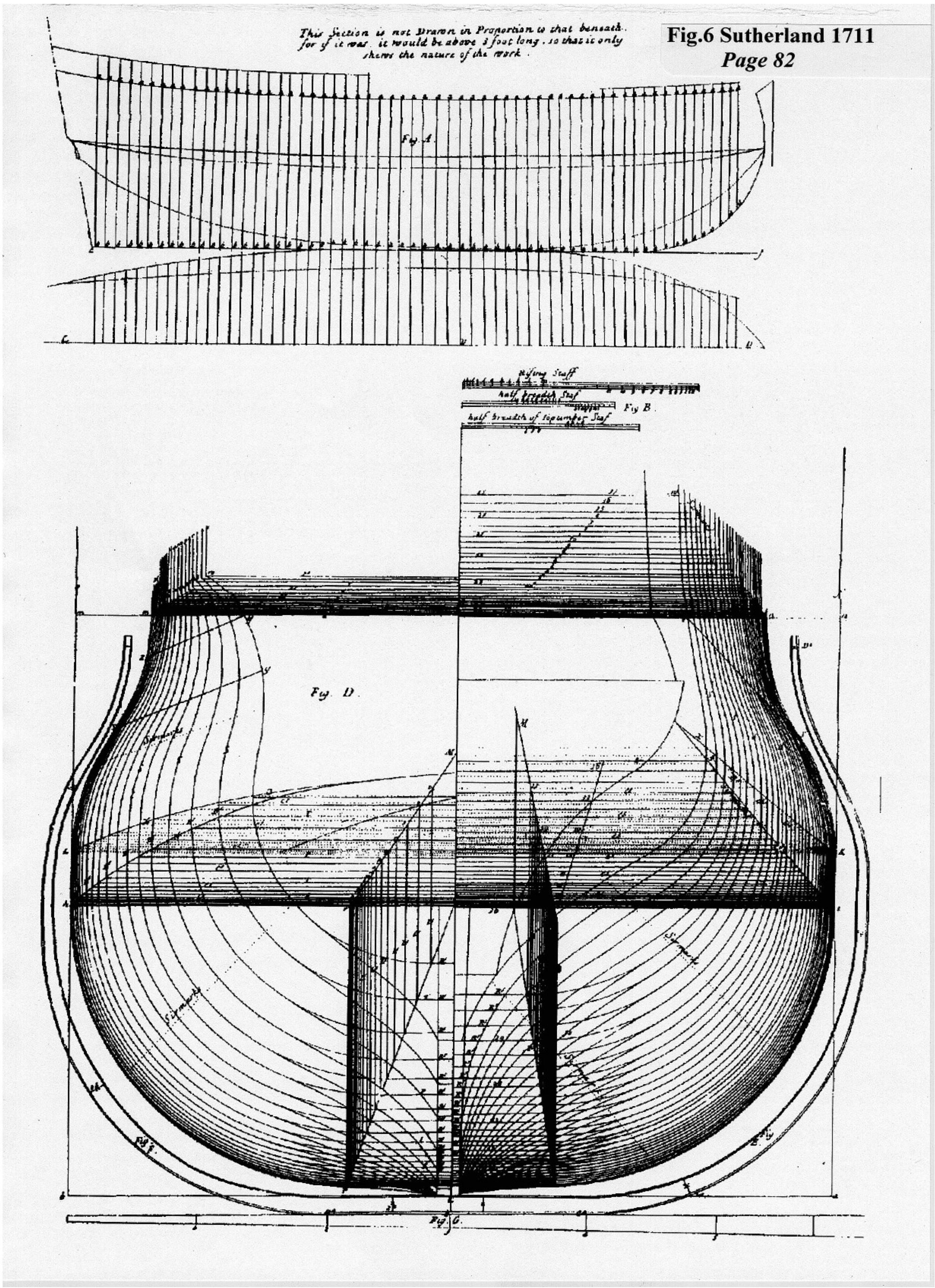

Fig. 6. Sutherland 1711. Facing page 82. Body plan.

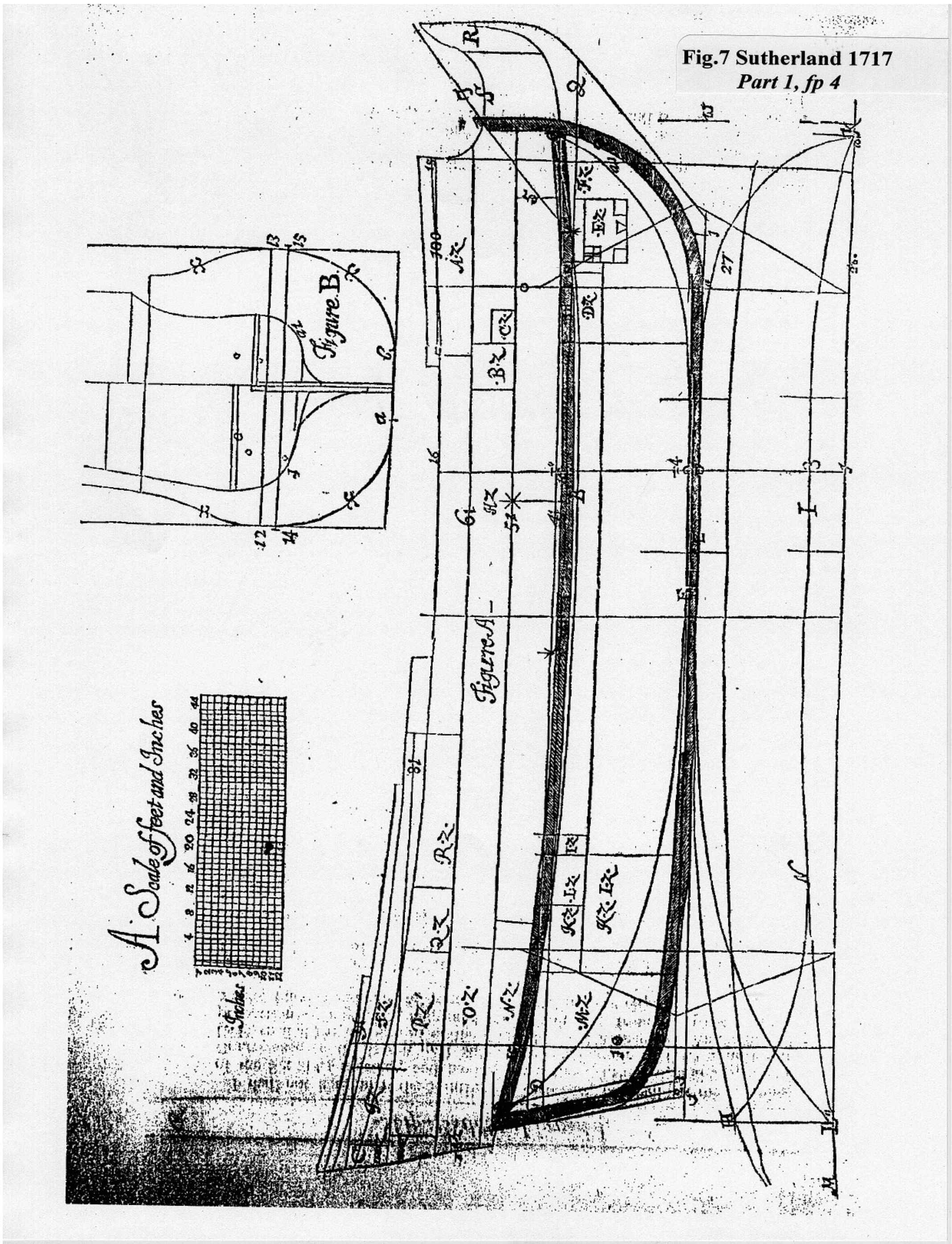

Fig.7 Sutherland 1717
Part 1, fp 4

Fig. 7. Sutherland 1717. Facing page 4. Lines plans.

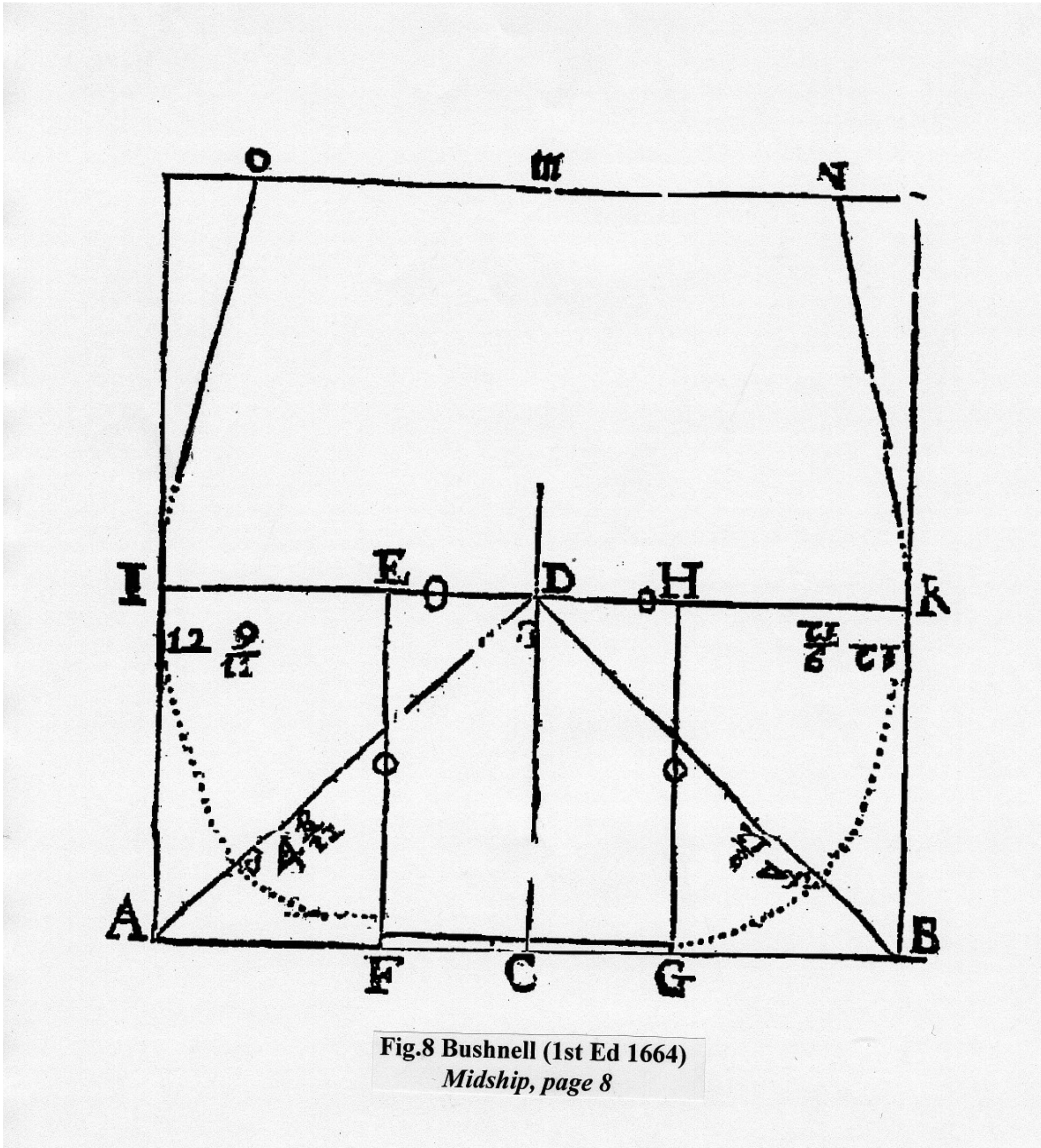

Fig. 8. Bushnell 1664. Page 8. Midship mould (From 4th ed.1678).

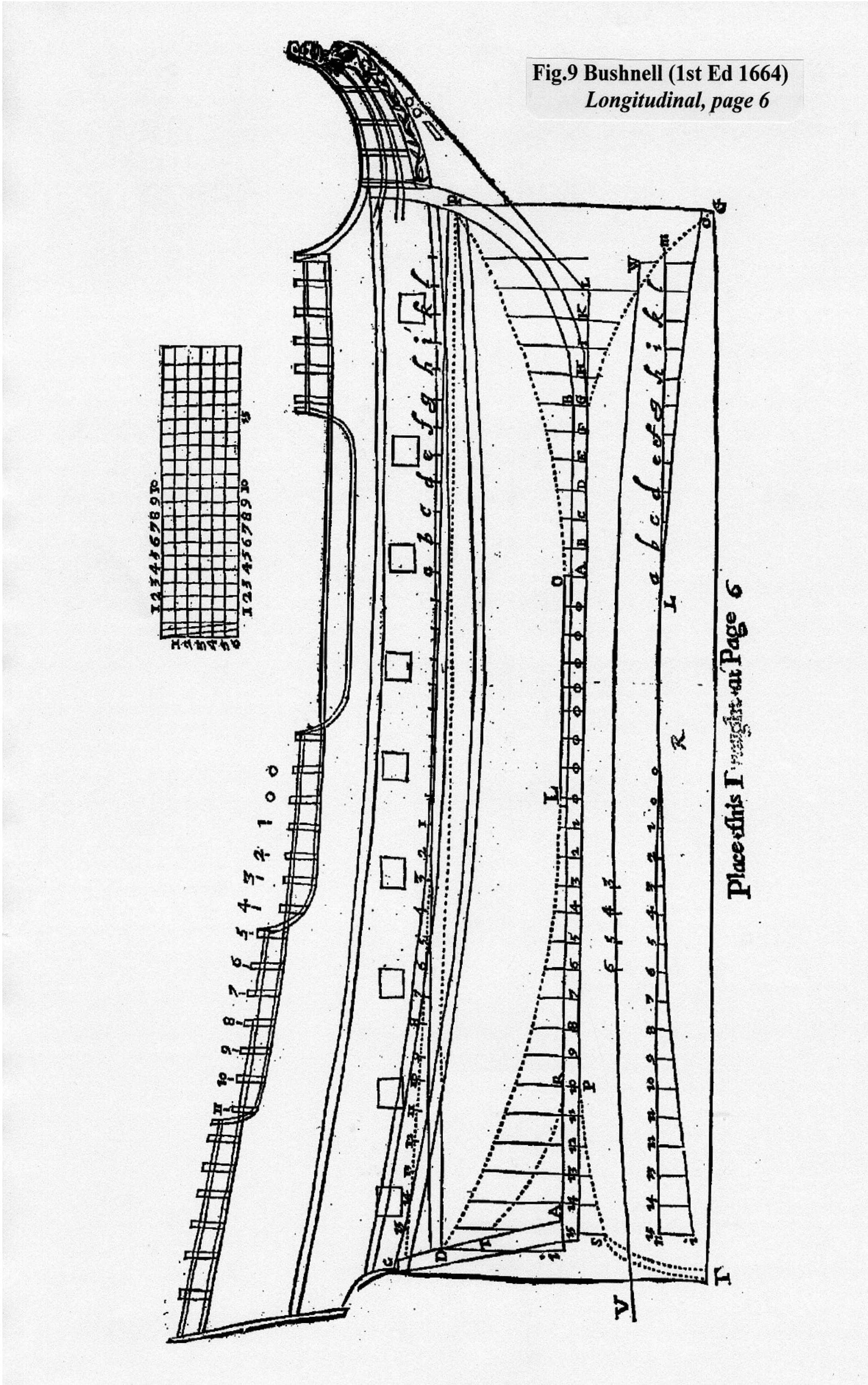

Fig. 9. Bushnell 1664. Facing page 6. Longitudinal (From 4th ed.1678).

Postscript, July 2003

It was suggested above that Baker was inactive at the time James I came to the throne. This was partly due to changes in patronage, but he is also on record as declining Dudley's 1607 invitation to work in Italy, on the grounds of age (then 77). He did offer to send "models" (*modelli et strumenti*), but it is not known whether that happened, apart from the old problem of knowing whether the first term meant mould, drawing, or model as now used. The source for that period is J. Temple Leader's *Life of Sir Robert Dudley*, Florence 1895.

More recently, further work while formally translating shipbuilding sections of *Hydrographie* has revealed that Fournier's other *modern* method[46] for the midship mould is interesting in its own right, and not all that it appears.

Some very similar observations can be made about the early midship moulds in *Fragments of Ancient English Shipwrightry*, in particular the six that use four arcs from floor to breadth (including that identified as the method used by the Venetians twenty years previously). Current work on these is in preparation for the intended Navy Records Society/ Pepys Library publication of the manuscript.

This paper first appeared on the Max Planck Institut website in 2002 when it was entitled "The *Ancienne Méthod* as a special case of whole-moulding.”

46. *Op.cit.*, 1643, Book 1, Chapter IX: "*fait à la moderne*."

A Venetian ship drawing of 1619

© Richard Barker, February 2002

In 1952, G. B. Rubin de Cervin wrote[1] about a design for ships proposed for use by the Spanish against Venice, able to sail up to the quays in Venice itself; whence a rather fanciful description as 'Q' ships in the article. The context is that in 1619 someone - by inference a Venetian with shipbuilding knowledge - provided these plans to the Duke of Osuna, Viceroy of Naples, as part of the naval war between Spain and Venice, in which Osuna had also been attempting to acquire ships in England and Holland. These plans, or copies, were obtained by Spinelli, the Venetian Resident in Naples. Rubin de Cervin also reproduced three plates of drawings of this ship, which were in the Archivo di Stato, Venice.[2]

These are typical of shipbuilding drawings of the time - clearly quasi-technical, more or less to scale, but incomplete. Nonetheless, it is worth a glance at the section drawing, as it is replete with construction marks, and annotation in Venetian dialect. Unfortunately there is no mention of tonnage, and no more than a handful of explicit dimensions. The key parameter was that it was not to draw more than 10 or 11 feet (Venetian?), and had to carry a heavy armament and soldiers to be landed in Venice. It was broadly in the form of a galleass, presumably to ensure its approach without delay.

Details of the drawing

The elevation drawing has a scale in paces, subdivided into feet (*passos* of five *pies*). The plan has a scale of paces, part divided into feet, and part into half-paces. The section drawing has the first pace divided into feet, and then is marked in half-paces. The description following is necessarily based on the published commentary and plates.

The section has characteristics individually recognisable from other sources. The breadth of floor is marked, apparently 11 feet (though it scales nearer 13.7 feet, which would be close to half-*bocha*) - measured as the *fondi*, roughly on the outer face of the frame but at the height of the top of the floor, which is the point marked here and conventionally; not as the literal flat between the bilge arcs, which is about 9 *piedi*. The heights are divided above a dual base line - one for the bottom of the keel, and another close to a foot above it from which the measures are clearly made. There are four equal divisions, marked *3pie*, *6pie*, *bocha* and *regia* (which last is translated as main beam, and certainly corresponds to the notional level of a second deck, scratched in as a thickened straight line, but also to the geometric maximum breadth of the hull). Each has a breadth marked, which appear to be *piedi* 21, 25, 27 and 29. Thus the moulded breadth at the *bocha* is 27, and the maximum moulded beam at the *regia* is declared to be 29, though it actually scales close to 30. The divisions are closely 2.5 *pie*, and the 11 foot

1. “Galleons and 'Q' ships in the Spanish conspiracy against Venice in 1618," in *Mariner's Mirror*, Vol. 38, 1952, pp. 163-183 + plates. Two sceptical notes appeared in the next volume (39, 1953, pp. 60-1).
2. The section drawing of interest here bears the stamp N16-lxxxv. The drawing is also reproduced by G. Penzo, *Venetian ships*, London 2000, fig. 18 (also as *Navi Veneziane*, Trieste 2000), in which it is stated that the whereabouts of the drawing is not currently known. Longitudinal views of the vessel are in Figs. 17, 19.

draft (on an even keel) is thus at the *regia*: not a normal place for the waterline, which for stability reasons ought to be below the actual maximum breadth.

The decks are marked (as horizontal lines, without camber, and unrealistically slender) as follows. *Prima coperta*, *tra coperta* (tweendecks) and *coperta* 7 *pie*. The dimension in the last of these is clear and scales correctly. The other two are equal and scale at close to 5 *pie*. 5 could well be the indistinct cipher in their labels. Allowing for any ballast and the curvature of the floors, the space below the first deck is actually very constrained.

The frames are shaped with a flat floor, only turned down sharply at the garboard to meet the keel at about half-height. There is an arc for the wronghead, which may well be centred at the height of the *regia*, with a radius of 10 *pie*. The breadth has a short radius arc, apparently centred on the height of the *regia*. (There are a number of marks which might be compass holes visible in the photograph).[3] That arc may be close to 5 *pie*. The net result is not far different from a quadrant raised on a flat floor; but geometrically is certainly different, as there is that tangent arc of short radius below the *regia*. There must be a third reconciling arc, and this can be seen to have a radius close to 15 *pie*. Wales (or ribbands) are drawn on the section, passing through the intersections of the frame with the floor, *3pie*, *6pie*, *bocha* and *regia*, but these are certainly not at the surmarks between the component arcs. The maximum breadth scales at closer to 30.7 *piedi* than the 29 declared: a notional 30 *piedi* breadth would correspond to the 5, 10 and 15 *piedi* radii of the frame arcs being rational fractions of the notional rounded number of the breadth. (If the wronghead were say 5.5 *piedi*, quite possible from the image available, it would be just half of the declared width of floor: without the original manuscript such issues will not be resolved, except to say that most primary measures will be suitably round multiples of the local foot).

The gunwale is drawn at approximately twice the height of the *regia* above the flat floor, but there are clearly two attempts at this detail, with the first (including the frame) drawn lower, and with no effective rail in the waist. An upper deck is also drawn in, but the final bulwarks are still only about 2 feet high. The transom has a breadth about equal to half the maximum breadth at the *regia* (scaling 15.7); and a height at the top-timbers twice that at the transom. The tuck lies roughly at the height of the *bocha*, but has the cipher 9, its scaled height above the bottom of the keel. The height of the sternpost scales at close to 20 over the bottom of the keel. The sternframes are formed from an arc of 10 *piedi* radius, extended upwards by an arc of 15 *piedi* radius, and a hollowing arc of a still larger radius.[4]

The only detail of structure occurs in the sternframe, where a series of transoms and verticals are drawn, including the framing for a pair of gunports on the second and upper decks. These are only around half a metre square, and while those on the upper deck are

3. The photograph available is too small for accuracy, and the drawing itself slightly sketchy and assymetrical, but the method of seeking the geometric construction is as used in recent work on the *Mary Rose*. A summary is given in R. A. Barker & B. Loewen, "Raiding lost arcs," in *Proceedings of International symposium on archaeology of medieval and modern ships of Ibero-Atlantic tradition*, ed. F. Alves, *Trabalhos de Arqueologia*, 18, Instituto Português de Arqueologia, Lisbon 2001, p. 429.

4. This re-use of the arcs of the main frame in the sternframe is also apparent in the *Mary Rose*.

impossibly close to the deck, those on the lower deck are drawn with sills at about a metre above the deck, which is equally improbable.

General issues arising from the drawing

There are several points of more general interest. Firstly, the use of the phrase *bocha*, implying breadth of the hull, in conjunction with the *3pie* and *6pie*. This is a much older Venetian arrangement in frame design. The very names suggest an original typical usage in a small vessel, where a real height of 9 *pie* reflects the actual vessel. The system reflects hulls framed with flare at the gunwale, not tumblehome, with real maximum breadth at the head of the futtocks. At ten feet it is not far different here, but the system was employed on larger vessels, and on galleys too. Little is known about the circumstances, and how the geometric moulding was associated with the three points defined. That it was is hardly in doubt: the longitudinal variation of frame shape of all vessels in this environment was determined by sophisticated geometry. It could be that the dimensions were used to determine surmarks between arcs, or, at least, moulds: but there are too many for smaller vessels using at most two arcs; and there is no possibility that measurements, generally to no greater precision than a quarter-foot (here all are in round feet) could closely represent a moulded curve. In this particular case, the sequence 25, 27, 29 at equal vertical intervals represents a straight line, not the manifest arcs, so they must be rounded figures; or require another explanation. It could be that they offer no more than a contractual guide to the approximate shape required.[5]

Secondly, based on a visual assessment of the mould construction in the photograph (without benefit of all the silver-point marks and compass holes that are certain to be present in the original), the third arc for the breadth, necessary only in a larger vessel of more than one deck, essentially, is ostensibly tacked onto a hull designed in the old way, with two arcs to the *bocha* (though the surmark does not coincide exactly here in attempting to reconstruct from a rough drawing). The *bocha* ceases to be the true breadth. There is a suggestion of a grid constructed here based approximately on the *bocha*, but certainly no inked vertical line framing the true maximum breadth. Similar problems of interpretation occur in some of the earlier drawings of Mathew Baker, where an initial grid is drawn for the frame geometry that does not represent the actual maximum breadth. The details are not expressed in text or terminology in Baker's extant work, and are not yet understood. It has a particular impact on what dimensions are being used to define the capacity, or tonnage of the ship. Upperworks may make a ship more seaworthy or defensible, but they do not increase its capacity (rather the opposite, in terms of hull weight and low-angle stability, on the same bottom). When they came to be used widely, and fashioned to be more seaworthy, with tumblehome,[6] there must have been a step change in the method of specifying hull dimensions in a contract, and a corresponding impact on the tonnage rule - though primarily in the correcting factor used with the same product of a length, breadth and depth.

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5. Rubin de Cervin appears to state that the curve of the side was formed by a *meza luna* (p. 179), but that is erroneous; current theories appear to revolve around the use of parabolae in Venetian shipping of earlier periods but are not convincing in this writer's view.
6. For a wider discussion of tumblehome as such, see R. A. Barker, "Why tumblehome?," in *Mariner's Mirror*, Vol. 84, 1998, pp. 95-7.

The term *pontal(e)* occurs in Portuguese, Genoese and Ragusan methods, and may reflect the same point: a relic of a period when ships were not generally built up and multi-decked. It is expressed by Pimentel Barata as "first-deck height.”[7] In tonnage methods and shipbuilding data mostly for the sixteenth century, this *pontale* is much smaller than the depth measure of comparable English or Spanish ships, for example, where depth reported (and used in tonnage calculations) is more likely to be that at or close to the maximum breadth of the hull, well above the waterline; but not necessarily at a deck level to reflect enclosed volume, either. It is unfortunate that the documents in this case do not preserve a tonnage measure, though few extant contracts at and before this period do.[8] Even where tonnage is recorded together with linear measures, interpretation towards understanding the early tonnage measurement rules in use is usually difficult, and every example is valuable.

Thirdly, it is difficult to understand how a ship such as this was to function with so many decks. The space below the upper deck is generous, at 7 feet beam centre to centre, or close to 6 feet clear between deck and beam - but then it had to accommodate the oarsmen. It is the two spaces for stowage that are the mystery. The 'tweendeck space of 5 feet centre to centre is not in fact atypical for contract measurements of the sixteenth century for merchant vessels in the Mediterranean. A clear height of about 4 feet (especially Venetian feet, about 1391mm, or 4.5 English feet)[9] is just sufficient to handle almost any barrel; but at the same time rather wasteful for the butt in use in the Adriatic, of perhaps 0.6 tons, and approximately 3 Venetian feet in diameter. If these decks were planked, then much of the space was necessarily wasted. The space below the first deck is even more constrained, as wherever the 5 feet is measured to in this system (top of beam at the side of the ship to the top of the keel seems most likely, but cannot be proved here) it has to include the floor timbers and any ceiling planks; and any ballast. On that basis, even a Venetian butt might be too large to be accommodated in this space. It is possible that the beams at the "first deck" were not in fact planked, but represent merely a structural feature for the frame.[10] In other contracts the phrases *intra coperta* and *infra duas copertas*, or *altezza insenta* occur. *Orlo* and *banda* occur for the height of bulwarks, too. In the contracts seen for two-deck Ragusan vessels the usual phrase for the first space above the floor is *pontale*, sometimes at the *bocha*, sometimes related to the

7. Eg J. da Gama Pimentel Barata, "The Portuguese galleon, 1519-1625," in D. Howse, ed, *Five hundred years of nautical science 1400-1900*, Greenwich 1981, pp. 181-191 translates *pontal* as the height of the first deck, which is *not* the main deck in the ships he is describing, but in the hold. The unit of measure, the *palmo/pedalj*, seems to be the same in the same three areas.

8. For example, the large collection of sixteenth century data provided in F. Ciciliot, *Nautica Genovese*, Savona 1993, has no complete data sets at all, though some might be associated from separate documents by date. Tonnage seems only to be defined after construction? It is a moot point whether this is because tonnage was still not assessed by arithmetic rule, despite the existence of such rules long before in Italy.

9. Rubin de Cervin gives an equivalence of 1.1 English feet, but this is not accurate enough. In 1554 it seems to have been 347.735mm (1.141 English feet), but other values from 1.137 to 1.167 are recorded.

10. For a roughly contemporary comparison we have the example of the English *Defiance* of 1591, whose specification includes "…. a beam of 32 feet, and be 15 feet under the beam of the main overloppe [here meaning main gun-deck, not an orlop in the hold]. Eight feet above the keel ten beams were to be placed on which to lay a false overloppe so far as need shall require." Cited by M.Oppenheim, *History of the Administration of the Royal Navy, 1509-1660*, 1896, p. 129, from SP Dom. ccxxiii, 45.

first deck. It is as though they are expressing a system such as we have in the present Venetian drawing: *pontale* is the old height at the *bocha*, and the *copertas* and *intra coperta* are the physical divisions of the decked spaces, which do not correspond with the *bocha*.
The earliest tonnage rule[11] for single deck ships is based on a multiplication of *bocha* and *pontale* (and then keel length): it is not so clear what happens when there are two breadths and at least two depths to choose from. The old tonnage rule appears, then, to have been developed for single-deck (or un-decked) vessels, and confusion reigned when it was applied to more developed hulls.

Wider implications of the composite features of the drawing

Finally, the great interest of this single draught, ostensibly from Venice, lies in its relationship to English shipbuilding design, and in particular the unresolved enigma of the "Venetian" frame designs given by Mathew Baker in the so-called *Fragments of Ancient English Shipwrightry*,[12] around 1570. The present drawing is closely dated at 1619. The geometric arc system is in precisely the form developed by Mathew Baker. Baker also records a series of complex multi-arc frames which he explicitly describes as those used by the Venetians, implying furthermore that up to around 1550 they used four arcs.[13]

However, this is unlike all other known Venetian records for Venetian shipbuilding. All the manuscript sources such as those studied by Lane and Anderson, or the earliest version of the so-called *Fabrica di galere*, by Michael of Rhodes, ca 1434,[14] record a sys-

11. R. C. Anderson noted its existence in "Jal's *Memoire No. 5* and the manuscript *Fabrica di Galere*," in *Mariner's Mirror*, Vol. 31, 1945, pp. 160-7. (Jal had not). He gives it in an anglicised form, without any original terminology, as T = (K*B*D/30) for Venetian feet and butts (p. 165, citing f. 50 of the manuscript). In fact the original text, published by E. A. d'Albertis, *Le construzione navali….*, Rome 1893, pp. 217-8, is little more informative: *portada* of any ship, square or lateen, uses….*cholumba* (in paces, with a divisor of 6), *bocha*, *choverta.* It appears, from the results, not any explicit text, that the same form of rule was being used in Ragusa in 1512, in cases where *bocha*, *pontale* and keel length are the only three contractual measures recorded. In "Italian naval architecture about 1445," in *Mariner's Mirror*, Vol. 11, 1925, pp. 135-163, Anderson had attempted (p. 150) to fit a rule of $K*B^2$ to Timbotta's data for ships of the mid-fifteenth century (for lack of depth data, and knowing such a rule was later used in England) but without success. He had no success with the Timbotta data in 1945 either, using the *Fabrica di galere* rule of K*B*D, but we may note that the data covered a wide range of ships sizes, up to 1000 butts, and its actual date is unknown, as it is inserted in a later copy (1500 +/-) of a manuscript originally written nearer 1410-20. Gatti also observes the same problem with fragmentary data from Ragusan contracts from 1512-1583, with the additional problem of having to convert Ragusan *carri* to Venetian butts, an uncertain process. Again, the thirteen contracts cover 5 different types of ship from 30 to 200 *carri*; and only 5 give both depth and tonnage, so difficulties are not surprising. L. Gatti, "Imbarcazioni Ragusee nel secolo XVI," in *Studi di Storia Navale,* ed H.Bresc et al, 1975, pp. 73-96 (kindly provided by Furio Ciciliot). In fact, it is noticeable that two of the early Ragusan contracts do result in a tolerable match, but they are all small vessels where only three dimensions - *bocha*, *pontale* and keel are recorded at all, and it may be supposed that the vessels more nearly match those for which the rule was formed.
12. MS 2820, Pepys Library, Magdalene College, Cambridge.
13. R. A. Barker, "Fragments from the Pepysian Library" in *Revista da Universidade de Coimbra*, Vol. XXXII, 1986, pp. 161-178.
14. Sotheby's catalogue, Western MSS, 2 December 2000, pp. 60-72, a text taken from that by Andreas Mayor in a catalogue of 1966, and with more illustrations.

tem where horizontal measures across the frames are recorded at a series of levels, in some cases just the *trepie, siepie, bocha*, etc; and in others at rather more levels at intervals of for example one *pie*. Such measures are usually only given to the nearest quarter-*pie*. The two systems are not compatible. It is probable that the system of offsets is providing a compact, portable record of a more complex system, which is adequate for a contractual record of the size and shape of ship.[15] While this system cannot re-create the original arcs, it could re-create the effective shape by adjusting a spline to be a close match to the majority of points set out on a moulding floor, from which new templates could be created. In the characteristic Mediterranean system of rotating the template for the side of the hull about the bilge, in all frames fore and aft of the master frame, this is quite adequate.

Bellabarba effectively states and demonstrates the point in an article tracing the development of design processes.[16] He states that the design was based on arcs, and only communicated to the shipyard as the series of offsets. Galleys could suffice with a single arc, while large ships might use four - he cites Teodoro's manuscript of 1550 as a case in point for that. However, he re-creates the drawing for a galley in his article, and demonstrates the problem in most descriptions perfectly. A single arc is to reconcile a straight side sloping at about 73 degrees (though the explicit dimensions given are for 75.96 degrees), and the flat floor. Yet it is to have two touches with those lines and also pass through two arbitrary points defined as offsets at specific levels (and at many more levels in other cases). This cannot work, and indeed the drawing as published is fudged: the single arc centre shown is not correct - there are two centres, and the two arcs do not meet properly. Neither does the straight line actually pass accurately through the top of the side at the declared point. The reality is that the offsets at specified levels, given to a limited accuracy in such records, are only an approximation of the geometric values. It is not difficult to see how moulds thus created and copied and modified over a long period might drift from an original arc, or compound of arcs and lines, to appear more like parabolae.

The present source document also suggests then that the original Venetian system may indeed have been based on arcs, though most other traces of it have disappeared. There is no proof, however, that the clear (and characteristic) multi-arc system of the 1619 drawing relates to methods used a century earlier in Venice. That also raises the question of whether by 1619 the English system may have migrated back to Venice; or whether for example the unknown shipwright who prepared the drawings and was "someone close to Osuna and well-informed about matter in Venice" could have been of a different nationality, accustomed to working with arcs, but also familiar with the moulding system using offsets preferred by the Venetians, and perhaps many another shipyard in the Adriatic or Naples.

We might note that at this period Robert Dudley had been working in Italy for some years, claiming to have built successful warships,[17] and from around 1610 had been writing on naval architecture[18] (he had been a pupil of Mathew Baker indeed, at one

15. Touched on in R. A. Barker, "English shipbuilding….," in É. Rieth, ed, *Concevoir et construire les navires*, Technologies, Idéologies, Pratiques, Vol. XIII, 1998, pp. 109-126, at p. 119.
16. S. Bellabarba, "The ancient methods of designing hulls," in *Mariner's Mirror*, Vol. 79, 1993, pp. 274-292.
17. J. Temple Leader, *The life of Sir Robert Dudley*, Florence 1895, collects the evidence.

point) and using that very term at an early stage. He was based in Pisa and Leghorn. He constructed a large galleon in 1608, the *St. Giovanni Battista*, 64, a ship which had success against Turkish warships. How far the influence of that success spread to other shipbuilders is a matter of speculation.

There are a series of midship sections and longitudinal plans in *Dell'Arcano del Mare*,[19] for ships and oared vessels. The galleon has a profile much like the northern European warships of the early seventeenth century that feature in English and Danish draughts, for example, and narrowing and rising lines all extending the full length over the posts. The midship sections use scales of English feet, and a system which follows Baker, but with an exaggerated shape - very shallow, with a long flat reconciling arc. Dudley is said to have taken a great many mathematical instruments with him from London, in 1605/6, but not to have updated his knowledge of these. The details of these midship drawings have some resemblance to one of Baker's drawings, in terms of carpentry - knees and inclined pillars to the decks in particular, but in terms of a background grid, shape, and other details he is very different (which may be partly due to the engraver, of course).

Interestingly, it appears that the second, futtock arc ends at the corner of a grid of breadth and depth 24 feet wide and 5 or 6 feet deep above the keel. The breadth arc then forms the true breadth at around 8.5 to 10 feet above the keel, and significantly wider than 24 feet. The futtock arc is thus a reconciling arc in name only here - it is actually formed second in order, not third. It thus matches an intermediate set of moulds in Baker's work, where the corner of a grid might well be the archetypal *bocha*. However, the corner of the grid in Dudley's examples is in no way the *bocha* of the lower hull as described above: it is far too low in the hull.

The futtock arc is determined to touch a quadrant drawn inwards from the lower corner of the grid, as in many Portuguese examples, with a radius of about 4 feet. Its actual use appears to be by trial and error, however, with no system apparent.

A Portuguese example

There is one example known from the Portuguese archives, of a similar date, that shows a similar combination of features. There are sufficient differences for it to be a coincidence, in all probability, but it will be mentioned here for completeness. Manuel Fernandes compiled a set of ship draughts and texts, dated 1616,[20] which includes one anomalous section for a very large ship (some 14.8 metres beam) at sheet 83. This vessel, described as a four-deck *nao*, does not correspond to any of the texts in the volume, and is indeed in a different drawing style. The majority of his draughts are

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18. See also O. Dunn, "Robert Dudley books and manuscripts owned by John Temple Leader," in *Mariner's Mirror*, Vol. 47, 1961, pp 142-4. These points are directly from Leader.
19. Sir Robert Dudley, *Dell'Arcano del Mare*, Florence 1646, in four volumes. The work was published posthumously: the material is thought to date from the 1620's. The galleon profile at least is reproduced in Charnock, *History of Marine Architecture*; Witsen reproduced some of these sections, as "English" - four of these are given by A. J. Hoving, "Dutch 17th century shipbuilding" in *Model Shipwright*, No.58, 1986, p. 35.
20. M. Fernandes, *Livro de Traças de Carpintaria*, Ajuda Palace Library, Lisbon, MS 52 XIV 21, (Facsimile edition, Academia de Marinha, Lisbon 1989).

based on a single circular arc for the ship's side, faired to the floor with a short-radius arc, more or less in keeping with most of the Portuguese manuscript sources extant from the period 1570. This one draught has a prominent arc forming the bilge, which is more than mere fairing - it is an integral part of the construction, with a radius equal to one third of the breadth of the ship. A long arc then sweeps up to a point between the second and third decks. Above that there is a third arc of the same radius as the bilge arc, which forms the breadth of the ship, above the third deck, followed by a short reverse sweep in the tumblehome, forming the bulwark. Also uniquely in this collection, there are a series of offsets marked for the main arc below the breadth. These define the distance between the maximum breadth of the ship and the actual breadth at each level. (In contrast, the sternframe on sheet 82 has actual breadths marked for each transom in its drawing; and of course the Italian system has breadths rather than narrowings, too). They are at intervals corresponding to deck heights, of 7-1/2 *palmos de goa*, from the base line upwards, but they do not occur at deck positions. All the measures fall within the main arc. There is however no obvious zero point at the upper end, for any numeric progression; and the centre of an arc is clearly defined. The supposition must then be that they have been measured from the drawing, to the nearest half-*palmo*. We might speculate that these would be of most use on a moulding floor, where a radius of nearly 16 metres is likely to be inconvenient to handle directly, or failing that, as a means to check the accuracy of assembly of the numerous frame components in a ship of this size - one futtock per deck at least. We thus have another three-arc system broadly in line with the contemporary English system, though the rationale for its geometry is unclear; coupled with an unusual set of offsets. The midship section alone says nothing about how the frame was to be modified fore and aft, and equally if the offsets are to check accuracy of assembly, they relate only to the midship frame.

It is known that before this period there had been at least one English shipbuilder named Lambert at work in Lisbon,[21] though on vessels of some 400 tons, not of the size drawn by Fernandes. Whether there is any connection to explain this one draught is a matter of speculation.

A Greek mould

There is one midship section, in the *Fragments of Ancient English Shipwrightry* (f. 12) for a Greek ship. We might suppose that it was collected by Baker in 1552, when he visited Chios in the *Bark Aucher*; the alternative source being Levello or other shipwright from the Adriatic working in England, probably in the 1570's. This is identified as a *screatse*, and is of around 100 tons burthen. This is indeed a known type of vessel in Adriatic and Aegean waters, the *skyrasa*.[22] It is of interest here not because it has any offsets - it does not - but because it is another example of a mould from the area of Ve-

21. CSPD 1595-1598, ed M. A. E. Green, HMSO London 1869, cclii. 58 9 June 1595, William Lambert of Liverpool, five ships at Lisbon; similarly cclxviii. 69, September 1598, John Lambert of Chichester, many ships after the English fashion at Lisbon. Also reported in *Naval Tracts of Sir William Monson*, Vol. IV: three named ships of 400 tons by Lambert at Lisbon.

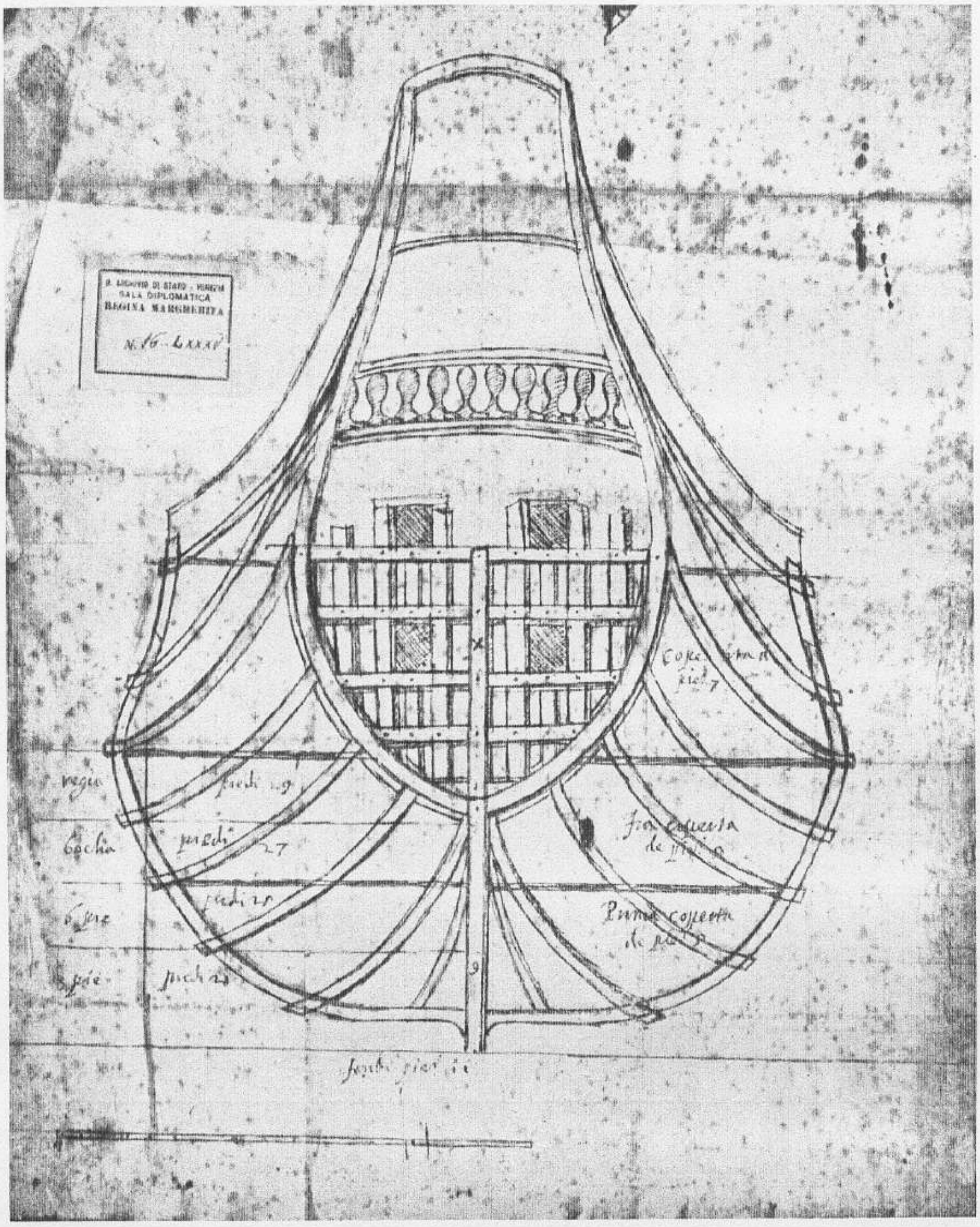
22. Known, but references are rare. Hakluyt mentions one at Candia in the sixteenth century. R. C. Anderson, in *Mariner's Mirror*, Vol. 6, 1920, p. 189 gives several examples. Pantero Pantera (*L'Armata Navale*, Rome 1614) mentions it as a square rigged type (*schirazzo*), Antoine de Conflans (*Le livre de faiz de la marine*…. MS ca 1515) has it as a trading vessel in use at Venice (*esquiracces*).

netian influence that simply does not show the characteristics recorded in extant Venetian sources. This has, uniquely in the *Fragments*, a curved floor, followed by the usual series of three tangent arcs.[23] It shows a series of construction lines for the geometric rationale, which is similar in principle to Baker's early methods, most similar to what he calls Venetian. This is not quite a case where the initial grid of breadth and depth defines the surmark between the top of the futtock and the additional arc at the breadth, that creates the tumblehome. The difference is so small, however, that we might wonder whether the detail had been copied correctly, and the original did perhaps have a surmark at the *bocha*.

Conclusion

This note is primarily intended to draw attention to this little known Venetian drawing, and a Portuguese counterpart, each containing an unusual combination of data for the design of a midship frame. Specifically, each has one element that is ostensibly alien to the local shipbuilding tradition as revealed in the majority of extant texts. The Venetian drawing in particular has a wider potential significance, in that its whole rationale differs from the norm of Venetian sources. Perhaps in time this pair of unusual drawings may throw light on what was happening in real shipyards, but for the present they are an enigma.

23. The labelling and dimensions are corrupt but recoverable: “a breadth of 40 feet and depth of 10 should read 20 and 10. Worked numerically the system actually produces a breadth of 19'11," rather than the 20 feet stated, too. Curiously, the curved floor timber recurs in other English manuscripts of the early seventeenth century: both the Newton MS (R. A. Barker, "A manuscript on shipbuilding, circa 1600, copied by Newton," in *Mariner's Mirror*, Vol. 80, 1994, pp. 16-29), and the Scott MS (formerly RINA MS. 798, now in private hands) show it. However, each is superposed on what is otherwise a standard English three-arc mould, with the centre of the breadth arc defined on the initial grid of breadth and depth. R. C. Anderson reconstructed the mould of the *Mary Gonson*, a ship of about 1514, with a curved floor timber, but did not give his reason for doing so: "The *Mary Gonson*," in *Mariner's Mirror*, Vol. 46, 1960, pp. 199-204. (See also R. A. Barker, "Blisters - a Venetian bubble?," in *Mariner's Mirror*, Vol. 71, 1985, pp. 82-3, though this is in need of revision after such an interval).



STERN VIEW OF THE 'Q' SHIP

(*Archivio di Stato, Venezia*)

Additional note on the "Venetian drawing of 1619"

April 2002

Éric Rieth wondered (in a letter of 25 March) whether we should have a more detailed discussion of the ribbands in this drawing, which I did not comment on to any extent: specifically they look like real timbers; and are they related to the diagonals in later drawings?

Yes, I agree they look like real timbers, but I am not so sure that they have anything to do with "diagonals." It seems to have been characteristic that ships around 1500 had lots of heavy strakes, extending well below the waterline (- but not that low!; whereas by 1600 in England there was only a main wale, which more or less touched the waterline, and nothing below that). There were not enough of these strakes in illustrations for them to be seam battens, though. They are conspicuous in the Greenwich painting of "Portuguese carracks." Perhaps this 1619 drawing is just a sketch reflecting what the planking might be? It is conspicuous (at the level of a crude drawing) that the spacing of most of the "ribbands" is reasonably constant along the curve of each section - does that suggest that it would fit a simple planking scheme with the maximum of straight planks? There is that one "rogue" nearest the keel, drawn differently though......

But in this sketch (and that is all it is, as finished: a geometric grid to start, and some compass work, but not a high quality drawing) there is only the one section and the sternframe. Any "curve" of the ribbands is thus extremely arbitrary, and any diagonal would have to be related to many sections. I think they represent the existence of real wales/ribbands, noting that the first starts at the end of the floor. Intended to provide fairing and shapes for some part of the remaining sections, plus strength during assembly.

I do not see any evidence to sort out how more than that, though. We might suppose *meia-luas* or similar up to "almogamas," but equally it could reflect a particular builder working on three frames and ribbands? Perhaps that might be because it was a very atypical shape for a specific purpose, with no standard measures or proportions to apply to *meia-luas*? But we are reduced to guessing.

A Similar Atlantic and Mediterranean Ship Design Method: the Case of the French Royal Dockyards at the End of the XVIIth Century[1]

Eric Rieth

Introduction

One important question of the history of naval architecture is the difference, or, on the contrary, the similarity between the Atlantic and Mediterranean ship design methods from the Renaissance to the end of the XVIIth century.

In the case of France, which is the purpose of this paper, the sources of the XVIth century - archaeological data and written evidences - are very rare. There is a big contrast between the scarcity of the French documentation of this period and the wealth of the Venetian, Spanish, Portuguese and English documentation. It is necessary to wait for the end of the XVIIth century and beginning of the XVIIIth century to have a corpus of French manuscript sources which can give the possibility to compare the Atlantic and Mediterranean ship design methods.

It is the principle of the methods, and not their geometrical demonstration, which is the purpose of my remarks. Firstly, some words to remember the historical context.

The historical context

In 1669, Colbert is appointed State Secretary of the Navy. When he dies in 1683, his son, Seignelay, is appointed in his turn State Secretary of the Navy until his death in 1690. In somes twenty years, the father - "le père fondateur" - and the son - "un ministre matelot" - according to the definition of the French historian Daniel Dessert, will be the "shipbuilders" of the first navy of the King Louis the XIVth.

This navy, with more than 80 ships of line, can be characterized, from the point of view of ship design methods, as a navy of transition between two technical cultures: the old medieval culture and the new modern culture.

The first is characterized by the use of the mediterranean whole moulding method and its three traditional "instruments of design": the master mould, the rising square and another wooden scale used to obtain the narrowing of the breadth line. In the French documents, the three "instruments" are named: "le maître-gabarit, la tablette et le trébuchet" (1).

The new modern technical culture is characterized, in its first pre-mathematical step, by the layout of transverse sections in scale 1/1 on the ground of the shipyard and, later, on

1. This note is a new, corrected and completed version of a paper published in French: "Le cas de la France à la fin du XVIIe siècle: une même méthode de conception des navires au Ponant et au Levant," in: F. Alves (ed.), *Proceedings International Symposium on Archaeology of Medieval and Modern Ships of Iberian-Atlantic Tradition. Hull remains, manuscripts and ethnographic sources*: a comparative approach, Instituto Português de Arqueologia, Trabalhos de Arqueologia 18, Lisbon, 2001, p. 259-268.

a lofting floor. In this "graphical" method in scale 1/1, which gives the possibility to design - before the building - the geometrical shape of all the frames, the diagonals must be sketched as oblique straight lines. One important matter can be noted: during this first period of the new modern technical culture, that is to say chronologically before the end of the XVIIth century, the geometrical concept of the plans at reduced scale in three orthogonal views - transverse, horizontal and longitudinal - is not yet used by the French shipbuilders, not even when some experimental tests are made during the years 1680-1685.

One of the oldest tests is given, for example, by a plan of a fluit for galleys dated to the years 1684-1685. The author of this graphical document is the Mediterranean master shipbuilder François Coulomb. It is very interesting to note that a plan of the same François Coulomb, dated of the same years, shows a tranverse section of a small ship of line with diagonals sketched as curved lines. With the drawing of diagonals as curved lines, it seems geometrically impossible to design the shape of the transverse sections using the geometrical process of the time (convexity of arcs, equilateral triangles...). It is possible that with these two drawings of François Coulomb, we have one of the geometrical keys to understand the way to the second step of the new modern technical culture of the shipbuilders.

This second step is, in France, the general use of the plans in three views since the years 1715-1720 and, in correlation with this full graphical method of design, the use, some years later, of the hydrostatic calculations (metacenter in particular). At this moment (the years 1740-1745), the cultural rupture with the old medieval ship design methods is complete.

The documentation

The manuscript documents which illustrate the period of transition belong to two categories of sources. The first is composed of treatises on naval architecture. Their topic is of general and theoretical dimension. Even if a particular model of ship of line - a 84 guns' ship for example - illustrates the topic, it is a theoretical ship of line which has not been confronted with the practical experience in a shipyard.

The second category of sources, by contrast, is composed of practical documents, shipbuilding estimates in particular. These documents were always written for a particular ship, in a practical perspective. In general, it is a list of dimensions and proportions which were defined by a shipbuilder in relation with a precise request.

For this presentation, I have selected five documents.

The first document (2) is not a classical written treatise on naval architecture but an illustrated treatise composed of 50 drawings (fig. 1). Every drawing shows, in the context of the Toulon Royal Dockyard, the progressive steps of the building of a first rate ship of line (of three decks with 84 guns). The document named l'*Album de Colbert* is dated to the year 1670.

The second document (3), dated to the year 1683, is a manuscript written by the master shipbuilder François Coulomb. Its title is: *Livre de construction des vaisseaux*. This book of shipbuilding must be close to the creation in 1680 of the first school of shipbuilding for the "Gardes de la marine," the future naval officers. F. Coulomb was appointed the first teacher of shipbuilding at the school of Toulon.

The third document (4) is an anonymous manuscript dated probably to the year 1691 and entitled *Traité de la construction des galères*. This treatise, published in 1983 by the Dutch historian and linguist Jan Fennis, is composed of two parts: the first, theoretical, describes the hull design method of galleys; the second, practical, describes all the steps of building galleys.

The fourth document (5) is the manuscript of the reverend Father Hoste. This cleric was teacher of mathematics at Lyon and Toulon for the "Gardes de la marine." The manuscript entitled *Architecture navalle ou pratique de la construction des vaisseaux* can be dated to the end of the XVIIth century. This practical treatise describes, on the one hand, the design methods "suivant la construction ordinaire" (according to ordinary shipbuilding) that is to say according to the practice of the French royal dockyards at the end of the XVIIth century. On the other hand, the manuscript describes the "new" design methods defined by the reverend Father Hoste in a perspective of innovation and progress.

The last document (6) is a treatise written as a note-book by a French naval officer, La Madeleine, whose greatest part of professional activity has been made in the Ponant fleet. The manuscript entitled *Tablettes de marine* is, according to La Madeleine, "le fruit de plus de quarante années d'expérience" (the result of more than forty years of experience). In this chronological context, the oldest architectural references of this note-book are contemporary with Colbert's period of the first navy of King Louis the XIVth.

One part of the manuscript is close to a chapter of the treatise on naval architecture *Elémens de l'architecture navale* first published by Duhamel du Monceau in 1752. In his famous book, Duhamel du Monceau has copied, in reality, from La Madeleine the description of the ships design method called "la méthode des anciens constructeurs" (the method of the old shipbuilders).

The ship design method

These five documents have many common aspects. They describe the same ship design method that La Madeleine has abstracted in this way: "Nos premiers constructeurs, à qui la géométrie n'était pas encore connüe, travailloient à l'aide d'un maître gabary avec lequel ils formoient tous les couples qui doivent intervenir entre la varangue qui commence les façons de l'arrière et celle qui commence les façons de l'avant. Ils donnoient l'acculement à leurs varangues par le moyen d'une tablette sur laquelle ils marquoient les différents acculements des varangues, par le moyen d'un triangle rectangle réduit suivant la progression aritmétique, et ils déterminoient l'ouverture de leurs couples par le moyen d'une buchette appelée le trébuchet sur laquelle sont marquéz les différents trébuchements qui donnent l'ouverture aux couples."

Free translation of this paragraph: "Our first shipbuilders, who had not yet any geometrical knowledge, worked with a master mould. With this instrument, they defined the shape of all the frames which were situated between the two tail frames. They gave the rising of the floor timbers with a wooden scale on which they inscribed the different graduations of the rising. To obtain the graduations, they used the geometrical figure of a rectangular triangle reduced according to an arithmetical progession. They defined the breadth of the frames with a wooden scale on which are inscribed the different trébuchements. ” And La Madeleine precises that between the two tail frames and the extremities of the hull - stern and stem -, the shipbuilders designed the shape of the frames with ribbands.

This ship design method is used for all categories of ships and galleys. However, according to the written sources, the galleys have a particularity. As the ships, their predesigned frames, between the two tail frames, have the three classical modifications: narrowing, rising and breadth narrowing. But they have also a fourth modification or, more exactly, a correction of the shape named in French "le recalement." This geometrical correction, which follows the modification given by the breadth narrowing ("le trébuchement"), is made by a sliding of the two tangent moulds: the floor timber and futtock moulds. This sliding of the two moulds seems look like the "hauling up, hauling down" described in the English treatises. There is, however, an important difference. In the English ship design method, the sliding of the moulds is a primary geometrical modification of the shape. In the French galleys design method, the sliding of the moulds - "le recalement" - is only a secondary correction.

Now, the main question that it is necessary to discuss is the relation between this ship design method of Medieval and Mediterranean tradition and the architectural practice of design attested at the end of the XVIIth century in the French Atlantic Royal Dockyards.

Some elements of answer

A first element of answer can be given by the origin of the master shipbuilders working in the Atlantic Royal Dockyards. The greatest part of these men are of Mediterranean origin as at Brest, in the years 1660-1680, the two provencal master shipbuilders Laurent Hubac and his son Etienne. In Rochefort, the first master shipbuilder working between 1669 and 1680 is François Pomet from Toulon. The famous and mysterious master shipbuilder Blaise Pangalo working at Rochefort and Brest between the years 1680-1690 comes from the Napolitan region.

It seems very probable that these men, whose apprenticeship was made according to Mediterranean tradition, have continued to work in the Atlantic shipyards following their initial education. On this assumption, it seems logical that the builders and carpenters working under the control of men as Hubac, Pomet or Pangalo, were familiar with the ship design method of their masters. An operation as "le trébuchement," in which the upper end of the mould is tilted outward, from a fulcrum at the junction of the futtock and the floor timber, necessitates great precision and professional experience.

A second element of answer can be given by different shipbuilding estimates and graphical documents (7) dated to the year 1679 whose authors are the two master shipbuilders from Brest, Laurent and Etienne Hubac (fig. 2 and 3). The choice of the dimensions quoted in the estimates (for example the length of the main floor timber, the rising of the floor timber of the master frame and tail frames, the height of the entrance and run...) as the choice of the figures (for example, the three main transverse sections, the rising and breadth lines) can be interpreted, from my point of view, as evidence of the Mediterranean whole moulding ship design method.

The third element of answer can be given by a document (8) whose author is probably the famous Blaise Pangalo. The document is entitled "Table des renvoys du dessin cy joint d'un navire de second rang faite à Brest en Août 1680" (indications list of the drawing of a second rate ship of line, Brest, August 1680). The document is a commentary of a transverse section (fig. 4) on which is noted the position of the diagonals according to the Pangalo's method: "En A. La ligne de la hauteur de tous les fourcats et acculement des varangues dont nos Mtres charpentiers n'ont aucune connaisance jusqu'à présent si ce n'est entre les deux gabarits de lof" (A. The rising line of all the cant floors and floor timbers which actually our master shipwrights do not know except between the two tail frames moulds). From my point of view, these two moulds, fore and aft master mould, represent the material and intellectual evidences of the Mediterranean whole moulding ship design method practiced at the Brest Royal Dockyard in the years 1680.

A fourth element of answer is given by the note-book written by La Madeleine. This naval officer has been educated as "Garde de la marine" at Rochefort in 1670. He was appointed lieutenant at Brest in 1680 and commander, always at Brest, in 1703. The greatest part of his maritime activity was made in the Ponant fleet. In this perspective, it seems very probable that his perfect knowledge of naval architecture, "the result of more than forty years of experience," has been acquired close to the shipbuilders working at Rochefort and Brest, that is to say in an Atlantic cultural context. Now, his description of the whole moulding method is one of the best that we have in the French documentation. Moreover, the *Tablettes de marine,* which propose a new method to calculate the tonnage have been examined in 1712 by the commissary of the Rochefort Royal Dockyard, Mr de Beauharnois, and the Conseil de construction du port de Rochefort (council of shipbuilding of the harbour). It is a sort of "imprimatur" of the manuscript.

The fifth and last element of answer is given by a shipbuilding estimate of two ships of line, the *Orgueilleux* and the *Admirable*, two 80 guns'ships. The document has been written in 1690 by the master shipbuilder from Toulon Laurent Coulomb (9). In this estimate, the main dimensions are:

largeur au maître-bau (breadth at midship beam)

longueur du plat de la maîtresse-varangue (length of flat of the main floor timber)

acculement de la maîtresse-varangue (rising of the main floor timber)

largeur (au fort) au niveau de la varangue qui commence les façons de l'avant et largeur (au fort) au niveau de celle qui commence les façons de l'arrière (extreme breadth on a level with the floor timber which begins the entrance; extreme breadth on a level with the floor timber which begins the run)

acculement de la varangue qui commence les façons de l'avant et acculement de la varangue qui débute les façons de l'arrière (rising of the floor timber which begins the entrance; rising of the floor timber which begins the run) longueur des façons de l'avant et de l'arrière (length of the entrance and run)

hauteur des façons de l'avant depuis le dessus de la quille jusqu'au dessus de la lisse (lisse de fond) (height of the entrance since the upper part of the keel to the floor ribband)

hauteur des façons de l'arrière depuis le dessus de la quille jusqu'au dessus de la lisse (lisse de fond) (height of the run from the upper part of the keel to the floor ribband)

trébuchet de l'avant (fore trébuchet)

trébuchet de l'arrière (aft trébuchet)

From my point of view, these different data, inscribed in a naval architectural logic, are the expression of the classical Mediterranean moulding method. The historical importance of this shipbuilding estimate is that it concerns two ships of line, designed by a Mediterranean shipbuilder, but built during the years 1690-1691 at Port-Louis, near Lorient, in Brittany where Laurent Coulomb worked as master shipbuilder. It seems a a piece of evidence that the builders and carpenters that worked in this Atlantic dockyard were necessarily familiar with the moulding method of Medieval and Mediterranean tradition. In this perspective, the "trébuchement" of Mediterranean origin must not be a "mysterious" thing for the workers of Atlantic origin, but a common practice In others words, this document could illustrate the fact that in the context of the French Royal Dockyards, there was a similar technical culture, and the same ship design method, between the shipbuilders of the Mediterranean and Atlantic coasts.

Conclusion

In conclusion, three principal aspects can be underlined:

firstly, the French documentation used for this study has been limited to the Royal Dockyards. We are ignorant of the precise situation of the private shipyards which produced merchant and fishing ships and boats;

secondly, the documents are limited to ships of line. We do not know if the same design method has been used for small ships and boats of war;

thirdly, our French sources - textual and iconographical - are dated to the years 1670-1712. The central question which remains without answer is, from the point of view of the design methods, the potential similarity between the practices of the end of the XVIIth-beginning of the XVIIIth century and those of the XVth-XVIth centuries. Now, this last period is historically very crucial because it corresponds to the first time of the carvel construction along the French Atlantic coasts.

In view of the scarcity of our written sources, it is to be desired that some historical replies be given by future archaeological data. For me as a medieval nautical archaeologist, it will be one of my wishes during this workshop.

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2. Vincennes, Service Historique de la Marine, ms SH 140-1513. Edition of the document in: M. Vergé-Franceschi, E. Rieth, *Voiles et voiliers au temps de Louis XIV*, Editions du May, Paris, 1992, 118 p.

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6. Paris, Musée National de la Marine, library, ms R 711.

7. Paris, Musée National de la Marine, library, plans inv. J2q/10788; J9q/6960.

8. Paris, Musée National de la Marine, library, plan inv. B9e/11201.

9. Paris, Musée National de la Marine, library, ms J 355.

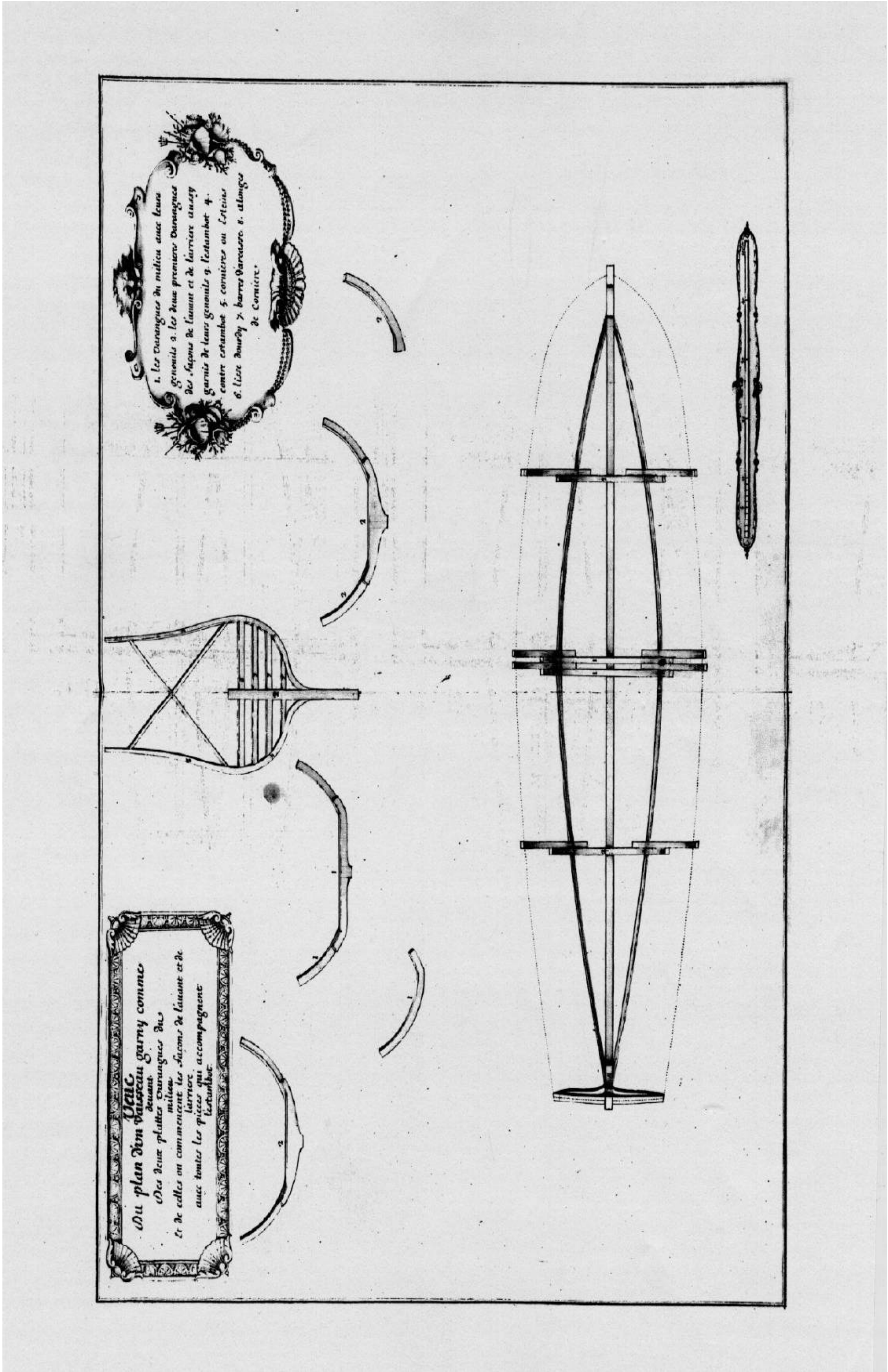

Fig. 1. The principal elements drawn are the two master frames, the two tail frames and the low ribband (in probable correspondance with the rising line). The dotted line corresponds to the breadth line (*Album de Colbert*, plate 4).

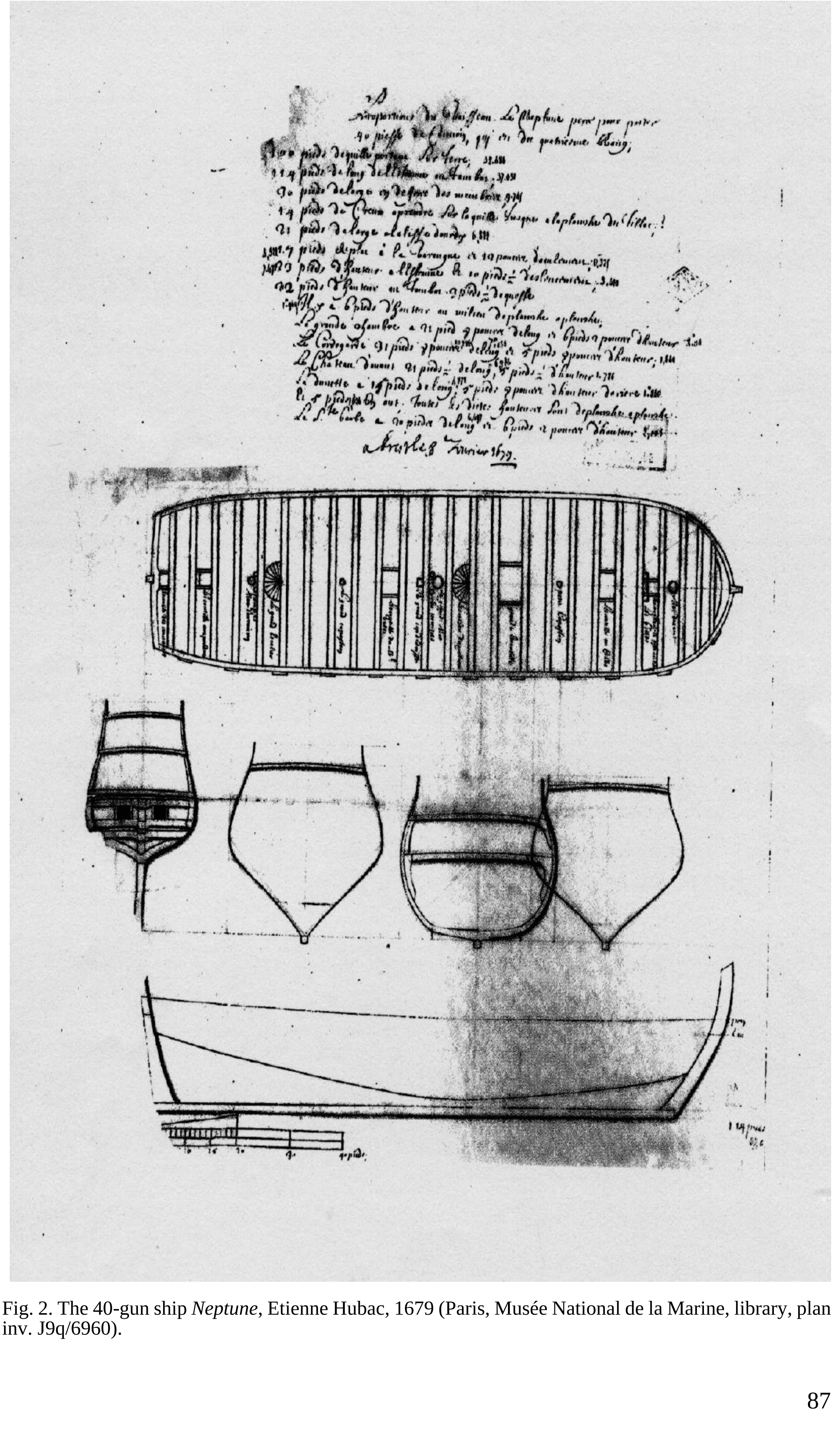

Fig. 2. The 40-gun ship *Neptune*, Etienne Hubac, 1679 (Paris, Musée National de la Marine, library, plan inv. J9q/6960).

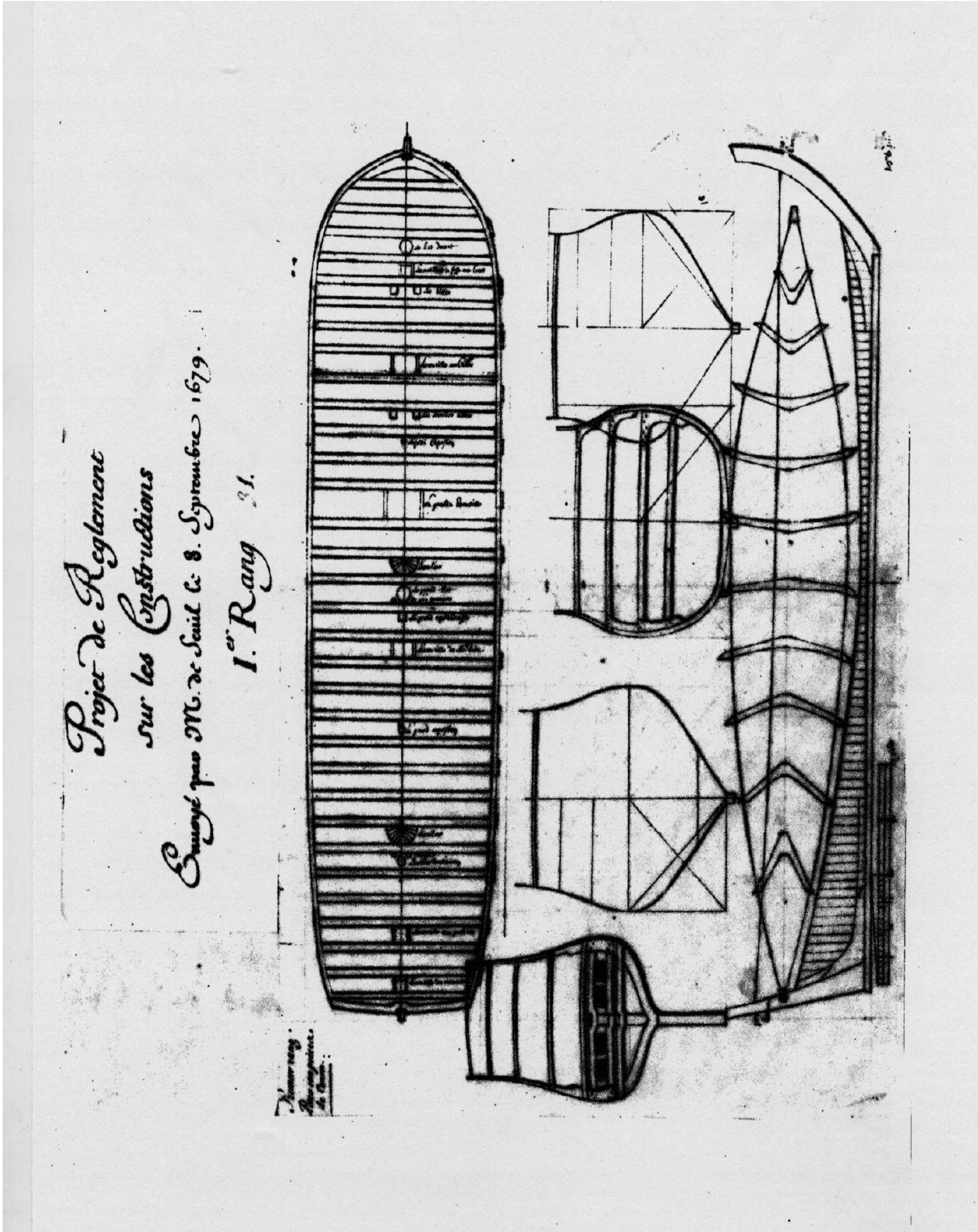

Fig. 3. A 100-gun ship, Etienne or Laurent Hubac, 1679 (Paris, Musée National de la Marine, library, plan inv. J2q/10788).

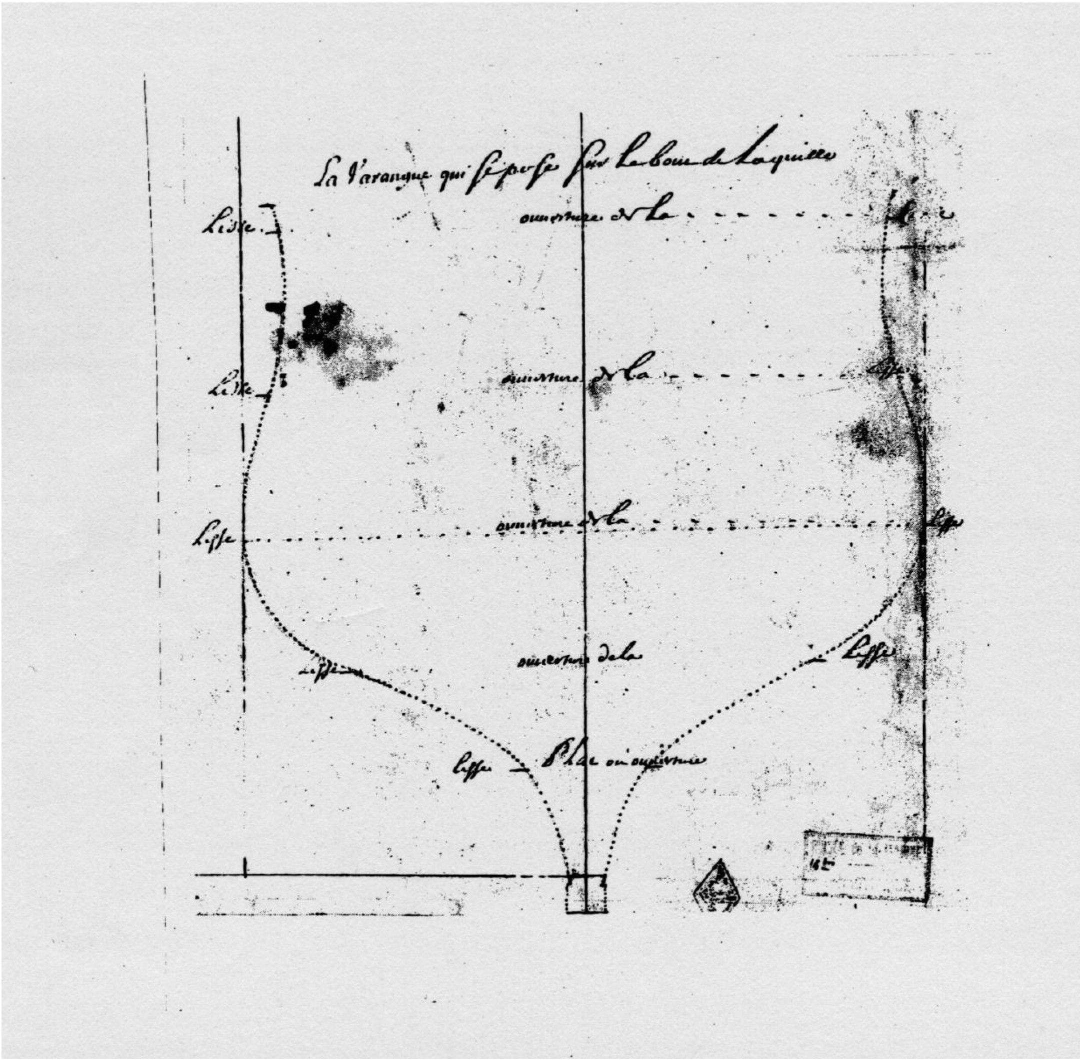

Fig. 4. The "coltis" cross section of a 80-gun ship, 1680 (Paris, Musée National de la Marine, library, plan inv. B9e/11201).

Section II

Shipbuilding Practices

From Wreck to Shipyard: The Example of the Port Berteau II Wreck, France (VIIth c. A.D.)

Eric Rieth

Introduction

The aim of this note[1] is to present the hypothetical operating process of an early medieval architectural project from two points of view: those of the "customer" and of the shipwright.

The Port Berteau II wreck, chosen as example, is situated in the lower part of the river Charente, near the town of Saintes, Charente-Maritime, at a distance of 65 kilometres from the Atlantic coast. In this section of the river, the power of the tide was still important before the building of the Saint-Savinien dam in the second part (1866-1881) of the XIXth century and made easier the relations between the maritime and the inland navigation.

The wreck and its reconstruction

From 1992 to 1997, the Port Berteau II wreck, which has the particularity to be preserved at a depth of 7 metres in an inversed position on the bottom of the river (fig. 1), was excavated under my direction. This excavation is the most recent step of a long research programm of nautical archaeology to study the medieval water transport of the Charente in relation to the paleo-environmental context and the anthropic structures localized in the bed and along the banks of the river.

The chronological data come from three radiocarbon dates and the dendrochronological study of 158 samples of oak. The tests have resulted in the construction of a dendrochronological average of 149 years and in the proposition of dating of the felling during the winter 599 AD. The building of the ship could be dated to the year 600 AD and the shipwreck to the beginning of the VIIth century.

In relation to an ancient depth of the Charente situated between 1,50 and 2m., the analysis of the archaeological remains and stratigraphical profiles have permited to propose an hypothesis for the shipwreck. It seems possible that the ship was laid up on the right bank of the river, near Port Berteau, and that its loss was the result of a flood.

The archaeological characteristics of the wreck indicate, first of all, that the shape and structure of the hull (fig. 2) is connected to a maritime tradition of shipbuilding. In other respects, the carvel strakes (fig. 3), the caulking driven in from the outside of the strakes, the direction of the joint between the strakes and the frames (treenails driven in the frames from the outside of the planking), can permit to conclude that the hull structure was built according to the "frame-first" method. It is not the purpose of this note to discuss the historical consequences of this archaeological evidence of a "frame first" construction in the Atlantic context of the early medieval period. But, in relation to the problematic of the

1. This note abstracts a paper, in press, in the Proceedings of 9th International Symposium on Boat and Ship Archaeology held in Venice in 2000.

development of the medieval "carvel" construction, the Port Berteau II wreck could permit, by its dating, a new reading of this important historical question.

The architectural reconstruction of the hull, founded on the unfolded developed plan of the starboard planking on the one hand, and on 32 transverse sections of the hull on the other hand, has been realized with the collaboration of a naval architect, Marc Ginisty.

The main characteristics of the reconstruction are (fig. 4):

axial structure built on a keel;

14,30 m in length overall, 10,30 m in length of keel, 4,80 m in breadth and 1,20m. in depth in hold;

weight of the hull: 5,7 tons in light condition and 6,8 tons ready to sail without ballast;

maximum burden: about 10 tons.

The operating process: from the "customer" to the shipwright

Through the characteristics of the wreck, two stages of the operating process of the shipyard can be reconstructed. The first, which corresponds to the functionnal choice of the "customer," is revealed by four principal elements. The relation between the length of the hold and the length overall gives a coefficient of 0.591. Compared with other coefficients of early medieval wrecks, the coefficient of the Port Berteau II wreck is one of the most important and indicates that the capacity of freight has been probably the first architectural factor selectionned. The shape of the master-frame (fig. 5) - flat floor-timber, chine with a great arc, vertical sides - is favourable to great capacity and, also, to small draught and good beaching, two nautical characteristics of inland and coastal navigation. The small freeboard - 90 cm. in light condition and 40 cm. in load - is the sign of a navigation in maritime protected waters. The position of a beam in the area of the hold, a little before the middle of the length overall, is evidence for propulsion by sail.

From the point of view of the "customer," the architectural project of the Port Berteau II ship can be abstracted in those economic and technical terms: a sailing merchant ship with a maximum burden of 10 tons, which must be able to navigate along the coast and on inland waters, and to beach with facility on the shore and along the banks of a river.

The second stage of the operating process corresponds to the reply of the shipwright to the conditions expressed by the "customer." Two levels of answer can be determined. Firstly, the shipwright, who, probably, is also the designer, with his knowledge and experience, is able to translate in precise architectural terms the request of the "customer," that is to say: definition of the dimensions and proportions (breadth/LOA: 1/2,9; depth/breadth: 1/4; depth/LOA: 1/11,9), design of the hull, shape of the master-frame, type of structure, method of construction. Secondly, he can define the different sorts of supplies (wood and iron in particular) which are necessary to the materialization of his architectural project.

For this crucial aspect of the operating process, the dendrochronological study has given some precise data. Oak (*Quercus sp.*) was the only species selected by the shipwright. Most of the trees, felled in the region during the winter in a period of vegetable repose, come from the same open area situated at a low altitude. In general, the trees are young, with a diameter of 10 to 30 cm.

The nails give other interesting data. They can be classified into five principal groups according to the shape of their head: nails with triangular, square, rectangular, round and "en bouton" (buttonlike) head. Some groups have particular functions. The nails with triangular head, for example, have been used to join the butts of the wales in the bow and the stern.

From the point of view of the shipwright, the necessity to find oaks, nails, but also oakum and pitch for the caulking of the seams of the planking, involved the existence of an organisation to collect the various marerials and to transport them to the shipyard. One question is concerned with the nautical specificity of this organization. Indeed, an ambiguity exists for some supplies. For example, the nails with triangular head are not exclusively used in shipbuilding but also in house building.

If we examine now the point of view of the "customer," the supplies imply an investment whose nature is different according to whether the "customer" is, or is not, the owner of the forest, the field or the smithy.

The shipyard

The first problem is the identification of the technical operations associated with the building of the "frame first" Port Berteau II ship. The transformation of the oaks into pieces of carpentry is realized according to two methods. All the longitudinal pieces (carvel strakes, planks of the decks) were cleaved and fashioned with axe and adze. The other elements of the hull (stem, stern, beams, frames) were shaped by reduction, with axe and adze, of a trunk, a half-trunk or a big branch. The joint between the frames and the carvel strakes involves two operations: drilling a hole in the planking and the frames and then, driving in treenails, from the outside of the planking. For the butts of the strakes in the stem and the stern, the nails are directly driven in the wood. The same operation is realized for the nailing of the deck planks to the beams. Another important operation is the caulking of the seams between the carvel strakes with a vegetable oakum mixed with pitch and driven in from the outside of the planking.

To cleave, to fashion, to shape by reduction, to drill, to drive in treenails, to nail, to caulk...: these operations must not necessarily be associated with different workmen. Moreover, a nautical specialization does not always seem a necessity. For example, a carpenter of houses can realize the jointing between the strakes and the frames. Nevertheless, other operations as, for example, the placing of the strakes or the caulking of the seams, involve the participation of specialized workmen. Lastly, a responsible of the shipyard seems an absolute necessity to manage, to arrange and to control every stage of the building.

The second problem is the evaluation of the technical level of the shipyard. Using a theoretical unit of measure, according to the J. R. Steffy's method used for the study of the

Serçe Liman wreck, the principal dimensions of the hull form a coherent dimensional system which can be interpreted as a sign of a strict geometrical definition of the architectural project. Our theoretical unit of measure corresponds to 60 cm., that is to say the distance between the two fore crossbeams TRV3 and TRV4. Using this unit, the length overall, for example, is equal to 24 units, the breadth is equal to 8 units, the depth in hold is equal to 2 units, the distance between the mast-beam (TRV 5) and the aft beam (TRV 6) is equal to 4 units... Another illustration of the technical level is given by the plan of the planking. In the aft part of the hull, for example, the planking shows a geometrical organization indicating technical capabilities. Between two strakes of reference (VRG2 and VRG7), which correspond to the greatest breadth and the middle of the chine (fig. 6), the other strakes have a complex shape: their edges are curved and some of their extremities are tapering.

These evidences of technical capabilities can be understood only in relation with experience, past and, perhaps, "tradition," in shipbuilding.

Conclusion

On these conditions, it will appear that the building of the Port Berteau II ship and its regular use as a freighter on the Charente and along the coast could be associated, in the regional economy of rural character, with one of the two regional powers and possible "customers," builders and owners of the ship: the church or some important land owners. In a pre-merchant economy, the agricultural surplus of the ecclesiastical or lay domains and salt could have been the principal freight of the Port Berteau II ship.

References

E. Rieth, C. Carrierre-Desbois, V. Serna, *L'épave de Port Berteau II (Charente-Maritime). Un caboteur fluvio-maritime du haut Moyen Age et son contexte nautique,* Documents d'Archéologie Française, 86, Editions de la Maison des Sciences de l'Homme, Paris, 2001, 154 p.

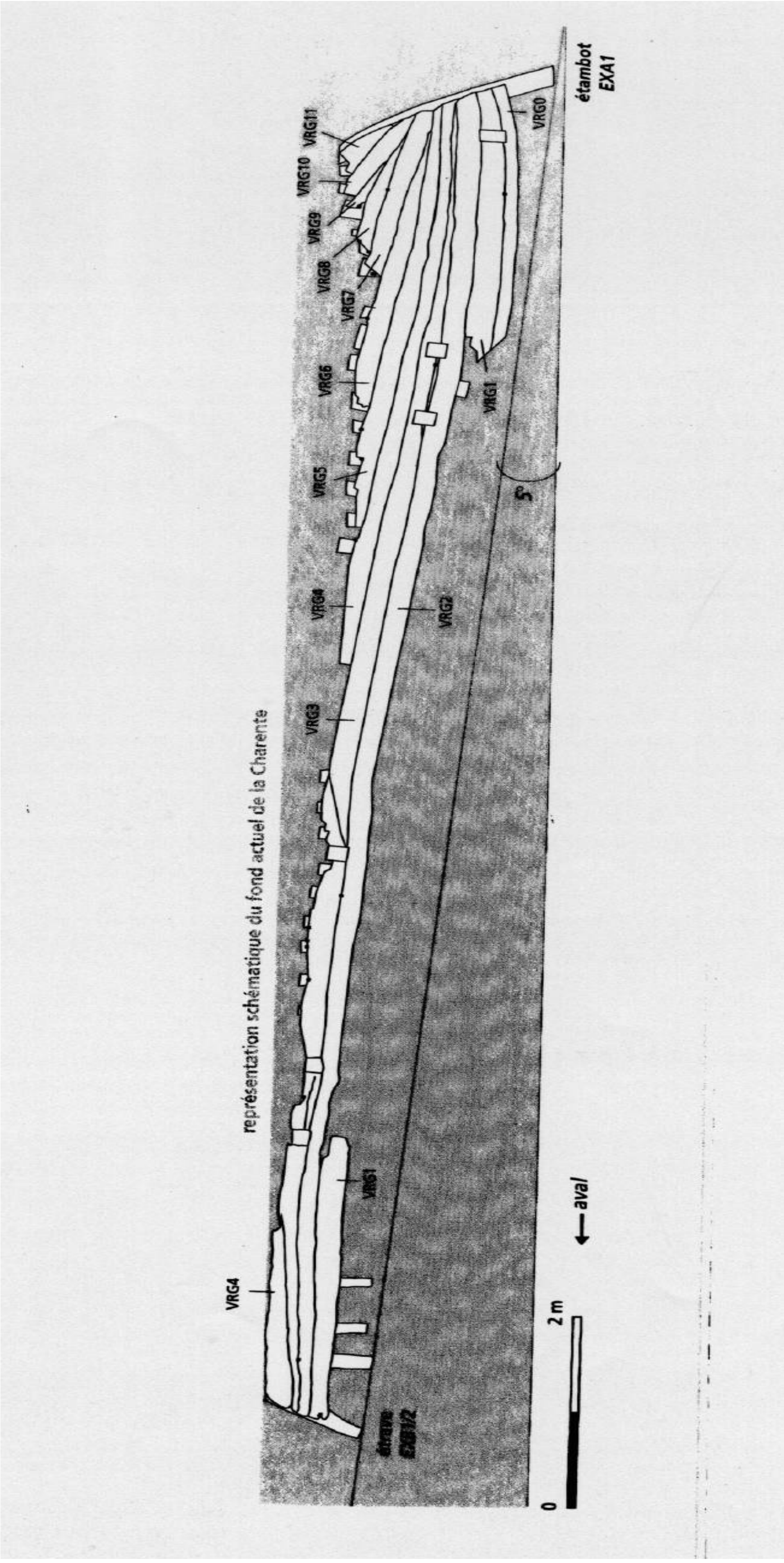

Fig. 1. Lateral elevation of the starboard planking (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 28).

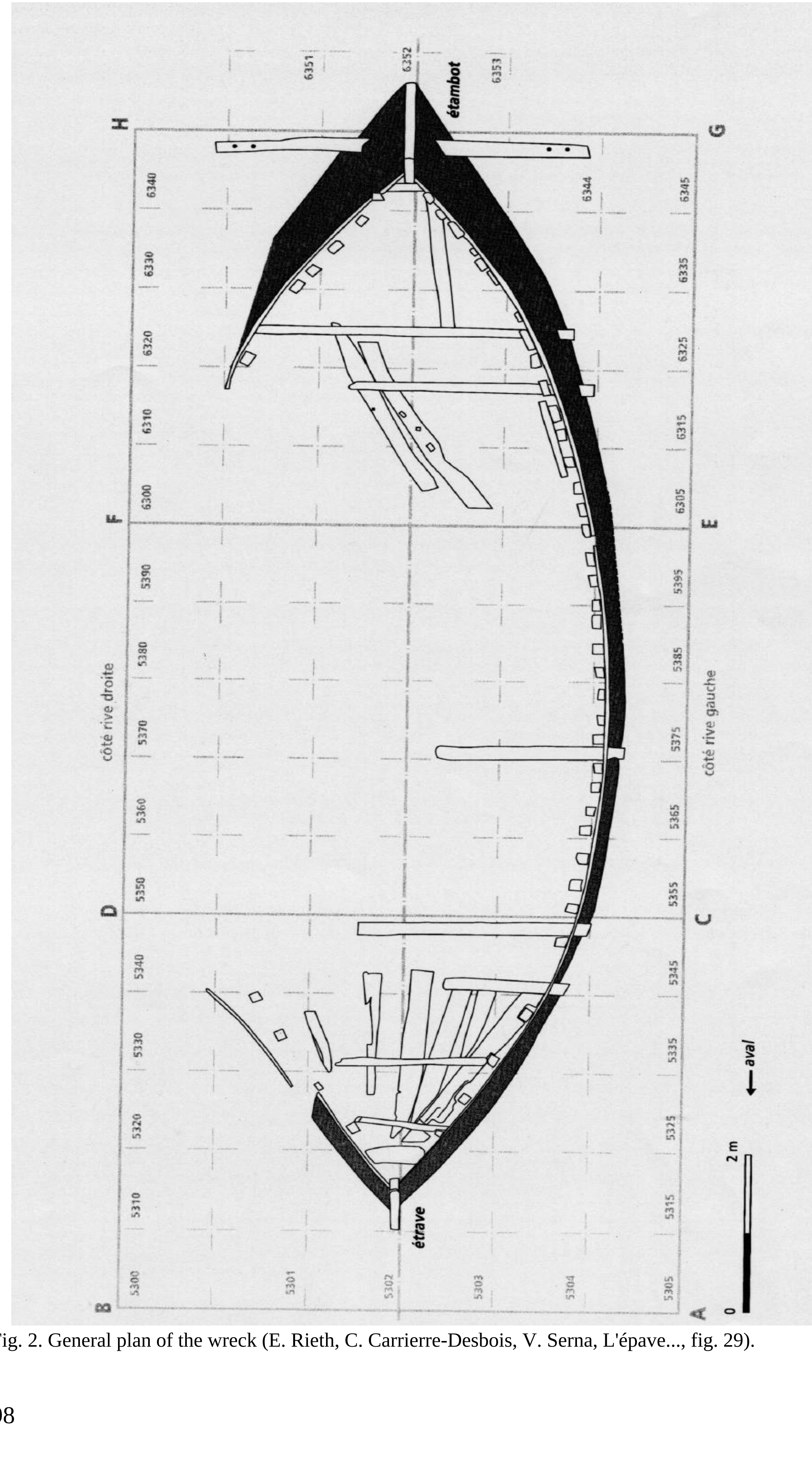

Fig. 2. General plan of the wreck (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 29).

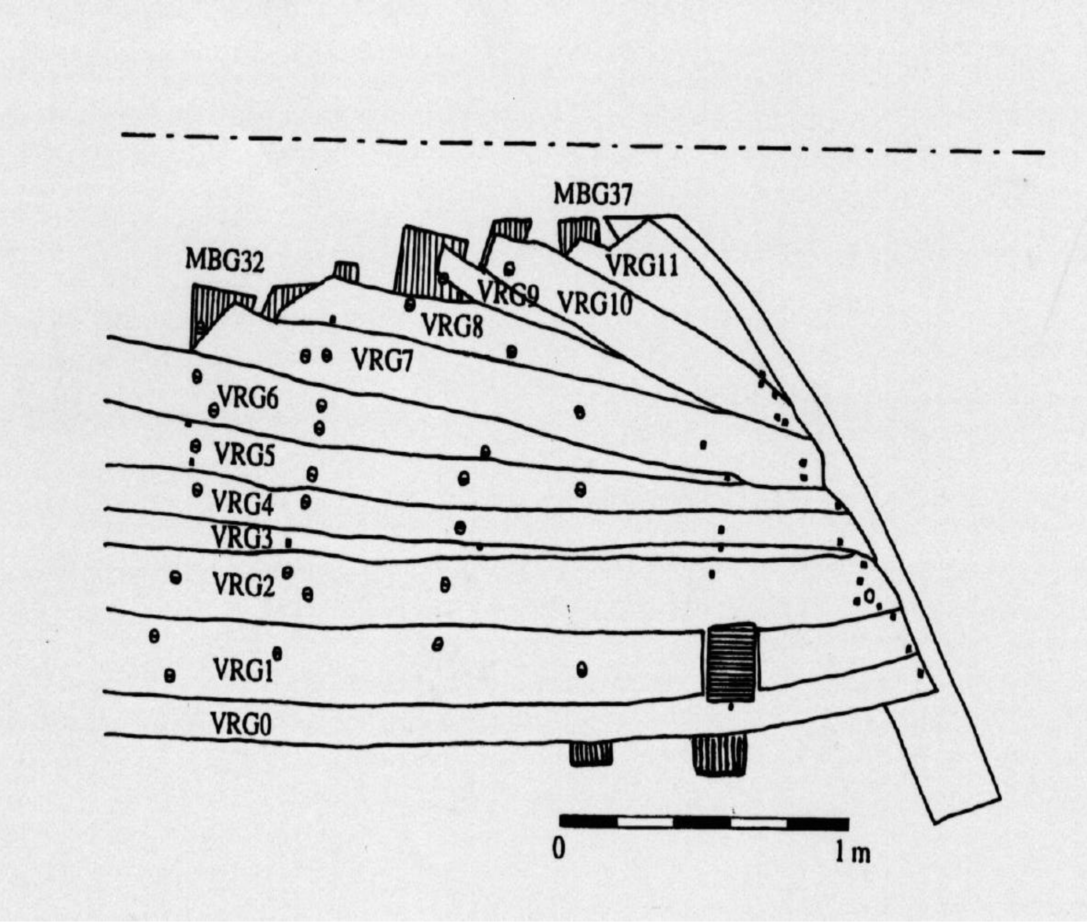

Fig. 3. Aft part of the starboard carvel planking and stern-post (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 73).

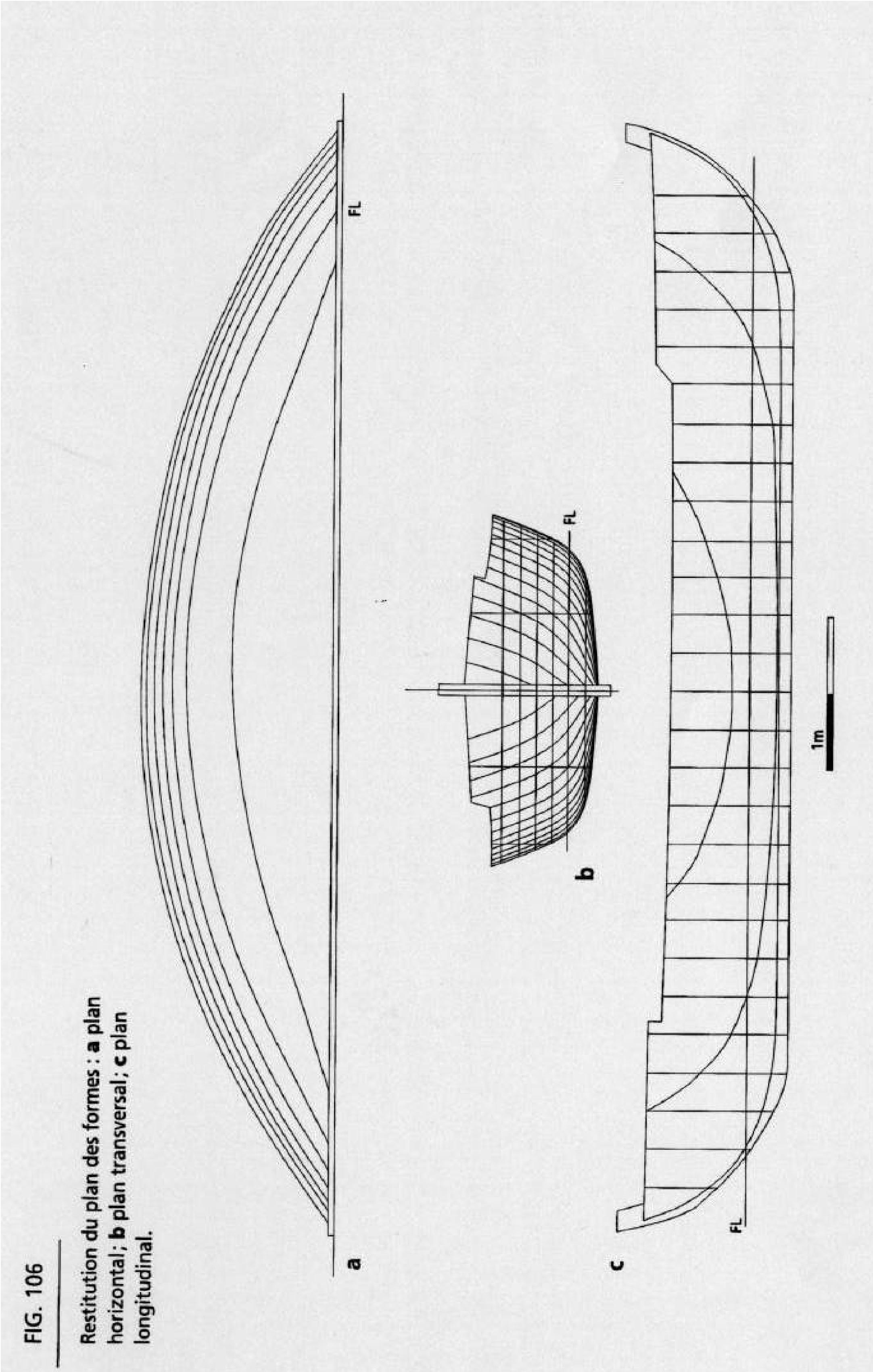

Fig. 4. Reconstruction of the horizontal, transversal and longitudinal lines (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 106).

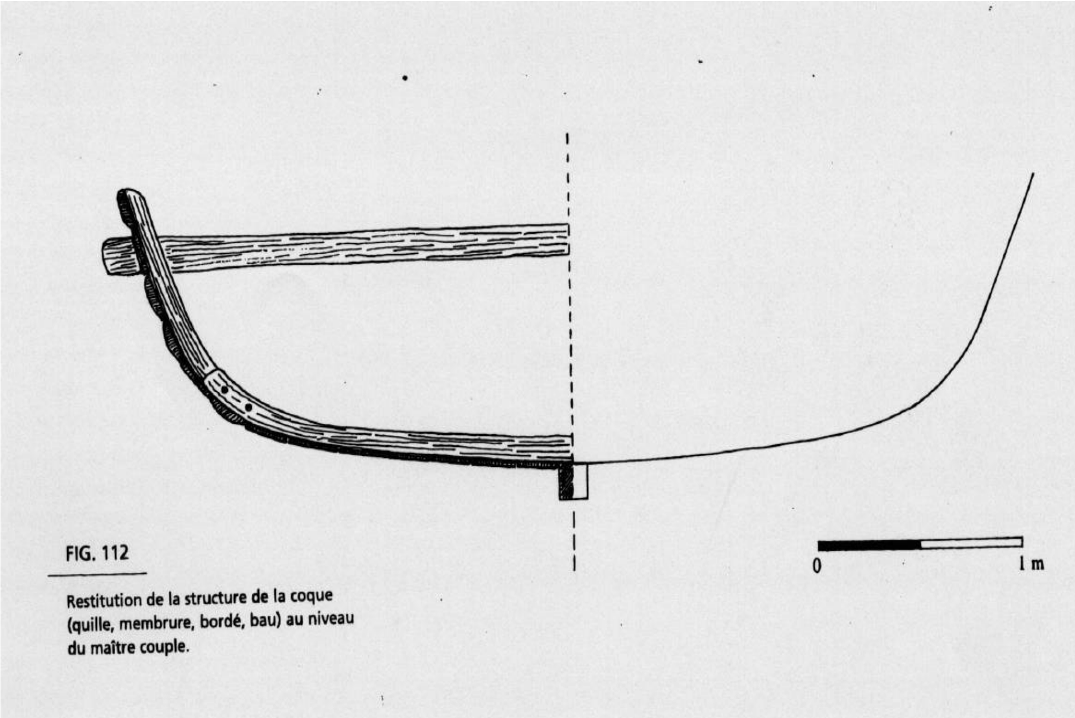

Fig. 5. Structural reconstruction of the master-frame (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 112).

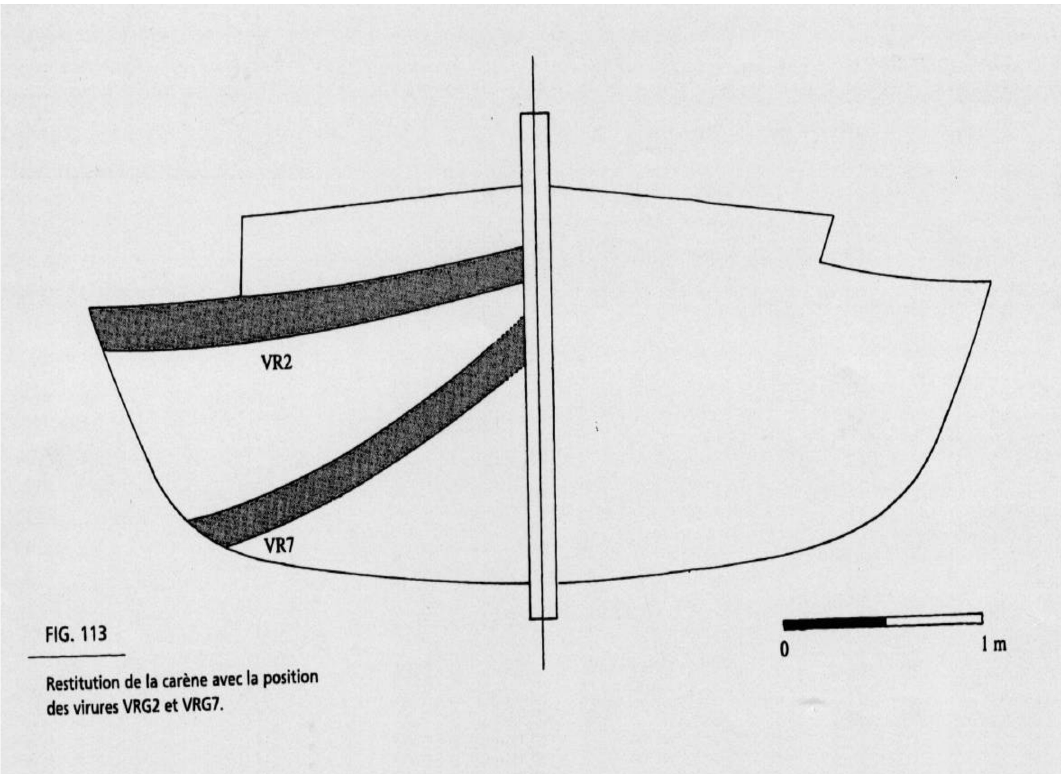

Fig. 6. Reconstruction of the cross-section with the archaeological position of the two planks VRG 2 and VRG 7 (E. Rieth, C. Carrierre-Desbois, V. Serna, L'épave..., fig. 113).

"CRADLES OF NAVIGATION" RE-VISITED

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This paper was originally presented, and published in an abbreviated form, for the VIII Reunião Internacional da História da Náutica e da Hidrografia, Viana 1994, whose theme was the Treaty of Tordesilhas of 1494: "The limits of land and sea" (*Limites do mar e da terra*, Ars Nautica/Patrimonia, Cascais, 1998, pp. 67-87). This text is an up-dated version of the full 1994 text, used as the basis for a presentation in Berlin in November 2001. There is substantial additional material, but only one significant change. The date of the launching arrangements for the *Royal Louis* of 1692 at Toulon (which were always an anomaly, and explicitly noted as such in Berlin) are now presented as contemporary with Chapman's visit to Toulon in the 1750's, and not with the ship of 1692, whose drawings were copied at Toulon by Chapman and others.

"..les Portugais.... estiment qu'il vaut mieux que le vaisseau entre dans l'eau par la pouppe, que par la proue. Ils ont sans doute leurs raisons: mais il n'est point aisé de les découvrir."

Saverien, *Dictionnaire historique, théorique et pratique*, 1758.

"Let's first make it, I'll warrant I'll find some way or other to get it along, when 'tis done."

Robinson Crusoe, ca 1700.

The shoreline represents a natural boundary between sea and land; the last sight of home; the first sight of a distant land, perhaps of a new discovery. It was a major hazard for the seaman, despite the ancient practice of pilotage prior to celestial navigation.

The logic may however be partially inverted. For the ship, it was the first sight of its intended home: but for a ship of any significant size the limit of sea and land was also a most fundamental barrier to navigation. Ships are only built, and to some extent repaired, on dry land. That barrier presented great problems for shipbuilders and seamen alike, that had to be overcome before any navigation was possible. Cradle (*berço*, *ber*) is a good term for the structures created to tend the infant ship on that first short and perilous voyage.

Its significance for a conference on the Treaty of Tordesilhas and the limits of land and sea was obvious. That treaty was to divide the world; more precisely the oceans, as little was known of the lands in question. Without ever larger ships to master and exploit the oceans and new lands that division was meaningless.[1]

1. Some other practical aspects are considered in earlier papers: R. A. Barker, "Careening: Art and Anecdote," in *Mare Liberum*, No. 2, Lisbon 1991, pp. 177-207; "Caravelas, Tides and Water," presented at UNESCO "Maritime Routes," Sagres 1992, published in *Studia* 54/5, Lisbon 1996, pp. 101-125; "Barrels at sea: water, stowage and guns on the Portuguese ocean," in *I Simpósio de História Marítima. As Navegações Portuguesas no Atlântico e o Descobrimento da América*, Academia de Marinha, Lisbon, 1994, pp. 365-379.

This paper will explore some of the evidence for early methods of launching large ships about 1500, and in the subsequent period of exploitation of the new discoveries up to the early nineteenth century; and also for the even more difficult process of hauling large ships ashore for repair; all at the limit of sea and land, but also of technology. The records are sparse until about 1600, and even then difficult to interpret fully, even contradictory. Knowledge of many critical practical details has vanished, and has not yet emerged in archaeological contexts. It is however certain that the methods of launching large ships underwent a profound transition at the end of the seventeenth century, when cradles and slipways developed to allow the largest ships to slide freely to the water. Before that development, and in many places for long after, ships were laboriously dragged afloat in immense temporary structures, "worlds of timber," the cradles of the title. The process could take many days to complete. With skill and good luck momentum may have taken over in some launches, especially of smaller vessels, but that, as will be shown, was not the expectation in most recorded cases. Many of the sources used are necessarily much later material. This will be put in context to explore the general development of methods in Europe, and to illustrate the nature of the original problem. Significant differences emerge between northern and southern European methods. The methods of the industrial age such as patent slips and floating docks are essentially omitted here; and the use of dry-docks for shipbuilding in England from no later than the period of Tordesilhas is similarly only touched upon here.[2]

The resources required to launch a large ship were vast: men, materials, and equipment probably more powerful than that required for any other contemporary application. They would vary in extent and detail with local conditions such as tides. The launching of Brunel's *Great Eastern*, at 12,000 tons launch weight stretched the technology of steam and iron as surely as any earlier large ships had done that of timber, rope and muscle. This ship was the great *nau* of its age, intended to steam non-stop to India and beyond. The launch was a national event, probably better recorded than any other launch. That launch was also protracted, begun in 1857 and completed in 1858; but the challenge faced by earlier shipbuilders was very similar. Indeed features of the cradle can be traced directly back to the cradles for India *naus*, and the records provide insight into much older problems. Only after the shipbuilders' triumph over brute forces at "the limit of land and sea" could navigation begin.

The paper is illustrated with drawings which should be regarded as simplified representations, not exact. Translations given are generally by this writer. Terminology is a problem, but as far as practicable later English terms are used for consistency (see also Fig. Hand-out). Brad Loewen and Éric Rieth in particular have kindly assisted this study with copies of some of the French and Spanish sources.

The North

Chronologically the present evidence starts in the North, and while the methods differ from those recorded from Iberia, they are probably more ancient, and provide points of interest. Two distinct sets of early records can be adduced for launching in northern Europe: late thirteenth century records for English galleys, and for the launch of a small

2. R. A. Barker, "The pre-history of the dry-dock," paper presented at 7th ISBSA 1994; *Archaeonautica*, Number 14 -1998, ed. P. Pomey & É. Rieth, CNRS Paris 1999, pp. 317-322.

vessel in Flanders in the fifteenth century; and seventeenth century Dutch texts. There is a comparable modern example too - *listing*, below.

Twenty galleys were ordered to be built around the coasts of England in 1295, and a number of basically similar summary accounts in Latin survive from their construction.[3] They seem to have averaged about 100 oars, but were still relatively small vessels. Typically the building site was set up specially, and perhaps surrounded with a fence for security. Purchases of scaffolding and alder spars for shores are recorded, and launching seems to have been carried out on rollers running on planks down a slipway dug for the purpose - a delf. At one site (Newcastle) eight labourers were employed for four days in wetting cables.[4] The published commentary suggests that this was to shorten the cable to start the vessel moving down the slipway, but if rollers[5] were in use there is no obvious need for very large starting forces; wetting a cable will only move the hull a very short distance and cannot readily be repeated. The description is however reminiscent of later texts describing wetting the gammonings to help lift large vessels off their keel blocks prior to launching.[6] The hull weight has been estimated as not less than 50 tonnes. Considerable quantities of rope were bought, apparently for the operation of launching. Several similar fragmentary notices have survived for isolated launchings.[7]

The launch in Flanders in 1438-9 was of a pair of small carvels for the Duke of Burgundy, which were built (if not necessarily launched) by Portuguese shipwrights sent for the purpose. Their size is not stated but can be estimated from the work recorded as of 35-50 tons burthen: again, small vessels. The relevant items are:[8]

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3. Collected in for example I. Friel, "The documentary evidence for shipbuilding in England, 1294-c.1500," in C. Villain-Gandosi, et al., eds, *Medieval ships and the birth of technological societies: Vol.1: Northern Europe*, Malta 1989, pp. 139-149. In the 1994 version of this paper it was suggested that unidentified timbers termed *underloute*, purchased for such galleys, may have been part of a cradle. In fact this is ruled out by a derivation of the term as part of a stem in nordic shipbuilding, reported by R. C. Anderson, "The underloute of the Newcastle galley," in *Mariner's Mirror*, Vol.25, 1939, pp. 230-1 (and see also pp. 441-2).
4. Delf: R. J. Whitwell and C. Johnson, "The Newcastle galley, AD 1294," in *Archaeologia Aeliana* 4th series Vol. II, 1926, pp. 142-193. Cables: J. T. Tinniswood, "English galleys, 1272-1377," in *Mariner's Mirror*, Vol. 35, 1949, pp. 276-315 (p. 283).
5. We might note that roller in such a case may actually mean a round-wood bearer that will be greased, but not actually roll. It certainly has no connotation of roller as in roller bearing, and without a prepared rigid surface even a deliberately rounded piece will not roll well, but dig in. They will also tend to crush, discussed further below.
6. *Encyclopédie Métodique, Marine*, Paris 1783, art.: *berceau*, Vol.1, pp. 140-2.
7. At all periods from the classical onwards superficial accounts can be found of exceptional and bizarre launchings, that testify either to man's ingenuity or desperation, but further examples will be omitted on this occasion.
8. J. Paviot & É. Rieth, eds, *Un compte de construction de caravelles Portugaises a Bruxelles en 1438-9*, CNRS, Paris, typescript, nd; (published in *O Arqueólogo Português*, Série IV, Vol. 6-7, 1988-9, pp. 307-31).

> Item for the *estrain* that was put under the said carvel when it was lowered to the ground..... Ii s.
>
> Item for tallow (*sieu*) to pay the said carvel beneath, and the planks (*ays*) on which it was launched into the water.....xxii s.
>
> Item to two men who have worked for eight days to make the ditch (*fosse*) where the said carvel was launched into the water, at three s. per day each, worth.....xlviii s [and another man assisting them for two days.....vi s].
>
> Item to four mariners who hauled upon (*preste*) the ropes to put the said carvel into the water and for the loss of one of the said ropes which was broken.......xxv s.
>
> Item to a man who has put his *escote*[9] across the river to ferry the men to pull the said carvel into the water..... Iii s.
>
> Item for having brought the said ropes and two great cables from the town hall and returning them...... Iii s.
>
> Item to six men who watched (? *alerent*) all night to lower the sluices (*ecluses*: locks?) of the mills to lower (*oster*) the water of the river in order to ensure that the said carvel should come to no harm in launching to the water......xvi s.

We can see similarities with the accounts above. In some way the hull was lowered from its keel blocks, though here it was apparently run directly on greased planks down the slipway dug especially through the river bank. (The volume of earth dug out can hardly have exceeded 100 cubic metres, from the labour recorded; it was a short ramp to the water, rather than a canal). In some way the water levels in the area (on regulated rivers, not a tidal estuary) could be manipulated to facilitate presumably both the digging of the slipway and the actual launch. *Estrain* remains a mystery: possible derivations centre on some form of ropework.

The greased planks onto which the hull was lowered are a possible link to the later methods of the Netherlands, and argue for some continuity between 1438-9 and the first available Dutch records, from the second half of the seventeenth century. For a vessel of this size, and bearing in mind the Dutch practices described below, the operation of lowering may well have consisted of first wedging and levering the hull over onto blocks under one bilge, to raise the keel off its building blocks, removing part of the keel blocks, and then reversing the tilt to lower the bilge blocks it had rested on, successively.

Dutch sources contribute further insights to the processes of building and launching.[10] Dutch methods became divided geographically into two traditions, with a boundary developing somewhere between Amsterdam and Rotterdam during the seventeenth cen-

9. *escote*: small working boat, typical of the Low Countries (modern schoute) - *Le livre des faiz de la marine et navigaiges d'Antoine de Conflans*, MS about 1519, ed. M. Mollat de Jourdin & F. Chillaud-Toutée, 107e Congrès Nat des Soc Savantes, Brest 1982, pp. 9-44. Tinniswood, *op.cit.*, p. 283, indicates that the term *shout* was a small flat-bottomed work boat in England ca 1300.

10. A. J. Hoving, "A 17th century...vessel...research into original building technique," in *Carvel Construction Technique*, ed R. Reinders and K. Paul, Oxford 1991, pp. 77-80.

tury.[11] Van Ijk described in 1691[12] (Fig. 1a) the new procedures of the southern area centred on Rotterdam, in which the shipyard consisted of a floor of planks something over 3 metres wide and some 40 metres in length specifically to spread the load from the keel blocks. These were set up to a height of about one metre. This height was necessary because some of the frames were set up in advance of planking. The bottom planking had thus to be worked on from below. Witsen described the original method still centred on Amsterdam in 1671,[13] and although he has less to say about the structure of the slipway and stocks it is clear that the keel blocks were much lower - perhaps only 0.3 metres above the floor of the yard. This was because the bottom planking was built up before any framing, and was therefore completed while the hull remained much lighter for a given size of vessel. The whole assembly, which had the stiffness and strength of a shell at this early stage, was simply tilted to each side to provide better access to the underside of the planking. Witsen's keel blocks are restrained from movement during this process by posts driven against them. Apart from the fact that the northern Dutch method of building as a whole has obvious links to the methods of mediaeval northern Europe as seen in the remains of cogs, for example, the reasons for the different developments in this otherwise relatively small and homogeneous area are obscure. Historically there has been a much stronger boundary between Rotterdam and Flanders, than between Rotterdam and Amsterdam. Nonetheless it may be that Flanders' role as an entrepôt - for Portuguese trade for example - may have extended to shipbuilding methods in its closer neighbour (only certain aspects of southern European methods were transferred).

The final development of Dutch methods of launching for large ships, at least for the northern area, is recorded in engravings and models from the eighteenth century.[14] Chapman also records the details (for a relatively small vessel) for 1768[15] (Fig. 1b), where it contrasts sharply with the French and English methods. It is quite unlike the methods described elsewhere in this paper in many details. Firstly, there is no cradle. The bilge is supported directly on two inclined planks erected under the bilges: inclined both at the angle deemed necessary for the hull to slide, which might be steeper than the original line of keel blocks,[16] but also transversely to match the angle of the bilge, giving a dihedral effect. This would provide the primary means of securing the stability of the hull during launching, provided the sliding planks (supported on piles of transverse planking that formed the standing way) did not move under the loads applied, either vertically, or sideways under the inevitable wedging action. These ways have no need to extend inland beyond the point of maximum section of the hull. Typically this was forward of midships, and the Dutch continued to launch bow-first, so the launching ways

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11. A. J. Hoving, "Dutch 17th century shipbuilding," in *Model Shipwright*, No. 58, 1986, pp. 28-36; and personal communication.
12. Cornelis Van Ijk (or Yk), *De Nederlandsche Scheeps-bouw-Konst open gestelt*, Amsterdam, 1697 (preface dated 1691; facsimile 1979).
13. Nicolaes Corneliszoon Witsen, *Aeloude en bedendaegsche scheeps-bouw en bestier...*, Amsterdam 1671 (facsimile 1979).
14. Nederlands Scheepsvaart Museum, Amsterdam, displays many such, including a model of *Hercules*, 1782, Catalogue RS566(2).
15. F. H. Af Chapman, *Architectura Navalis Mercatoria...*, Stockholm 1768 (and various facsimiles), Plate LXI.
16. Compare David Steel, *The elements and practice of naval architecture*, 3rd edition, London 1822 (first 1805), p. 394.

were relatively short. The ways were built upon piles of planks set at close intervals, and they were heavily shored laterally to posts driven along the slipway. There were also means to reinforce the guidance of the hull, built around the keel: either a series of grooved blocks, or a channel formed of planks in place of the original keel blocks. If there had been any vertical load transferred back to these pieces, the hull would have tended to fall sideways: they can only have been intended to guide it in a straight line while its weight remained on the two standing ways. Interestingly these ways are markedly steeper beyond the end of the building area, but no indication is given of their extension beyond the water's edge. It is almost as though the whole ship is intended to pitch forward into deeper water as the bilge moves forward (indeed this appears to be happening in the frontispiece of Van Ijk's book, the bow of a small vessel plunging, and the stern rearing up from the ways), but at great risk that the stern would then ground heavily dynamically, as buoyancy lifted the bow (Fig. 2). Witsen has a similar illustration, showing the point of rotation. It is difficult to see how it could work unless the bilge is firmly supported at least until the stern is clear of the end of the building slip, making the method suitable only for vessels with long flat floors. It also required deep water adjacent the slip; such a site would not serve for hauling ships ashore. Van Ijk himself remarked (the translation is by courtesy of Albert Hoving):

> ".. some years ago it happened that a ship fell over on its side while being launched, the sliding plank being too low and loose. One of the planks was pushed aside, and the ship stopped on the slipway, hanging at the stern, where it burst open almost beyond repair. For this reason (I am told) the Portuguese build their ships with the stern low, to go into the water first."[17]

We will return to this final point later.
Minor details such as the shores and dog-shores, and rope restraints to guard against premature movement of the hull, and the sequence of removal of keel blocks, and the provision of drivers to start the hull are all very similar to other methods in Chapman's time, and described below. It is a conspicuous consequence of this method that the hull is effectively supported at only two small areas at the bilges during the launch. It may therefore have been much less suitable for large vessels, unless the frame timbers were reinforced to suit. Severe hogging stresses are also set up in the hull.

At about the same date as Van Yk, Rålamb in Sweden published his *Skeps byggerij….* in 1691. The author had studied both English and Amsterdam shipbuilding, preferring some aspects of English methods, but in a well-known plate shows stages of construction in two Dutch methods, bow to water. The final stage has a ship ready for launch, with a very conspicuous dagger-shore from the hull planking (indeed Sutherland's drawing of 1711 is strangely reminiscent of this detail - see below). Judged solely on the lines in the plate as reproduced there appear to be longitudinal standing ways ending under the bilge, in the Dutch fashion, but real detail is not discernible. The text[18] refers to bilgeways squared from old masts, and they thus seem to be sliding with the vessel, on transverse groundways alone: not the Dutch method. The hull is packed up off the bilgeways, and there is no support under the keel. The figure also shows single shores

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17. Van Ijk, *op.cit.*, p. 94. Hoving comments that most ships launched by the methods described had a draught on launching of around one metre.
18. I am indebted to Lars Bruzelius for a working translation of text linked to Plate I, Fig. 4.

fore and aft (like the later English spurs) from the bilgeways to a wale, to prevent the ship falling over (in the apparent absence of poppets).

A model[19] in the Royal Danish Naval Museum is of a large ship, *Tre Lover*, representing its launching in 1730. This appears from the photograph (p. 47) to be in the Dutch method, bow-first, with standing ways raised under the bilges, but no cradle. There are drivers placed at the stern, and heavy tackle between the water's edge and a cable suspended round the sternpost: clearly free-sliding was not to be relied on here.

Before turning to Mediterranean and Iberian methods, a few other primitive methods may be noted. One published text describes the preparations for the launch of a "galleon" of some 500 tons in Poland in 1571.[20] The ship itself was built by Venetian shipwrights. It was launched with a cradle made from three specially purchased large tree-trunks (needing six horses to haul each one), and ten smaller "tree-trunks" which were only on loan - and were perhaps rollers, if they were not to be altered. This text contains two other intriguing references: to testing watertightness of the hull before launching by partly filling it with water; and for loading ballast in barrels - perhaps for convenience of handling, or for lack of suitable stone. It may also be noted that shipbuilders (like seamen) were itinerant, and must have taken their own local methods with them, but equally may have adopted the methods of others as they observed something different or better. In the case of Portugal, many aspects of shipbuilding can be traced to early employment of Genoese shipbuilders from the twelfth century,[21] and this must extend to methods of launching, as we shall indeed see below.

Three similar examples may be mentioned from other areas. One recent Greek method for small vessels was to place a pair of tree-trunks under the hull, one under each bilge, and large enough to extend below the level of the keel, and running on rollers. Another method of handling the great weight of the hull during operations such as lowering it, avoiding damage from levering on small areas, and reducing the risk of supports slipping, was to pack sand-bags under it, cut away the original supports, and then burst the sand-bags.[22] As described, this was to lower the hull sideways to rest on a standing way laid at one side of the keel, and reminiscent of the account of 1439 from Flanders. A method observed in Madras about 1850 used coils of rope packed with sand, which were slowly unwound to lower the hull.[23] Such simple practical devices may have been widely used, unrecorded, within more complex operations on large ships - and most notably for the Flanders carvel which was explicitly lowered by otherwise unknown means.

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19. Illustrated in S. Dayton, "Orlogsmuseet," in *Model Shipwright*, No. 94, 1995, pp. 38-48.
20. J. Litwin, "The first Polish galleon and its construction register from 1570-1572," in *Carvel Construction Technique*, ed. R. Reinders and K. Paul, Oxford 1991, pp. 56-60.
21. Octávio Lixa Filgueiras, "Gelmirez e a reconversão da construção naval tradicional do NW (séculos XI-XII).....," in *Bartolomeu Dias e a sua época*, ACTAS II, Porto 1989, pp. 539-576.
22. Kostas Damianidis, personal communication.
23. Captain H. Congreve, Madras Artillery, "A brief notice of some contrivances practised by the native mariners of the Coromandel coast, in navigating, sailing, and repairing their vessels No. 4: Description etc, of the Mud docks," in *Madras Journal of Literature and Science,* Vol. CXVI, Madras 1850, pp. 101-4.

Sometimes passing references testify to the use of brute force. Pyrard de Laval observes in 1610: "I have also seen an elephant draw ships and galleys ashore, or launch them afloat," and reports that for beaching in Cananor a century earlier (1501) "they put the side of the vessel foremost, and under the said ship they put three pieces of wood, and on the side next the sea I saw three elephants kneel down and with their heads push the ship on dry land." In the time of Akbar (1593) an unusually large ship was built that took 10 days to be launched by 1,000 men - capstans not being in use at that time; and while in 1501 it was customary to launch with an elephant on each side of a ship, this had been abandoned since the elephants sometimes caused the death of seamen.[24]

One method noted by Ollivier in 1736 from France,[25] though declining in use, was to actually launch the vessel "on its keel." This required the supporting grid to be built up to the keel, and a form of bilgeway which he terms *coite* (not unlike the *coënte* of later cradles' bilgeways), was actually fastened directly to the hull, so that the hull was supported in three places. This has some similarities with the Dutch method. The *coite* was only removed on first careening of the vessel. Ollivier clearly dislikes this method, which he states was prone to premature movement, and to overturning of the ship. It was also, he adds, damaging to the hull, for lack of adequate support, and much more difficult to restart the launch if movement stopped.

This method is what Bouguer describes in 1746,[26] though with fewer reservations; and ostensibly only the vocabulary differs between Mediterranean and Atlantic France.

Something very similar was in use around St. Malo in the early twentieth century, to launch *Terre-neuviers* of around 350 tonnes hull weight, which has been described in some detail, with the contemporary French terminology.[27] The slipway here was extended on timber trusses into deep enough water.

There is even a record from the East coast of England from the first half of the twentieth century,[28] which clearly indicates that early Northern methods survived for smaller vessels, in parallel with developments for larger ships. The account is for wooden fishing drifters of around 28 metres length, launched at a yard near Lowestoft, where the method was known as listing. A standing bilgeway was established under one bilge, consisting of long lengths of "hollows," baulks with the upper surface hollowed out. On this was placed a single long "round." The mating faces were smoothed and greased (with a mix of horse fat and Russian tallow, which was liable to seize in cold weather) as the sliding surface. The vessel was then jacked up on the other side, until it rested on the round, at its bilge, packed up as necessary. A similar arrangement was then constructed under the keel, in place of the stocks, and the hull lowered again. The hull was then winched to close to low water mark, shifting the hollows from the bow end as it passed,

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24. Laval is in A. Gray, *The Voyage of François Pyrard de Laval*, Vol. II, Part II, Hakluyt Society, Vol. LXXX, 1890, pp. 127, 344; these and other references from Varthema are given in A. J. Qaisar, *Indian responses to European technology and culture*, 1982, OUP Delhi, pp. 26, 33.
25. Blaise Ollivier, *Traité de Construction....*, MS dated 1736, published Nice 1992, Art.: *lancer un vaisseau*, pp. 225-7; *berceau, belier, languette*.
26. P. Bouguer, *Traité du navire de sa construction et de ses mouvements*, Paris 1746, pp. 73-9.
27. J. Le Bot and A-M Gautier, "Le lancement des terre-neuviers," and P. Servain, "Les lancements à Fécamp," in *Chasse-Marée*, No. 115, 1998, pp. 14-29. Kindly provided by João Pedro Vaz.
28. E. Frost, *From tree to sea*, Lavenham 1985, pp. 137-148.

to extend the ways to the water. The ground surface steepened near the water, and a more conventional launching was arranged for the final descent on the next high tide.

Mediterranean methods

The most useful notices available from primitive Mediterranean methods for launching are Crescentio's in 1607, and a representation of the Venice Arsenal purportedly from 1517[29] showing galleys and larger vessels supported on piled blocks under the bilges - which if correctly drawn cannot be the original keel blocks for initial construction, though they may take the place of shores. The same methods had clearly also spread to Portugal, as revealed by the use of the Italian term *vaso* in Portugal no later than the first half of the fifteenth century, noted by Carbonell Pico,[30] and presumably derived from the older Mediterranean galley tradition:

> "So many people joined in the work of putting the galleys on their *vasos* and launching them that most were launched by hand, *without capstans*….."

- a significant phrase, as we shall see. At the far side of the world, a shipbuilding village might still have to assemble a thousand men to push one of their new vessels (no larger than Vasco da Gama's) into the water by hand.[31]

Crescentio had heard a garbled account of the tides of the Gulf of Camboia, which he describes as a great convenience for launching in comparison with the difficulties of the Mediterranean. He then describes the Italian techniques used for galleys and larger vessels, based on the use of articulated bilgeways, supported from the hull by ropes, and moved on rollers. While it is not a clear description (despite reference to hollow boxes, the *vasi* are drawn as simple planks on edge, for example), the elements for larger vessels are identifiable (Fig. 3):[32]

> "Therefore certain square beams are made, which they call *vasi*; but because these have to be easy to manoeuvre, and need to be dragged along the ground, and of little weight, they make them of four planks, so that they remain hollow (*vuoti*). These *vasi*, which in a galley are generally six, for the ordinary [galleys], joined together, form the base of the cradle (*letto*) in which the vessel which has to be launched is put.
>
> Upon this vessel, at the stern and at the bow, are put other similar timbers, which they call cross-pawles (*crocere*) and *sifutti*, which embrace the stern and bow of

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29. Museo Correr, Venice. Reproduced in C. Thubron, *The Venetians*, Amsterdam 1985, pp. 78-9. G. F. Bass, *History of sea-faring,* shows that it is inscribed as an eighteenth century copy of an original dated 1517.
30. Maria A. T. Carbonell Pico, *A terminologia naval portuguesa anterior a 1460,* Lisbon 1963, p. 518, citing Lopes, *D. João I*, I CX 212.
31. G. A. Horridge describes the circumstances and ceremonies for "200 ton" vessels launched by hand in *The Konjo boatbuilders and the bugis prahus of South Sulawesi*, MMR40, Greenwich 1979, pp. 22-3. H. H. Brindley describes launching of Siberian river boats of about 150 tons capacity about 1850, by gatherings of over 400 pushing on long poles, in a note in *Mariner's Mirror*, Vol. 3, 1913, p. 187.
32. Bartolomeo Crescentio, *Nautica Mediterranea...*, Rome 1607 (written by 1601), Book I Chapter XIV, pp. 85ff.

> this vessel, and so that it cannot fall or hang to either side. These *crocere* and *sifutti* are raised upon certain timbers which are called chocks (*tacchi*, cf Fr. *taquet*). In the place where one *vaso* is joined with another, is put a pin (*perno*) of heavy timber, which is called *suggio*, and projects on the inside, so that a rope may be fastened onto this which they call *embrese*, which following the side of the galley goes to and is fastened to the outrigger (*baccalaro*) of the galley; and in that manner is the galley secured to its cradle. Rollers (*palanchi*) are set at every six *palmi* [about 1.5 metres] under the cradle, which serve in place of wheels. Tackles work upon (? *lavori*) certain iron rings, put in to this end from one side to the other, in the *vasi* of the cradle towards the stern, as the present example of the cradle of a galley demonstrates.
>
> The ordinary galley is launched by hand with only the rollers underneath, and the mast tackle (*prodani*) and when they are near the shore, the tackle is lifted from the *taglie*, and is put at the stern of the cradle into tooth A, which is made in the upper part of the *vasi* at the stern, and passing a hawser (*gumenetta*) to another galley in the sea, and these slaves pushing the sides of the cradle, and others hauling on the tackle, and all at the same time the galley making a good pull of the oars (*arrancata*), they will easily launch the new galley."

Larger vessels require the intervention of capstans in addition to the heaviest gear normally carried on galleys for their mast and yard tackle, the *prodani*. The cradle is structurally incomplete: something must have prevented the *vasi* separating under the hull, presumably ropes.

The Savona archives contain a record of the loan of eight beech *vasi* by a shipbuilder in 1575.[33] These were some eight metres long, probably sufficient as a set for any local vessel, arranged as in Crescentio's drawing.

The drawing from Venice shows piles of baulks with alternate layers in different directions, just like those drawn by Lavanha for his keel-blocks, but placed at intervals under either bilge, apparently in addition to keel blocks as such. There is no indication of the relationship between these blocks and any *vasi*; but one vessel appears to have an isolated bow-cradle corresponding in part to later forms. Some of the hulls are ostensibly located broadside-on to the adjacent basin to which they would presumably be launched; and this may be related to a later account of launching galleys at Malta where the vessel was turned before launching (Teonge, below). It is perhaps unwise to place too much faith in this painting, as though the extant version is said to be a copy of an original of 1517, the hull forms at least have certainly been up-dated in the copy.

A painting of the Marseilles arsenal about 1670 by J-B de la Roze[34] shows a number of galleys being built behind walls that prevent their launch directly to the water. They must be moved more or less sideways a considerable distance before launching, though unfortunately the details of any arrangement for achieving this are not evident. This too may reflect what was described for Malta at the same period. These Mediterranean galley cradles were suitable only for longitudinal movement, and transverse movement on the narrow *vasi* must have required some form of standing way, not rollers.

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33. Personal communication, Furio Ciciliot, 17 June 1995.

34. Painting in the Musée de la Marine de la Chambre de Commerce, Marseilles.

The great timber cradle

The next major source chronologically (1616) is Fernandes[35] (Fig. 4), who is of course describing the largest cradles of the whole era, for an India *nau*, an order of magnitude larger than Crescentio's vessels. He calls the cradle *e(m)nvazadura* (modernised as *envasadura*), clearly related to the original *vasi*. Fernandes was evidently a master shipwright, and approached his text from the point of view of a carpenter: the term great might well serve to describe a group of cradles. His drawing, although carefully to scale and containing two projections, is incomplete, and the vocabulary and syntax partly a mystery, but it is clear that he combines his *vasos* - in this case three lines of them under each bilge - with the piled baulks supported upon them to form cribs (*casas* - crib being a convenient rendering rather than an exact term). These are interlocked with multiple rows of *dragas*, which function as daggers, to hold the blocks carrying the hull's weight in their place. Pairs of daggers would in later methods be bolted either side of the poppets fore and aft, clamping them rigidly in line, and it may be supposed that Fernandes' *dragas* are their forerunners. The origin of the English term dagger for this context was apparently unknown in the early nineteenth century, and it may conceivably be a phonetic corruption from the *dragas* of these cradles.

In each case the problem is to support the weight of the hull upon the *vasos*, which form an articulated bilgeway, although the contact at the upper end of the support is steeply inclined at the ends of the hull, and will tend to be pushed sideways. Fernandes notes a difference in height of five *palmos de goa* (1.23m.) for his cribs across their width, matching the slope of the hull, which would be extremely difficult to fill with stable wedges: his text and drawing are incomplete and details are unclear. One major puzzle is that the layout of the *vasos* in plan follows the curve of the bilge: so do the cribs; and they appear to overhang the *vasos* by a considerable margin. By comparison with the later straight bilgeways and poppets and stoppings-up set upon them, this must have made it very difficult to fit the *dragas*. It does allow the height of the cribs to be minimised while providing maximum lateral and structural support at the bilge. The spread of the bilgeways appears over time to have become progressively less as a proportion of the ship's breadth, which helps to reduce the height of the cribs, stoppings-up and poppets, and the slope of the hull where they meet; but this also changed the nature of the support to the hull, and there may have been a relationship with developing systems of framing, for example, to permit it to happen. Such factors are far more significant in large vessels, but there is as yet no documentary or archaeological evidence to explore this further.

The tendency for the *vasos* and everything above them to separate is controlled by a heavy cable stretched across under the hull at every joint in the *vasos*. (The *Great Eastern* had the luxury of long North American timbers beneath the hull and of iron bars, but serving the same function). All the longitudinal strains of dragging the weight of the hull are carried through the *vasos* by the heavy pins, one *palmo* square linking all the *vasos* at every overlap. It is possible that this articulation is simply for ease of assembly of necessarily short components, but also that it was necessary to compensate for imperfect groundways. Interestingly, the *vasos* at the head of the cradle are turned up quite

35. Manuel Fernandes, *Livro de Traças de Carpintaria*, MS 52 XIV 21, Biblioteca da Ajuda; facsimile Academia de Marinha, Lisbon, 1989. Text ff 54r-56r, drawing ff 79v-80r.

markedly, as though to prevent their digging into the ground: did the groundways not extend far enough, then? That is certainly the implication of their stated length. It seems from this aspect that the hull was built with the bow towards the water, though it is not explicit (not least plan and elevation differ).

Items that are unclear are how the heads of the cribs are restrained, and how the complex of drag ropes are attached to the hull, and to the machinery - anchors and capstans - necessary to haul the hull and cradle. It is virtually certain that they are comparable to those described throughout the next two centuries in other sources.

Gaztañeta's manuscript of about 1688[36] (Fig. 5) contains a similarly confused and incomplete account for a relatively large ship launched at Colindres in Cantabria. He too was a master shipwright. While the vocabulary is equally resistant to formal translation, it is clear that this method reflects an advance during the intervening 70 years. The cribs of Fernandes' cradle are now substantially replaced towards the end of the hull by individual inclined shores, probably in several rows across the width of the bilge, and all held in place by runs of daggers, bound across the shores by lashings at each intersection. (The upper dagger is drawn as single and is behind the poppets, unlike the later dagger plank. This may relate to the fact that in these earlier methods the poppets were actually restrained by the gammonings below the keel; though in this case they are not actually drawn). The bilge is supported through the central section of the hull on a solid mass of chocks and wedges, which also raised the hull clear of the keel blocks in the final preparations for launching. (What would later be called stoppings-up, longitudinal timbers directly under the bilge on which the chocks and wedges act, are apparently still absent - certainly from the drawing). The bilgeways (*bassos*, retaining the name though apparently not the form of the articulated cradles) are drawn as single timbers, almost as a convention. In practice these and all later bilgeways for large vessels would be made up from numerous lengths of very heavy timbers, all carefully jointed, and made smooth on the underside to ensure that they ran easily over the groundways. In this case the bilgeways seem to be joined by heavy timbers beneath the keel; though heavy ropes are in evidence in the text. There are already dog-shores acting between the groundways and the bilgeways to prevent the cradle moving prematurely; and some of the terminology indicates that driving shores, wedges and levers (*palanculas*) are all set up to start the cradle moving. These devices are an express statement that the first movement was vital: once moving the force needed was reduced (see below). The building slip appears to be relatively level, and then cambers away steeply to the water. Some considerable force would thus be necessary to move the cradle initially, and the effect of such uneven support to the hull cannot have been good, leading to severe hogging of the hull during launching (though there seems to be a reference to broad wedges required to support the stern "when the bow lowers"). This may be one reason why ships were almost immediately careened (or in England docked) after launching. There is no evidence here of launching ways extended beyond the immediate building area: see discussion under slipways.

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36. Antonio de Gaztañeta Yturribalzaga, *Arte de Fabricar Reales*, MS notebook ca. 1682-90, published Gonzalez, Apestegui and Garcaia, 2 Voll., Barcelona 1992. Drawing f 236v, text (mostly headings without text) ff 237-241. Facsimile is Vol. II.

An English account of 1636 refers to the cradles used to launch ships by the Portuguese, actually in Goa.[37] The form of the cradle is not specified, but may be as that of Fernandes:

> "At our being here was launched a new galleon of 14 foot by the keel, as they say [*sic*: possibly *rumos* - 21.5m.], being first blessed, Christened, and named *el buen Jesus* by the Archbishop that came over in the carrack aforementioned. She was launched in a device wherein she was built, called a cradle, which is a *world of timber* made up and fastened on either side to keep her upright, and so with cables, capstans and a multitude of people, they forced her into the water, the way[s] being first very well timbered and tallowed. There was another on the stocks. They are very long a-doing and issue at excessive rates [cost]. I went aboard the carrack formerly mentioned. She is said to be of 1,600 tons, of a strange form, her beakhead in such manner and so capacious that [it] would measure near 20 tons, and the biggest longboat in our fleet would easily lie in her fore-chains; 12 main shrouds of a side; steered below with tackles fastened to her tiller; all monstrous strange methought."

Most large English ships were built in dry-dock, and needed no such vast cradle, whence the amazement at sight of such as Fernandes drew. Another English account of launching a Portuguese ship is given below - Barlow.

On the other hand, the term cradle was not unknown in England, even when launching from dry-dock. Butler has the following definition:[38] "a framed piece of timber.... Brought up and raised all along the outside of a ship by the bilge when she is in dry-dock; and it serves to launch a ship with the more security out of this dry-dock. And in some parts these cradles are also used for the same cause, when any of their great ships are brought only to be trimmed; and they are trimmed in these cradles." This latter remark concerns the grounding of vessels for graving, re-caulking, etc.

Smith adds that it was a frame of timber much used in Turkey, Spain and Italy for more ease and safety in launching.[39]

Albums

The next record to note represents a transition not so much of cradle construction (it is one or two decades earlier than Gaztañeta's), but of recording. Although unpublished at the time it is almost more readily classifiable as the first of the encyclopaedias than as a shipwright's record of carpentry. The Album de Colbert, anonymous and only datable to the period just before 1677, and reflecting the methods of Toulon, contains a drawing of a launching operation which places the emphasis on the tackle required to haul the ship to the water. It is a perspective view, and finely detailed by comparison with earlier records. It is the first to record the tackle (Fig. 6), and the means of anchoring the hauling forces offshore (capstans on grounded "pontoons," drawn as cut-down hulks in this

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37. R. C. Temple, ed., *Travels of Peter Mundy in Europe and Asia 1608-67*, Hakluyt Society 2nd Series Vol. XLV, Cambridge 1919, p. 59.
38. W. G. Perrin, ed., *Botelier's Dialogues*, Navy Records Society 1929, p. 145. Botelier was Nathaniel Butler, b. 1577).
39. John Smith, *A Sea Grammar,* London 1627 (facsimile 1970), p. 1.

case). The heavy grillages of groundways are clearly drawn as forming a plane surface and to spread loads over the rough ground of the shipyard. The bilgeways are again drawn as single timbers, though this was a fiction. The cradle (Fig. 7) has poppets fore and aft, but they are also continued along the bilge, interspaced between every second crib (though not yet as the later *colombiers*, as these spanned the bilgeway and stopping up). The cribs now show more clearly as alternate layers of baulks and wedges, built up to support longitudinal timbers called *coutelas*, literally cutlasses. One is under the bilge, effectively similar to the later stopping up; and the other is under the bottom, extending the whole length of the poppets fore and aft (and although it is not so drawn, almost certainly having the function of the English dagger-plank, nailed to the hull planking to act as a shole or sole-plate for the thrust of the poppets as the text implies). The function of the poppets is not just to shore up the hull, but to anchor the loops of the gammoning (three to each) which pass under the keel.

The main part of the hauling tackle is a set of very large multiple pulley blocks, fastened either to posts driven at the water's edge, or suspended from the transom on either side of the sternpost (it is a bow-first launch). A second set is similarly set up, but is lighter, and hauled directly by men, not a capstan: its function appears to be partly that of steering the cradle if it deviates, by pulling on one side, and slightly out of the line of launch. No guide ribbands have appeared yet. The text is not descriptive, but a catalogue referenced to numbered items on the drawing,[40] headed:

> "Profile [*sic*, but actually a perspective] of a vessel with all the necessary dispositions for it to be launched, borne and supported on the groundways (*parats*), the bilgeways, dagger-planks, poppets, complete with their gammoning (*lieüres*), chocks, wedges and transoms for strengthening the cradle (*vassade*), and other necessary apparatus such as pulleys, cables, *prode* or *caliorne* [triple blocks], the two pontoons grounded forward and well moored and held back astern, on which the capstans of each of them are rigged with their bars and the men necessary to turn them."

It is conspicuous that the tackle is set up not just to start the movement of the ship, but to act upon it over at least the full length of the ship: it was clearly expected that it would have to be dragged afloat. This emphasis on the tackle is a feature of subsequent French accounts, starting with the group of descriptions and proposals of 1702-3 for hauling ships ashore, published by the Royale Academie des Sciences, and described elsewhere in this paper.

The encyclopaedists: the carpentry cradle

The final group of sources to be described are eighteenth century, and may best be classified as a group as by encyclopaedists: they are the product of educated men, and were probably intended for publication, though not all reached that stage. These sources enable us to place the key date of transition in French methods between about 1677 and 1736. The cradles themselves have become less massive, more carpentry; but are not certain to slide freely.

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40. *Album de Colbert*. MS about 1670-7, Plate 29. Facsimile, Nice 1988.

Sutherland provides an early English example.[41] This is actually a limited account, but in the glossary to launch is "*to lower or slide* a ship off from the land into the water," and his "bulgeways" are simply "a piece of timber placed on each side of the bulge, to slide a ship." No other terms appear. The clearest feature is a massive dog-shore, which suggests a risk of premature sliding. Sutherland is concerned about the foundations of his slip, distinct from house foundations. If there is the slightest risk of settlement, he wants the ship to pass that point fast; but he prefers a gentler descent, to prevent her plunging too much and striking the ground. He makes a pretence of demonstrating that if the inclination of the slip is too great, the ship will accelerate disproportionately fast, but cannot quantify it. The keel is placed on splitting blocks, easily removed, above transverse groundways, which suggests that the hull is slid on the two bulgeways alone. The text mentions no sliding planks, but the plate, crudely drawn, could be interpreted as showing them, though the line could equally represent small ribbands to keep the bilgeways running in line. The bilgeways seem to be drawn out of scale, but with stoppings-up and poppets above them; they also have holes bored at both ends for ropes. The problem is compounded in that the plate shows a heavy longitudinal member between the bilgeways but above the transverse groundways, and running the whole length of the ways, and apparently below the keel, and not referred to in the text (Fig. 16). Another curious feature is the very conspicuous dog-shore reminiscent of the 1691 drawing by Rålamb: not only is it very prominent, but it acts directly on the breadth of the hull: while there is a cradle interposed between the ship and ways in Sutherland's method, a short dog-shore between bilgeway and ground would be quite adequate.

Ollivier represents the full transition, with a treatise dated 1736[42] that provides some of the best practical material of all, some of which has been noted above. He described bow- or stern-first launching as optional, and expects many but not all ships to slide freely, after initial resistance is overcome. He needs drag ropes to stop the ship drifting too far, for example. He does however say that vessels had not always been launched in such a simple manner with sliding cradles. The old method of capstans and tackle (*caliornes*) had been in use only a few years before, and was indeed still used by some. When ships had started to slide with this old method, the capstans could not keep up; in fact there were all sorts of hazards described for either method.

He has the following to say of the variant method noted above, where *coites* are secured to the bilges in lieu of a cradle - launching "on the keel":

> ".. Appears simpler than that of the cradle but is subject to various inconveniences. It often happens that the vessel forces its dog-shores and starts before they have been withdrawn, which puts it in danger of overturning. One has seen some examples. If it stops, it cannot fail to suffer greatly, because all its parts are insufficiently supported, and when it is stopped it is more difficult to move than when it is found in a cradle.....[the cradle is] preferred to the other in the ports of the ocean, where, formerly, all shipbuilders launched their vessels on the keel. Only the method of launching them in a cradle is in use in all the ports of the Mediterranean, and it is

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41. William Sutherland, *The Ship-builders Assistant*, London 1711, pp. 24-5 and plate (there is a facsimile, Rotherfield, 1989). Kindly drawn to the writer's attention during the Berlin workshop by David McGee.
42. Blaise Ollivier, *Traité de Construction, op.cit.*

> there very ancient. A kind of chariot is used in some ports of the ocean to launch boats."

Ozanne produced a series of ink sketches about 1765-70, another album in fact, with labelled features but without commentary.[43] They illustrate the process of launching from the construction of the bilgeways on, and including the means to start a ship that would not slide freely. That is, Ozanne represents the methods of Ollivier. The great size of the pulley blocks is clear; they are supported on temporary chocks on the sternpost (no rudder can be fitted in such methods of course). A pontoon fitted with a treadwheel is hauling from offshore, and the *arc-boutant* - a raking prop or lever acting on the sternpost - is having its wedges being driven, to lift and drive the sternpost. Ozanne's is also the first illustration to make it plain that the new bilgeway for a large ship was not actually a single timber, but was composed of many lengths, and at least two layers, all coaked and lapped to act as a whole. The stoppings up (*ventrières*, belly pieces) appear in the central section, above chocks and wedges. The poppets are now vertical (*colombiers*), but retain their gammonings (*liures*).

Bouguer, in his *Traité du navire* of 1746, gives a description of what is clearly the same process as Ollivier's launching on the keel. He gives vocabulary, noting the differences between the Mediterranean and Atlantic areas of France, though perhaps not reliably, as will be discussed below. That is, he is apparently describing methods that we might expect to find in Toulon, in connection with the *Royal Louis*. He also has a longer passage describing the damage that arose on launching, and the hogging that followed as the vessel went afloat. While his information is interesting, it is also superficial.

The frontispiece of Duhamel du Monceau's *Élémens de l'architecture navale* of 1758, shows a ship arranged for stern-first launching, but the text does not describe launching.

Chapman in 1768[44] reproduced a formal drawing of launching arrangements ostensibly for Toulon in 1692 (Fig. 8), with some descriptive text. The caption reads: "No. 1 shows the arrangements for the launching of the 112-gun ship of the line *Royal Louis*, built in 1692 in Toulon with a length from stem to sternpost of 193 feet, a breadth of 52.5 feet, and a draught of 28.33 feet (Swedish feet). The figure shows how far construction had advanced by the time when she was launched. *This method is still used by the royal yards*."

It has to be noted that representations of the several *Royal Louis* have caused immense confusion in the past, summarised by Anderson.[45] In essence, there is little doubt that Chapman's drawing is intended to represent the 1692 ship, and that he probably copied the original plans in Toulon, which he visited during his travels in the 1755-6.[46] His

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43. Musée de la Marine, Paris; published as *Deux Albums de Nicolas Ozanne (1728-1811)*, ed. J. Vichot, Paris 1977.

44. Chapman, *op.cit.*, also Plate LXI.

45. R. C. Anderson, "Review of *Le Sabord* 5; *Modèles de vaisseaux pour l'instruction des Princes*," in *Mariner's Mirror*, Vol. 18, 1932, p. 330.

46. The introduction to a 1969 facsimile of *Architectura Mercatoria Navalis* states that Chapman visited both Brest and Toulon. D. G. Harris, *F. H. Chapman*, London 1989, p. 20, states that he witnessed the construction and launch of a 60-gun ship at Brest in 1755-6, but does not mention Toulon. The *Royal Louis* drawing is *prima facie* evidence that he did visit Toulon as well.

plans agree broadly with the copy preserved in the Danish Archives,[47] a slightly smaller ship than the vessel commenced at Brest in 1757 in the newly-completed dry-dock there.

However, the launch arrangements, while no great surprise for the 1750's, are anomalous for 1692. This is a full engineering arrangement drawing, albeit to a small scale; the contemporary original source has not been located, except that it has great similarity to Bigot de Morogues' work - see below. It differs from that of the Album de Colbert: the cribs have been replaced with stoppings-up in their final form, and there is far more precise detail. The method is still similar, though: a series of rope gammonings under the keel are used in conjunction with wedges within the stoppings-up to lift the hull clear of the keel blocks just prior to launch.

Details typical of Ollivier in 1736, Bouguer in 1746, and even the Album of Ozanne in 1765, are missing in Chapman's drawing. The heavy starting lever, the *arc-boutant*, for example, the drag ropes and tackle. This is however a stern-first launch on a sophisticated cradle, and there are ropes placed to restrain, rather than to drag the ship, unlike the details of the *Album of Colbert* of 1677. On balance, it seems probable that such a cradle was seen by Chapman in the 1750's, and is not contemporary with the 1692 ship. In this case, the difficulty in the early version of this paper (noted prior to the Berlin workshop), where it suggested anomalously early stern-first launching and free-sliding, compared with all other French sources located, is removed.

Interestingly, the drawing of a launching arrangement given by Bigot de Morogues in his manuscript *Traité* [48] which dates from close to 1750 and has a context of Brest (indeed the description refers to tidal ports), is for practical purposes the same method as illustrated by Chapman, though in this case for a 64-gun ship. Its content is probably post-1738, as prior to that date Morogues had been an artillery officer. The technical content and drawing style are indeed so similar that we may suppose that the method observed was identical, or even that direct copying took place, by Chapman at least. That may reinforce doubts about the Toulon element of Chapman's caption, too? Morogues' drawing is provided with an extensive key for the components. The term for the lashings between the bilgeways is *traversalles*, and the cross beams above them are the *traversins*, for example; he also includes an *arc-boutant de chasse* acting on the stem, with its starting wedges, missing from Chapman's drawing.

There is a more elaborate description of the *avant-cale*, the extension of the ways to the water (but not beyond). The first layer are the longitudinal *corps-morts*, on which transverse *grillages* are placed, with shorter pieces between them in three lines to maintain their separation, the *entremises* and *clefs*, the whole being tree-nailed together, and the result is reminiscent of the *grade* in Fernandes. Under the ship itself the ways are raised by longitudinals called *longrines*, usually in several layers at the bows, on which *gril-*

47. R. C. Anderson, "The *Royal Louis* of 1692," in *Mariner's Mirror*, Vol. 28, 1942, pp. 246-8 and Plate 1. These two plans have 15/16 ports per tier, and a ship some 5 metres shorter than the record of the 1757 ship, which has 16/17 ports per tier. Sections in the bow and stern are also significantly different. Data for the latter ship was kindly provided by Larrie Ferreiro. (There is also an article on the various *Royal Louis* and their plans by J. Boudriot in *Neptunia* No. 112, Paris 1973).

48. Jean Boudriot, *Les vaisseaux de 50 et 64 canons*, Paris 1994, contains text and drawing of the *Traité de construction* by S-F Bigot, vicomte de Morogues.

lages are placed, between the stocks and with only two lines of *clefs*. The *coite* or stopping up is supported on chocks (*chantiers*) and wedges (*coins*). The poppets (*colombiers*) have a lip (*adent*) at their feet, to locate them on the bilgeway, and notches for the rostures near their heads. There is no dagger plank in this arangement, but the heads of the *colombiers* are cut to the moulds of the hull. The *rostures* are specified as white-rope - untarred, as they are to be wetted to shrink them. There are no sliding planks, only a guide ribband on each side. One new feature is that the edges of the *grillages* are to be chamfered - *abattre la vive arrête*. In theory at least, the ship will slide freely as soon as the final shores and keys are removed.

A warp (*grelin*) is attached to the hull on each side, to bring the hull under control after launching. The rudder is omitted at launching, and the gudgeons are protected by packings (*coussins de sape*) on the sternpost from impact with a raft of old masts (*drome, estacade*), placed to brake the ship as a drogue.

Another brief text from this period appears in Diderot & D'Alembert's *L'Encyclopédie*, dated 1765,[49] which appears to draw heavily on Saverien of 1758.

The most complete text for this drawing however is that of V** in the *Encyclopédie Métodique Marine* of 1783.[50] The procedures are more fully set out, including for example the need to allow the ship to adjust slowly to the strains of transferring it from keel blocks to cradle; of wetting the gammoning to increase its tension; drag-ropes to halt the ship when it floated; buoying the cradle, etc. His bilgeways were to be about 0.55 metres square, separated by struts, and held together by additional gammoning between them.

The provisions of Chapman's drawing of the French method are also to be found in a Spanish engraving[51] from a much later date. The 50-gun frigate *Restauración* was launched in 1825/6, and the details are broadly the same, still using three sets of ropes under the keel from the tallest poppets. The engraving overall is original, with a slip cut out of a steeper bank, and a dog-shore being pulled out with an ox-train, so there is no reason to doubt that the remaining details are contemporary, despite their archaic appearance.

Chapman is the first to refer to sliding planks between bilgeways of a cradle and standing ways, but only for the English method, published in 1768 (noting that elsewhere a sliding plank was an alternative to the cradle). Falconer's *Marine Dictionary* of 1769 has a text description under *launch*: "...the ship is supported by two strong platforms, laid with a gradual inclination to the water, on the opposite sides of her keel, *to which they are parallel*. Upon the surface of this declivity are placed two corresponding ranges of planks, which compose the base of a frame called the cradle….. Daubed with soap and tallow." He further indicates that the ways were generally extended far enough for the ship to float at the end of them, and that while starting screws were still provided,

49. *L'Encyclopédie ou Dictionnaire Raisonne des Sciences,* Vol. IX, art: lancer. There is also a set of plates dated 1769.

50. Encyclopédie Métodique, Marine, op.cit.

51. In the Museo Naval, Madrid, reproduced in E. Manera Regueyra et al., *El buque en la armada española,* 1981, p. 260. Date from J. P. Merino Navarro, *La Armada Espñola en el siglo XVIII*, Madrid 1981, p. 254 and n265 (p. 325). The launch was at Ferrol, possibly as late as 1827 (Duro).

ships usually slid as soon as the shores were removed. First rates were usually built in docks: the 100-gun *Britannia* was the largest ever launched from a slip in England.

However, Chapman's published launching text is probably based on his notes for the launch of a 50-gun English vessel in the early 1750's.[52] It contains a number of points of interest (text modernised):

> "Then lay your blocks and let their declivity be 3/4 inch to one foot [1:16] and hang 3 inches in the length of the keel, allowing your ship to drop afore and aft when she comes into the water. Let the foremost block be 3 foot 6 inches high, or according to the declivity you intend the launching ways, for the keel to go clear of the after part of the slip. The distances of the blocks one from another about 6 feet except the fore and after part of the ship, and there to be closer together to prevent the fore and after body from settling [comparable to the uneven weight distribution that causes hogging afloat]. Allow the splitting blocks to be 11 or 12 ins thick and to be as clear from knots as possible, and a cap of 5 or 6 ins thick according to the thickness of the false keel. The remainding part [of the blocks] to be of any rough thick pieces.
>
> Then begin about the launching ways, their declivity to be 1-1/2 inches to a foot if the depth of water will admit of it and if the water is not deep you must make the declivity [less] accordingly. The length of the bilgeways to reach forward to be able to fix a driver on the foremost end of each bilgeway, and to go under the lower cheek of the head; the after end to be about 12 feet afore the after part of the post, the outsides of the bilgeways to be 1/3 of the extreme breadth and the slip to round up about 3 inches in the length of the bilgeways. The bilgeways to be properly secured with chocks and sprigs at their ends and a plank pricked up to the bottom and treenailed through each shore and to have 3 spurs and a driver afore, and 4 spurs aft, with a long thick piece of fir fayed down between the chocks and the spurs and bolted through all and belayed with rings and forelocks, Number all the blocks and when you have split out all blocks except the 5 or 6 foremost ones, then cut down all the whole [whale?] shores except about 10 of a side clear aft under the wale taking care they stand against the ship, then cut away the after shores, first keeping people ready to cut away the rest when the ship starts. Mind in bolting the spurs that the bolts are above the light draught of water, and number all the blocks for the better giving orders what blocks to split out."

The English source most comparable to the *Encyclopédie Métodique Marine* is probably Steel's *Elements and Practice of Naval Architecture*, first published in 1805, from which the English vocabulary has been taken[53] (Fig. 9). It is worth commenting that in each language the vocabulary of launching is a considerable problem. Bilgeways and sliding ways, standing ways and groundways are confused in different descriptions, contemporary and later; daggers and dagger planks; the parts of stoppings-up, and wedges or slices, all cause confusion, partly because they are transferred from one method to another where the function and arrangement may not actually be exactly the same. Translation tends to confuse matters even further, not least because there is no English equivalent for the ropes under the keel. The French *rosture* is now given as

52. D. G. Harris, *F. H. Chapman*, London 1989, p. 20, 204-12.
53. Steel, *op.cit.*, Plate IX and pp. 394-6, and glossary.

strictly a woolding (as on a mast), which is not a correct term in its launching context: it is not a seizing, nor a strop, but nearest to a gammoning, as on a bowsprit. Steel has lashing for the similar ropes preventing spreading of the bilgeways, but that is not a normal usage of lashing. The early Italian, Portuguese and Spanish terms have often disappeared from any other context: there are sometimes are no known equivalent terms in English.

Steel calls the launching cradle a "grand piece of mechanism and requires every consideration." One pertinent comment is that cradles of his generation were greatly simplified, with the benefit of experience. He is strictly referring to the omission of the spurs formerly used in English cradles (as drawn by Chapman for example), that were a dozen or so frame-shaped shores bolted to the bilgeways and to the hull, for additional security in preventing the hull falling sideways, but complicating the process of separating the hull and cradle. He might as well be summing up the two centuries of development from the "worlds of timber" to the simple, if still massive, carpentry cradle of about 1800.

One interesting feature that only Steel refers to is that the cradle was first assembled piecemeal, cutting each piece to fit, and then dismantled in order to grease the bilgeways and sliding ways just before launching. The grease was a mixture of tallow, oil and soft-soap. This probably gives a truer reflection of the time and effort required to construct these huge cradles, but also to the critical effect of the loss of grease squeezed out during the first slow movement of the cradle (The problem continues to this day. The mix of lubricants is carefully controlled, and they are placed as late as possible, to avoid material degradation, with consequent increased friction, and loss under pressure, especially at high temperatures.[54] Tallow may be used as a hard coating on the timbers, covering the grain and minor irregularities, with a softer mineral lubricant between. The fact that ways caught fire is evidence that past practice was very imperfect).[55] Ollivier refers only to tilting the bilgeways with jacks to grease them. Steel also gives more details of the bilgeways (using decayed spars in part in his example), and joints between the parts, all snaped to prevent their fouling the joints of the sliding planks, and with all nails in these sliding parts punched a whole inch below the surface of the timber - itself a good indication of the violent nature of the movement of the cradle.

In addition Steel gives some quantitative details, for the launch of a 74-gun ship. The bilgeways are 140 feet (42.7m.) in length, 30 inches deep and 28 inches broad (762x711 mm.). The 23 poppets each side are to be of fir, 26 inches (660 mm.) athwartships (though they are drawn nearer 14 inches (356 mm.) square for the 40-gun frigate of

54. It was discovered in the twentieth century that there is a slow interaction between tallows and fish-oils or soft-soap, the traditional materials, which adversely affected lubrication: the tallow was softened, and amalgamation of the layers took place. This not only made starting the ship more difficult, but increased the likelihood of squeezing out the vital sliding surfaces. Tallow was also highly variable with animal species (Russian bear tallow was favoured) and other factors, but also with temperature, affecting its ability to withstand high bearing pressures without squeezing out. It also degraded if re-used.

55. Nonetheless, that is not surprising: the potential energy of the vessel and mechanical energy from any drag force employed will be primarily converted to velocity of the vessel, and heat. The heat is generated at the sliding surface, in relatively small quantities of material, and with any imperfections in the support and surfaces this would be concentrated on localised areas. Rubbing sticks together is after all a potent method for creating fire, simply converting mechanical movement into heat.

Plate 9); dagger planks are to be 3 inch (76 mm.) oak plank, nailed to the hull with large-headed nails, so that they could be prised off easily after launching, and the daggers are 40 feet (12.2m.) long fir timbers 12 x 9 inches (305x229 mm.). The ribbands that acted as guides to the bilgeways were to be 8 inches (203 mm.) square, and the inshore end that held the dog-shores was to be oak, coaked to the sliding planks. The dog-shore, supported by a block called the trigger, is capped with iron, and rests against a cleat bolted to the outside end of each bilgeway above the level of the guide ribbands. (When the two triggers are removed, the dog-shores drop, and the cleats are clear to slide above the top of the ribbands. To ensure that the triggers on each side are removed together, two blocks of pig-iron are released down channels at the same instant; a procedure still used today). The sliding planks are to be set on a plane sloping 1:96 to 1:48 steeper than the keel blocks (which will be on a plane or cambered slightly upwards). Even in this almost final development of the cradle, the two bilgeways are held together under the keel by "several turns of lashings" between ring-bolts, which are bolted through the bilgeways with fore-locks that can be withdrawn (working from the ship) after launching, so that the two parts separate. Similarly, the inshore keel blocks are left to last after the slices (wedges) are driven, and screws are used to drive the ship if it sticks on the ways, replacing the earlier *palancas* and *arc-boutants*.

One significant item can be gleaned from these sources. No French or Iberian source as late as 1783 is known to refer to the use of longitudinal sliding planks between the transverse groundways and the longitudinal bilgeways, while English methods recorded from 1768 do specify these features. (In a sense they are the central feature of older methods, and of the Dutch method, using no cradle). This may be a critical factor in reducing resistance to sliding, as it reduces the bearing pressure at every point of the bilgeway by a factor of about two, and removes all the arrisses of the groundways from its path (Fig. 10). If the bilgeway was crushed locally by uneven loads, that would hinder its movement, no matter how perfect its original surface. It is also much less likely that the vital grease will be scraped off the bilgeway by the edge of each groundway that it crosses.

A second curious but possibly significant feature is the absence of references to extension of the sliding surfaces below low water in early sources, such as Fernandes, Gaztañeta, Colbert, Ozanne, whose drawings show no trace of extensions, surprisingly. This will be considered further under slipways, below.

The puzzle of Bouguer's *Traité du Navire*

We may now consider a lengthy text by P. Bouguer,[56] dated 1746, and which is thus roughly contemporary with Ozanne or Ollivier, Morogues, or Chapman's visit to France. Bouguer has a reputation for the identification of the metacentre, and for mathematical naval architecture. The evidence of this passage, however, is that he was not really familiar with launching, or practicalities. He was based in Paris and Havre, so he ought to have been familiar with tidal Atlantic methods; he actually prefers the use of dry-docks. It is doubtful, taking his text at face value, that he understood the dynamics of launching, as he confuses the effects of launching on the keel with launching off fixed

56. P. Bouguer, *Traité du Navire de sa construction et de ses mouvements*, Paris 1746, Book 1, Section 1, Ch. XII (pp. 73-9).

bilgeways. The text extends to a discussion of the stresses imposed on launching and first flotation of a vessel, but not, it has to be said, in any quantitative fashion.

The text describes a method that is actually closer to Dutch methods (and with some aspects of launching on the keel) than other examples of French methods, and is perhaps archaic for 1746. There are a number of key terms which he uses differently from all other writers - *berceau* itself, *anguilles*, *colombiers*, and which suggest a garbled account. The text will be given in full, with interpolations to comment on the major differences and problems.

> "***On the method of putting ships into the water, and the means of knowing whether they have curved in the sense of their length by the force that they suffer in this movement***.
>
> One does not wait, to put a ship into the water, until it may be entirely constructed; its weight, which would be found much greater, would render this operation much more difficult, which is already only too difficult. One does not have in all the ports these basins, slightly extended, that one calls dry-docks [*formes*], in which one could not only finish a ship, but rig it and equip it; and where nothing more remains, to put it afloat, than to open the gates, when the sea is high. Besides in our ports we have too few dry-docks, and when one one has made two or three in the same one, one has placed them badly in respect of the extremity of each one from the others, which often prevents that each can serve its part; one ordinarily reserves them for repairs, that is to say, to make repairs, either to the planking or to the frames, of which ships have need only too often.
>
> Thus one nearly always constructs these vessels on the quays; but one takes care to render the platform [*plan*] on which one builds them inclined, so as to be able later to make them slide more easily down to the water, from which they are never very distant. One often gives six *lignes* of inclination to the platform, in each *pied* of length [1:24], so that it always makes an angle of about 2-1/3 degrees with the horizon, at least if one is not obliged to change the slope a little, because of the circumstances of the place. The slipway [*chantier*] on which one builds the ship is formed of baulks [*poutres*] placed transversely, or placed perpendicularly to the keel. These baulks are called groundways [*tins*], and the keel, instead of being placed immediately above [them], is raised, for the convenience of the workmen, and also for the reasons that will be seen below, on several billets or blocks [*coins*] placed on the groundways at intervals. The platform that the groundways make being inclined towards the sea, the keel is not horizontal, [but] it has the same inclination as the slipway; and one ordinarily puts the bow towards the water."

[This is archaic, and of doubtful accuracy. Ozanne already records stern-first launching in 1735; a slope of 1:24 is very slight for a slipway to slide a ship freely, as Bouguer goes on to describe. It may be the angle of the keel, often different from that of the slip itself. The groundways must be very closely spaced or contiguous].

> "One begins by placing the keel, and to the extent that one places each frame above, or even the sternpost and stem, one takes care always to support it with shores [*accores*] which are pieces of wood that serve for struts [*arc-boutans*]; and these are the same shores that stop the ship from falling to one side or the other, while one is building it. One pushes the work on at least to the first deck, one planks [*bordes*] the hull, or clothes it with its planking; and one also planks the first

> deck, which is supported by all its beams. Often the other decks are still not commenced; but it is absolutely necessary that the first deck is finished, to avoid different [various] accidents; and above all to make the ship more capable of supporting the movement to which one is going to expose it.
>
> One prolongs the slipway just to the water, putting in front of the ship, perpendicularly to its length, other baulks, other groundways that form a platform always equally inclined, and one puts above them, in the centre, a series of strong timbers [*madriers*] to serve as a path for the keel, which is held by long parallel ribbands [*tringles*], which they form like a groove [*coulisse*]. The vessel, while it slides on its keel, not being supported by its shores, would infallibly fall on one side or the other, if one did not prevent it on each side by long baulks situated parallel in the sense of its length, between which it is moved, and which being distant one from the other nearly its half-breadth, corresponding on each side to the extremity of the flat of the master floor. These baulks are extended to the water along the whole slipway or of the cradle [*berceau*] to which they are well fastened, and one calls them, because of their length, *anguilles*, in certain ports, but the name one gives them more often is that of *couettes*. They are never high enough to reach to the hull of the ship, although they may be very advanced [*avancées* ?] below; but one attaches strongly to the ship itself, on both sides, two other pieces of wood that are normally called daggers [*dragues*] in the West, and *colombiers* in the East, which bear or are supported on the *couettes* and which they can slide over. After everything is thus arranged, one always takes care to renew the keel blocks. One removes with heavy blows of clubs the old ones that are as though stuck with the groundways and with the keel, and which are engaged there by the impression caused by the great weight with which they are loaded; and to the extent that one removes them they are substituted with new ones."

[There is some confusion here. *Anguilles* for Ozanne, Ollivier or Morogues are the bilgeways, shorter than the vessel, with which they move. *Colombiers* are poppets in other texts, and *couettes* are daggers, attached to the hull (elsewhere *ventriéres* or *coittes*). Bouguer's *dragues* must move with the ship itself, but his *couettes* extend to the water, and are fixed. They are therefore more equivalent to the Dutch methods. The arrangement thus differs from Sutherland's drawing of 1711, where there are crude *couettes*, and ostensibly a sliding plank, but Sutherland's *couettes* are fixed to the hull, not to the slipway. The crushing of the supporting timbers during construction is probably very real - but what of the crushing of the keel? The nature of the central *madriers* is critical here. If there is indeed a central sliding plank, it is an early text mention, but it seems more likely that they are fillers to create a continuous run of transverse timbers, as in other contemporary sources. The editor of Ozanne inserts for *couëtte*, "path of planks to slide the bilgeway," but has to suggest that the drawings are simplified, because they do not show them. No other French text noticed refers to the extended, fixed *couettes*, but again the editor of Ozanne notes confusions with the term *couëtte* for *anguille*, and suggests that the full expression ought to be *couëtte mort*].

> "The ships which one wishes to launch into the water in this manner, are always supported in three places, under the keel, and at the two sides, by the *couettes* and *dragues*. But there are constructors who make them supported on only the two latter places. They remove the old keel blocks without putting in new; the keel is found in the air, and all the weight of the ship, along the whole route that it takes to reach the water, is distributed between the two *couettes*. The first method appears to me more certain, the body of the ship works less. With respect to friction

[*frottement*], it ought to be sensibly the same; one ought always to have the same difficulty, or the same resistance to overcome; because when a heavy body is only supported on two points, it is supported more on each, and the friction is greater; instead of when it bears on three, it is supported less on each, the friction on each is smaller; but the sum of the three frictions in the last case is equal to the sum of the two frictions in the first. Whatever that may be, one never forgets to rub the *couettes* with grease to facilitate the movement, and the same for the path for the keel, when it is necessary. One examines whether in all the length of the slipway, or the cradle, there is anything that can cause an abstacle; whether there is the least point of a nail, etc. Finally one removes the shores from the sides, and the ship is only held at the bow by the one shore that is supported on the stem, and which is called the *soûbarbe*; and besides that by a bight of cable that is fastened to the stern, and which is applied to a half-buried anchor."

[Yet another indication that Bouguer is not writing from first hand experience. Searching for nail-heads and other obstructions as he describes is in the wrong place and time to affect first movement. That has to be done before the *couettes* are placed beneath the ship itself.]

"If all the precautions have been undertaken well, and if the slope of the cradle is such as I have said, it suffices after having cut the restraining cable of which I have just spoken, to make the *soûbarbe* jump out, that piece of wood that is opposed to the movement of the ship, buttressed against the stem. The vessel on being set in motion starts with a slowness that permits besides to cross its path several times; but its speed is accelerated by degrees, and it soon goes with such rapidity, that nothing more is capable of stopping it, and that the slipway catches fire. To make the *soûbarbe* jump, one can strike it with a club; and the carpenter, if he does not lose his head, has all the time either to flee, or to throw himself between the groundways [*sic,* but there would be no adequate space between them]; but it is much better to use a long ram of which one assures blows from a distance, keeping it in a sort of channel. The *soûbarbe* in falling and remaining on the path of the vessel, would cause some accident, but it is attached to a rope; and several workmen, who are always in the ship, have the care to draw it promptly upwards. At the extremity of the stern, or heel [talon] there are several levers all arranged with long joists [*solives*] of 25 to 30 pieds, of which one engages the end under the keel, and which serve not to push the vessel, but to cause it some agitation, supposed that it does not start fast enough. One also attaches there, or makes fast there, to speak as the seamen, several ropes that come to be rendered at tread-wheels or at capstans where there is a world of people all ready to agitate. The least thing, as I have already said, a single piece of grit can stop the first movement, and render useless the efforts of several hundred persons, who are aided by different machines; the constructor in despair sometimes does not know what to do about it. But after the movement is once started, there are no more similar obstacles to fear; it is more a question of stopping the too great speed, with which the vessel will often go to strike the other side of the port."

[Nonetheless, there are extensive preparations made in the expectation that many ships will not slide freely, which matches the texts of Ozanne and Ollivier at a similar period.]

"One uses to stop this accident several restraining ropes; and as one knows from experience that the heaviest cable would not have sufficient strength, one puts several shorter ropes that one wishes to break, to destroy the first force. One sometimes also deploys these ropes, and attaches them coiled [?*plis*], with other different ropes that ought to be broken successively. It is good to take guard for the workmen and for the spectators, during the rupture of all these ropes, because they give blows like a whip, which have often killed or wounded several persons. One can also, to extinguish the movement of the vessel more promptly, hold attached towards the height of the stern various pieces of wood, and let them fall into the water one after the other as drogues [*à la traîne*].

II Of the curvature that vessels suffer in the sense of their length when one launches into the sea.

Another occurrence that is more difficult to avoid ..., ... [meaning uncertain]..., is the curvature that the ship receives ordinarily from the first instant in the sense of its length. The most part of readers know that all liquids push up bodies that float on their surface in proportion to the volume that they occupy: It is besides what I will have occasion to explain in the following book. The ship occupies at its middle much more space in the water, it is much supported in it: while it is the contrary for the bow and stern, at the same time that they are heavier [relatively]. Thus the support that the water furnishes is not distributed as it ought to be; it is applied principally at the middle, although it is the extremities that weigh more, and have more need. One ought not to be astonished after that that a body, as much weighed down as strengthened by all the pieces of wood that give it form, is curved or arched considerably, and that the keel in making a very sensible arc, turns its convexity upwards. This curvature which increases more and more, because the cause which produces it, acts without cease, obliges [us] to make great repairs to the ships, and in the end renders them incapable of sailing. But one can remark that the first effort that they suffer when one launches them into the water, already produces a very dangerous effect. Sometimes the stern is still on the slipway, while the whole bow is almost in the air and its weight makes an effort to curve the keel and all the other pieces situated in the same sense. It is true that if the cradle [*sic*] extends very far into the water, which one has the facility to do in the ports of the Ocean, profitting from the tide to work there, and high tide to put the ship into the sea, there is much less risk. However, the bow is found supported by the water while the stern is still supported on the slipway, the keel and various other pieces are in the case of a long and flexible body supported by the two extremities; and they acquire in bending downwards, more facility to arch then in the contrary sense. Thus even setting aside other accidents that are only too frequent, it would always to be wished that one had basins or dry-docks in all the ports to be able to construct all the vessels."

[There are further problems here. The alternative system described by Bouguer almost implies a single point support, roughly amidships, and the risk arises if the keel strikes the ground as the hull drops off the *couettes*. The description overall does indicate that the launching ways were not often (or ever) carried below low water. Bouguer also says that "if the cradle extends into the sea": he has not actually described the cradle, and no cradle is built below high water.]

"An infallible mark that a ship is bent or arched, is that one sees that the higher planks of which the ends were exactly jointed one to the other, while they were still on the slipway, are found a moment after to be considerably separated one from the other. One cannot doubt after that that all the work has given and yielded. To determine with as much precision as facility the quantity of the curvature, there is only, when the vessel is still on the slipway, to raise three rules vertically on the deck, or if one wishes, in the hold on the keelson, the one in the middle, and the other two at the two extremities fore and aft. One places sights at a certain height on the two that are at the extremities, and making a third sight rise and fall on the rule in the middle, until it may be exactly in a straight line with the first two, or surely on the same visual ray, one will measure its height above the deck, or above its keelson. If one then does the same operation when the ship will be in the water, and that one finds that it is always necessary to put this middle sight at the same height, it will be a sign that the ship is not arched; but if it is necessary to put it lower by a certain amount, as almost always happens, it will be a sign that the middle of the ship is elevated, and one knows exactly how much. Nothing will stop examining in this way from time to time what the progress of this evil is, in repeating the experiment on the keelson and on the deck, and one will know much better the remedy that it will be necessary to bring to bear."

Miscellaneous sources

Evidence for difficulties in launching, confirmation that large ships did not generally slide freely into the water until the eighteenth century, can be gleaned from a number of disparate sources, where such events evidently cause little surprise. Often, incidentally, these accounts also illustrate the point that foreigners are either writing the account of events, or are involved in the work: it is no wonder that there is a tendency for the methods of launching large ships in Europe to converge during the eighteenth century, reinforcing the gist of earlier instances noted, that must have been commonplace.

Henry Teonge (chaplain of *Assistance*, man-of-war) made the following entry in his diary for 22 February 1676, at Malta, which reveals an unusual amount about the ceremonies of launching ships; about launching - "turned her head.... thrust" - (which perhaps throws some light on the Venice arsenal picture of 1517); and even offers a memorable collective noun:[57]

"This day we saw a great deal of solemnity at the launching of a new brigantine of twenty-three oars [a side], built on the shore very near the water. They hoisted three flags in her yesterday, and this day by 12 [noon] they had *turned her head near the water*; when as a great multitude of people gathered together, with several of their knights and men of quality, and a *cloud* of friars and churchmen. They were at least two hours in their benedictions, in the nature of hymns or anthems, and other their ceremonies; their trumpets and other music playing often. At last two friars and an attendant went into her, and kneeling down, prayed half an hour, and laid their hands on every mast and other places of the vessel, and sprinkled her all over with holy-water. Then they came out and hoisted a pendant, to signify she was a man-of-war; and then at once *thrust* her into the water, where she no sooner was but they fired twenty-one chambers, and rowed to our Admiral and gave him a gun, who gave them another. Then she went into the cove where all their galleys lie, and was welcomed with abundance of guns. And there are four more just ready to be launched, all for the coasts of Tripoli."

There is silent testimony to similar multitudes and ceremony in an engraving of a launch in the Ribeira in 1727, and in the painting by Noël for a launch in Lisbon in 1789. In passing, we might note that these ships were launched stern-first.[58]

57. G. E. Mainwaring, ed., *The diary of Henry Teonge, 1675-9*, London 1927, p. 128.

A passage of rather greater significance for Portuguese shipbuilding history is to be found in the diary of another English seamen, Barlow, who found himself with others of the crew of the ship *Queen Cathrane* (ie Catherine of Bragança) waiting for a cargo of sugar to be loaded in Rio in 1663. The usual routine for seamen was first established:[59]

> "And the first work we did was to careen our ship and make her clean under water and new grave her and pitch her under water; and also cutting of wood for to burn, and also to dunnage our ship, and suchlike work."

The next item was far from routine: it was the launch of the *Padre Eterno,* one of the largest ships built in the seventeenth century. She was a five-decker, of 43.5 metres keel, and apparently around 2,800 tons deadweight capacity:[60]

> "And there a-building a great ship for the King of Portugal, which was then ready to launch, having been above three years a-building, the Governor desired of our commander for to help them with our men and what else we could do for the launching of her [perhaps a reflection of the sheer quantity of heavy tackle needed in such an operation], which was to be done on their Christmas Day, which they keep ten days before ours [with England retaining the Julian calendar]. But that day she could not be launched, nor in seven more, but on our Christmas Eve, betimes in the morning, we launched her off into the water, she being a very large and good ship."

This is slightly ambiguous (and says nothing of the detail of the cradle), but it appears that they strove for eight days in all to get her afloat. The other factor is that she only went afloat on the top of a tide - to explain the odd early hour, and it is *possible* that efforts were simply suspended to wait for a better tide. That is unlikely. No practical man would try to launch such a vast ship with less than the best tides available, even if it were in a place with spring tides of no more than about 1.2 metres range. They expected to launch it on the first day. A week later the tides would be declining. The tide-tables could of course be re-constructed to explore the matter. The account has all the hallmarks of dragging a ship to the end of the slipway, to let the tide float her off the cradle. It just took rather a long time to move her far enough down the sloping slipway for the tide to lift her. Interestingly, Barlow's sketch of the ship at launching shows it facing bow to land, albeit already afloat when drawn, and with a huge flag flying.

Launching still did not always go smoothly even in the Ribeira das Naus, much later than this. There is a record from 1711 of the launch of a large ship of about 70 guns, which took four days to drag into the water, breaking quantities of tackle and hawsers in the process. This was in charge of a French shipbuilder, Chabert, and at the same time English and Dutch were also building in the yard.[61]

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58. Engraving reproduced in A. J. M. C. Nabais & P. Oliveira Ramos, *Porto de Lisboa*, 1985, Fig. 5, p. 23. A. J. Noël: reproduction from Museu da Marinha, Lisbon, from private collection.
59. A. B. Lubbock, *Barlow's Journal*, London 1934, Vol. 1 pp. 84-5. MS JOD/4, National Maritime Museum, Greenwich MS NMM. The sketch is at pp. 76-7 of the MS, negative A1609, and is reproduced in C. R. Boxer, *Salvador de Sá....*, London 1952, fp 304 (text at p. 330). The keel length appears as annotation to the sketch.
60. James Jenifer, *Journal*, MS 2894, Pepys Library, Magdalene College, Cambridge, page 35. A. Mallet, *Description de l'Universe*, Paris 1683, Vol. 1 plate 92, represents the vessel.

Does this contradict a different account cited for 1721,[62] or indicate the date of a change of method in the Ribeira? The *Gazeta de Lisboa* for 21 November 1721 describes the launch of two 50-gun ships, which proceeded with "the greatest velocity," the Royal family being present, seated in a richly furnished Royal Box constructed for the occasion. The launch was followed by a customary celebration with sweets and drinks.

The same commentary indicates that ships were launched with great pomp, and that "no power gave impulse to the fall of the great machine and its cradle....." There are reasons to question the date at which this became viable in principle, but had launching become a scheduled event for Royalty to attend, and can the reported velocity be taken literally? Taken at face value these two accounts alone would place the date of transition in Portugal between 1711 and 1721, though other conflicting evidence is noted below.

Duro[63] refers to a small manuscript work in the Biblioteca Nacional in Madrid entitled *Arte de botar al agua los navios*, which he ascribes to the second half of the eighteenth century, but he does not transcribe any part of it.

A few interesting points appear in a dictionary published in French, translated from the Dutch, in 1736.[64] It contains plates that are reversed and modified copies of van Ijk's, and so launching bow-first in the Dutch method. The points to note concern the risk of fire, the Portuguese method, and internal reinforcements:

> "…After all these things are done, one makes prompt efforts to make the vessel run, because if it remains some time without support, and supported entirely on the keel alone, it could suffer, and receive some distress. So that, if for some reason one is forced to wait, it is necessary to put back the shores. All the timber that one puts under the vessel and on which it ought to slide, ought to be dampened, for fear that the shock produce fire.
>
> The Portuguese put their vessels on the stocks differently than other nations; because it is the stern of the vessel that is lowest and at the water's edge, and that descends first. They pretend by this means to avoid divers inconveniences that happen in launching.
>
> In the town of Sardam in North-Holland, where there is a very great building of ships, one is obliged to make them pass over a dyke, to lead them to the water. This dyke is raised with a slope on both sides, and is well decked (*parée*) and greased. Two cables are fastened to the stem, in two places, and besides to the keel that pass by various windlasses, or capstans, in each of which there are two pulleys, and three sheaves in each pulley, and there are twenty to thirty men to turn these machines……It is also necessary that it be well supported with shores within, that bear on the keelson, and run up to bear on the knees, and that on the slant, not in a straight line….. It is dangerous to make vessels pass this dyke in very dry times and

61. Luís Ferrand de Almeida, "Um construtor naval francês em Portugal (1710-1715)," in *Mare Liberum*, No. 4, Lisbon 1992, pp. 115-122 (documents 1 and 2).
62. H. Alexandre da Fonseca, *Os estaleiros da Ribeira das Naus*, Academia de Marinha, Lisbon 1990, np.
63. C. F. Duro, *Disquisiciones Náuticas*, Vol. VI, Madrid 1881, p. 243.
64. *Dictionnaire de marine contenant les termes de navigation et de l'architecture navale*, Amsterdam, 1736.

when one is obliged to do it, there must be no lack of grease and dampening of the deck and windlasses…."

Evidence from English launchings

There is surprisingly little evidence from English sources for methods of launching before the eighteenth century. One reason is likely to be that many large ships were built in and launched from dry-docks from no later than the very early sixteenth century.[65] An example features in the portrait of Phineas Pett, which has the stern of the *Prince Royal* (launched from dock in 1610) in the background.[66]

This was no panacea, but did have advantages, not least in that once the investment was made in adequate dry-docks ships could also be repaired in them very easily - if not overnight, whereas it would only be worth hauling a large ship ashore for quite major repairs. (This would become a significant factor in the efficiency of the Royal Navy from the eighteenth century).[67] Early docks were much more limited as to depth, because they had to drain freely at low tide, and had primitive gate arrangements that slowed down operations. It was precisely the need to drain dry-docks that limited their spread.

Phineas Pett noted some key points from the early years of the seventeenth century. He notes an event in 1609-10:[68]

> "there were two new ships, builded at Deptford for the East India Merchants, to be launched; whereat his Majesty with the Prince and divers lords were present, and feasted with a banquet of sweetmeats on board the great ship in the dock, which was called the *Trade's Increase* [1,100 tons, built by Burrell], the other was called the *Peppercorn* [250 tons], the names being given by his Majesty...... But the tide was so bad that the great ship could not be launched out of the dock, and the smaller, which was built upon the wharf, was so ill *strocken* upon the launching ways that she could by no means be put off, which did somewhat discontent his Majesty."

The larger ship was caught between the sides of the dock-head: these were then much narrower than the main part of a dock, and had sloping walls. If a very large ship was to be put in a dock, it had to be floated in or out on a very high tide, so that the widest part of the ship passed the widest part of the dock-head. In this case the tide did not rise as far as expected, and the ship became wedged. Other evidence indicates that at the end of the second day this ship was left hanging half in and half out of the dock, and so very ill-supported. Such incidents could damage both ship and dock, and were evidently not uncommon.

The launch of the smaller ship from stocks suggests that the process of driving wedges to transfer the ship to her cradle was badly managed, and either keel-blocks were not

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65. R. A. Barker, "The pre-history of the dry-dock," *op.cit.*
66. National Portrait Gallery, London, No. 2035 (on-line image available).
67. Examples in R. Morriss, The Royal Dockyards during the Revolutionary and Napoleonic Wars, Leicester 1983, pp. 18-21.
68. G. Perrin, ed., *The Autobiography of Phineas Pett*, Navy Records Society Vol. LI, 1917, pp. 75-6.

properly removed or the loading was placed very unevenly on the cradle, causing it to stick.

Butler's definition of cradle, above, using it also for launching from dry-docks, notes the other great problem of launching from docks that are too shallow for convenience. As the water rises to float the ship, the shores holding her upright must be removed. There is a danger that the ship will fall sideways during the critical phase where she is still partly supported on her keel, and is still unstable in the water. The dilemma is that additional ballast to improve stability also increases the height of tide needed to float the ship. This problem afflicted ships in the twentieth century too, and not just those launched from dry-docks.[69] A painting in Merseyside Maritime Museum illustrates the case of the *Baboo*, of 423 tons, which fell over in the Canning Graving Dock in 1841 as water was admitted.

Pett has another significant remark concerning the launch of a very small ship of his own at Gillingham in 1604 which: ".... By carelessness ran off before her time without any great hurt."[70] This emphasises two aspects: small ships generally are much less problematic to launch. This particular ship probably had bilgeways from single lengths of timber, without all the problems of jointing and uneven support of a much longer and larger ship. More significant is that it was possible in the right circumstances and with sufficient care to make the slipway so steep and perfectly flat that a ship would slide of her own accord. As techniques improved this would become the norm, but it is likely to have depended upon the use of bilgeways, rather than articulated *vasos*, and on having sliding planks between the bilgeways and the standing ways. The questions remaining, for lack of evidence, are whether Pett was lucky to be launching only a small ship; whether it was normal for a well-prepared launch in England to slide the ship freely at this period (this writer knows of no other comparable evidence before Sutherland in 1711); and if so how the cradles and ways differed from those of other places, which clearly expected to need to drag most ships most of the way to the water, even if momentum took over on occasion once a ship was moving at all.

Part of the answer to why some slipways could be steep enough to generate comments such as Pett's or Sutherland's lies in the strong tides at most major English sites, exceeding the launching draught of all but the largest ships of our period. Builders could build slipways out to the low water mark, and be sure of sufficient water to float their vessel. That is not the case in the Mediterranean, or many other areas. A steep slipway is less attractive if large ships have to be hauled out too.

Pepys observed one failure to dock a ship in 1662. The *Royal James* was left with her nose in the dock, shored up and waiting for the next tide.[71]

One of the more curious references to methods of launching - curious not least because there is no suggestion that it was anything exceptional at the time, is for a yacht built by Deane as a Royal gift to the French King, launched at Portsmouth in 1674:[72]

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69. W. A. Baker's *Mayflower* of 1957 acquired an undeserved reputation for lack of stability when it had to be launched from dock on too low a tide; a new Spanish vessel representing Magellan's *Victoria* capsized on launching - *The Guardian*, London, 25 November 1991, p. 8.
70. Pett, *op.cit.*, note 49 above, p 24.
71. L. A. Wilcox, *Mr Pepys' Navy*, London 1966, p. 88.
72. A. W. Johns, "Sir Anthony Deane," in *Mariner's Mirror*, Vol. 11, 1925, p. 183.

> "Which was drawn on a cradle on four wheels, two hundred yards to the seaside, where it was lifted with a tackle and other engines - though it weighed at least 42 tons - and let down gently into the ooze where the tide floated it."

It is also curious that this early reference to what would became a perfectly normal method of moving boats should also be for a launch on such a sheer scale. The sheerlegs needed to lift 42 tons would need extensive foundations and anchorages for its tackle. 180 metres is a surprising distance for a small vessel, too. With a tidal range of about 3.6 metres and a slope of 1 in 12 for a normal slipway, nearer 80 metres should have sufficed, suggesting that the yacht was actually built well inland for some reason. It also remains a mystery why the tide could not have lifted such a small vessel, rather than tackle: perhaps it was launched from a wharf otherwise used for masting ships or handling ordnance. Equally, one wonders how the yachts were to be transferred to the lake at Versailles as stated (and indeed whether they could actually have been used there), if 42 tons is actually correct.

One of the most intriguing accounts of launching in English actually comes from fiction, in the work of Defoe. It suggests that the problems of launching large ships was well appreciated on any shipowning waterfront of his time - around 1700, and London - and perfectly illustrates many of the problems reported in this paper. *The life and adventures of Robinson Crusoe* - by no means a childrens' story (more a parable of modern "management") - find him of course marooned on his island, and determined upon escape. The longboat was dismissed, the up-turned smaller ship's boat essayed:

> "… I went to the woods and cut levers and rollers….. at last, finding it impossible to heave it up with my little strength, I fell to digging away the sand, to undermine it, and so to make it fall down, setting pieces of wood to thrust and guide it right in the fall.
>
> But when I had done this, I was unable to stir it up again, or to get under it, much less to move it forward towards the water; so I was forced to give it over……. This at length put me upon thinking whether it was not possible to make myself a canoe or periagua, such as the natives of those climates make…. viz. of the trunk of a great tree. This I not only thought possible, but easy, and pleased my self extreamly with the thoughts of making it…. but not at all considering the particular inconveniences which I lay under, more than the Indians did, viz. want of hands to move it, when it was made, into the water, a difficulty much harder for me to surmount than all the consequences of want of tools could be to them; for what was it to me, that when I had chosen a vast tree in the woods, I might with much trouble cut it down, ….. so to make a boat of it, if, after all this, I must leave it just there where I found it, and was not able to launch it into the water?
>
> ….that I never once considered how I should get it off of the land; and it was really in its own nature more easy for me to guide it over forty five miles of sea, than about forty five fathoms of land, where it lay, to set it afloat in the water.
>
> I went to work upon this boat the most like a fool that ever man did, who had any of his senses awake. I pleased my self with the design, without determining whether I was ever able to undertake it; not but that the difficulty of launching my boat came often into my head; but I put a stop to my own enquiries into it, by this foolish

answer which I gave myself, 'Let's first make it, I'll warrant I'll find some way or other to get it along, when 'tis done'.

This was a most preposterous method; but the eagerness of my fancy prevailed, and to work I went. I felled a cedar tree: I question much whether Solomon ever had such a one for the building of the temple at Jerusalem. It was five foot ten inches diameter at the lower part next the stump, and four foot eleven at the end of twenty two foot, after which it lessened for a while, and then parted into branches. It was not without infinite labour that I felled this tree; I was twenty days hacking and hewing at it at the bottom; I was fourteen more getting the branches and limbs and the vast spreading head of it cut off, which I hacked and hewed through with axe and hatchet, and inexpressible labour; after this it cost me a month to shape it, and dub it to a proportion, and to something like the bottom of a boat, that it might swim upright as it ought to do. It cost me near three months more to clear the inside, and work it out so as to make an exact boat of it. This I did indeed without fire, by meer malett and chissel, and by the dint of hard labour, till I had brought it to be a very handsome periagua, and big enough to have carry'd six and twenty men, and consequently big enough to have carry'd me and all my cargo.

…..many a weary stroke it had cost, you may be sure; and there remained nothing but to get it into the water…. but all my devices to get it into the water failed me; tho' they cost me infinite labour too. It lay about one hundred yards from the water, and not more……I resolved to dig into the surface of the earth, and so make a declivity…... It was still much at one; for I could no more stir the canoe than I could the other boat.

Then I measured the distance of ground, and resolved to cut a dock or canal, to bring the water up to the canoe, seeing I could not bring the canoe down to the water. Well, I began this work….. it must have been ten or twelve years before I should have gone through with it: for the shore lay high, so that at the upper end it must have been at least twenty foot deep; so at length, tho' with great reluctancy, I gave this attempt over also.

This grieved me heartily, and now I saw, tho' too late, the folly of beginning a work before we count the cost, and before we judge rightly of our own strength to go through with it."

Bow-first launching

We have noted that the heavy pulley blocks near the sternpost are all supported from above, with ropes to the stern gun-ports in for example Colbert. This may reveal a possible key reason for all these early ships to be launched bow-first. With a straight sternpost and a long slender run, the hull is structurally better fitted to support the massive forces at the sternpost than at the bow, which is heavily sloping in several directions (Fig. 11). If they had tried to attach the hawsers on the stem it would have been much more difficult to stop them slipping down the stem towards the keel, and the hood-ends of the planking and their adjacent frames might have been disturbed by the loads. There are other reasons to do with the dynamics of what happened when the ship finally came afloat, and building with the decks more nearly horizontal. However it is possible that we will find that large ships came to be launched stern first only when the cradles and launching methods had progressed so far that the ships usually slid down the ways relatively freely. While they had to be dragged, bow-first was a better method. The change as we have seen occurred in France at least between about 1677 and 1736.

A comment on the practical shipbuilding problems associated with dragging large ships is contained in a letter from Corte Real to the King in 1623, on the merits of three and four-deck ships.[73] Reinforcement of the sternpost with a counter- or false-post is spoken of in the context of needing to drag these huge ships.

We may however note that if a ship was subsequently hauled ashore it was most practicable to do so bow-first, so that the keel remained more nearly parallel to the beach and ways, and reduced the stresses upon the hull, and the length of the slipway (Fig. 12). If ropes had to be attached to the hull to carry very large drag forces, they could then be placed around the sternpost in the same way as for launching. However, the ship had then to be re-floated stern-first. Now this dilemma and the need to develop techniques to accommodate it may have led to a realisation that launching could actually be performed stern-first too. This has dynamic benefits during launching, as the stern has less buoyancy than the bow, and will not lift so violently, increasing the load on the ends of the keel, and straining both ship and slip. It also allows the decks to be laid more nearly level during construction on a typical large vessel, which is another minor benefit to the work.

It will be difficult to distinguish in a view of a shipyard whether it was a new ship being launched stern-first, or a ship grounded for repair bow-first, and this may account for references to Portuguese launching stern-first surprisingly early, in the sixteenth century,[74] apparently based on iconographic evidence. One supporting item comes from Van Ijk, who as we have seen wrote in 1691 as a matter of surprise that the Portuguese then launched stern-first. Barlow appears to draw the same for 1663, though the issue is far from clear, and merits further investigation.

Bowrey's drawing implying side-launching about 1680 will be discussed below: that is the only early example discovered for this study that provides any detail, though there are several others cited. The method had great merits and would become very common by the nineteenth century, especially for shipbuilding sites on rivers (such as for the exceptionally long *Great Eastern*) and canals. (Indeed it is said that some American river

73. J. Frazão Vasconcelos, *João Pereira Corte Real conselheiro....*, Lisbon 1921, pp. 17-21, letter to Philip II, 19 October 1623. Copy courtesy of Leonor Freire Costa.

74. Alexandre da Fonseca *op.cit.* np but fn 19, citing *Quadros Navais*, Lisbon 1972, pp. 80-1 (not seen). "A. A." referred to Van Ijk's similar reference (note 12 above) for the end of the seventeenth century in *Mariner's Mirror*, Vol. 3, 1913, p. 189-90, which also has other items on launching matters. It might equally be objected that Fonseca reproduces on that same page a view of Lisbon dated to 1640-1656 clearly showing two ships in frame, bow to water, in the Ribeira. There is, too, a well known miniature of the Lisbon waterfront in the reign of D. Manuel (*Livro de Horas de D. Manuel*, ca1517-1526, reproduced in *Oceans* No. 26, CNCDP, Lisbon 1996, p. 45, and also published in facsimile by INCM, not seen) that shows a group of seven large vessels ashore in the Ribeira das Naus, six of them stern to water, one bow to water, and one actually broadside; unfortunately without any cradle or slipway detailed, and without means of distinguishing building and repair. We can also find very clear illustrations of ships building bow to water in Lisbon much later, for example in an engraving *Palácio dos Cortes-Reais* by Colmenas of 1707, published in F. Castelo-Branco, *Lisboa Seiscentista*, Lisbon 1990, with transverse cambered groundways. However, another view of Lisbon displays absolutely characteristic Dutch methods of shipbuilding in the Ribeira: the engraver has simply transferred details from one plate to another.

steamers, with lengths to 110 metres and depths of only 2.5 were simply allowed to float off level ground in spates, for lack of structural strength for conventional launching.

Dynamics of launching

A ship on its cradle reaches a point on the slipway as it is moved towards the water, however slowly, where the buoyancy of the seaward end starts to lift the hull off the slipway, rotating it about the landward end of the bilgeways. As soon as this happens, the end of the bilgeway is the only point where support is transferred to the cradle and thence the hull. At the same time, most of the buoyancy is concentrated at the other end of the hull. The relatively even spread of loads on the hull and slipway has transformed into severe localised loads, and causes the hull to sag - there is little support from the cradle in this sense. The ship has still to be moved some distance down the slipway before it is properly afloat and free of the slipway and cradle.

Launching a ship stern first will generally assist, as the stern usually draws more water and has less buoyancy than the bow, and the ship will tend to be further down the slipway before it rotates. Correspondingly, this requires a longer slipway. The curve of the stem also makes it less likely to ground during the process of rotation.

The greater the weight and draught of the vessel on launching, the longer the slipway needed to be, and the further below the high water mark. It was therefore advantageous to launch ships part-built. The ship was lighter to handle, needed less depth of water to float it, less (or no) ballast to make it stable, and was less likely to be strained by its own weight as it started to float and rotate. This also freed the slipway earlier for the next vessel to be started.

There is a contrary case in the methods where the primary support is on the bilge amidships - the Dutch method, essentially, but to some extent also with launching on the keel, or listing. As described above, the ship reaches a point where its centre of gravity is beyond the end of the standing ways, and it will tend to tip down into the water. However, this is shortly followed by the end of the bilgeway leaving the slip too, and the buoyancy will be tipping the vessel the other way: there is a very real risk of the keel striking the ground as its last support on the standing ways disappears. Launching into too shallow water or at too steep an angle can equally cause the leading part of the vessel to strike the ground.

This is a very real risk even today: one recent military launch suffered a collapse at the fore poppet, and the stem crashed to the slipway - striking the ground as it was termed - with structural damage. It happened to at least one of the famous heavy American frigates, for which items appear in the Naval Expenditure for 1798:[75]

> "…cost of additional wharf to ensure the safe launching of the frigate *United States*, the expense of heaving down the *United States* to repair injury to the false keel and rudder braces, by striking the ground in launching, ….. repeated trials to

75. American State Papers. Naval Affairs. Washington 1834, p. 38.

launch the frigate *Constitution*, and the additional means necessary to procure for her a safe descent into the water….."

Grounding

Small vessels can be hauled ashore manually when necessary, even when there is no tide to assist, or if it is necessary to carry out more protracted repairs than can be achieved between successive tides. Ships the size of *caravelas*, or rather larger vessels if they are designed to be so treated, and are being grounded on smooth sand or mud, with no risk of settling on rocks, or falling over, may be grounded in tidal areas relatively easily.

Classical galleys, which are estimated to have weighed around 30 tonnes, similar to a small *caravela dos descobrimentos,* were so hauled ashore in the almost tideless Mediterranean.[76] Theophrastus[77] indicates that the keels of triremes were made of oak, so that they could withstand the abrasion from being hauled ashore regularly. Merchantmen had keels of fir, and if they needed to be hauled out had an oak plank placed to protect them. There are places where geography and prevailing winds even led the ancients to transport their ships considerable distances overland, notably across the Isthmus of Corinth, but also at Ras Banas.[78] Dragging vessels up quite steep slopes was also a commonplace on Chinese (and other) canals and on the *overtooms* of Amsterdam's dykes.[79]

Some of the issues associated with grounding ships were considered in an earlier paper,[80] and will not be repeated here, but the point is made almost perfectly by a passage from Zurara's *Crónica de Guiné*.[81] Antão Gonçalves' caravela left the Rio de Ouro about 1441, and immediately it was "seen how his caravela needed to be repaired, he had it put ashore, where he made it clean and repaired what was necessary, *waiting on his tide, as was done before the port of Lisbon,* at which daring many were astonished."

Fonseca states that ships to be repaired in Lisbon were put aground in *cavas* along the shore,[82] though no other reference to this has been found. Presumably these *cavas* were similar to the various forms of early "dock," more or less permanent and either with or without gates, that occurred in England from the fourteenth century.[83] Trueba cites a

76. A paper on the launching of galleys, in shipsheds and on beaches was written by John Coates at roughly the same time as the first version of this paper: "Long ships, slipways and beaches," in *Tropis V,* Athens 1999, from the 5th International symposium on ship construction in antiquity, 1993.
77. Theophrastus, *Enquiry into plants*, V, vii.
78. S. M. Berstein, ed., *Agatharchides of Cnidus on the Erythraean Sea*, Hakluyt Society 2nd series 172, London 1989, p. 138. W. Werner, "The largest ship trackway in ancient times: the Diolkos…..," in *International Journal of Nautical Archaeology,* Vol. 26, 1997, pp. 98-119. The *Dictionnaire de marine*, 1736, *op.cit.*, (note 64 above), has a list of such sites.
79. For *overtooms* see note 64 above. There seems to be little published information about *overtooms*, but there is an illustration in J.van Beijlen, *Schepen van de Nederlanden,* p. 25, kindly provided by A. J. Hoving, with other notes. At an early stage these were the only means of passing between Dutch canals; latterly very large vessels were forced to pass them to leave the building yards.
80. R. A. Barker, "Careening Art and Anecdote," *op.cit.*
81. Gomes Eanes de Zurara, *Crónica do Descobrimento e Conquista da Guiné*, electronic edition, Oxford 1993, ch. XIII.
82. Alexandre da Fonseca *op.cit.*, np.
83. R. A. Barker, "The pre-history of the dry-dock," *op.cit.*

Spanish text that indicates that it was quite normal to haul ships ashore and even to raise them onto stocks for repairs to the keel about 1535: "*sean barados en tierra e puestos sobre picaderos de manera que descubran toda la quilla*."[84]

As India *naus* grew in size in later years, only the greatest tides would serve much purpose in simply grounding such ships before the port of Lisbon, and few places en route to India were any better provided - with the exception of some places in Guinea and between Maputo and Mombasa.

The dilemma was clearly a real one, as the polemic over careening of India *naus* at the end of the sixteenth century shows.[85] What is still not clear is what the alternative processes for repair of large ships were in India or in Lisbon, for example, and exactly how they were managed.

Hauling ashore

This is not just the reverse of launching: there are a few additional difficulties to note.

1. Ships to be hauled ashore were complete, and probably waterlogged from long service, and were thus much heavier than when they were launched. In so far as the upperworks and lower masts required additional ballast for stability, that too had to be hauled ashore.

2. Part of the force to be overcome was that of gravity, which had assisted in launching. The necessary forces are thus much increased. The only advantage is that the force is directly ashore, and does not have to be applied towards the water.

3. While a launching cradle can be carefully constructed to fit a ship for launching, and fell away freely as the hull floated, there is much greater difficulty in placing a cradle under the ship (or the ship over a cradle); and there is a problem in ensuring that the ship is properly supported in it, since in general the shape of the hull will not be matched. The old style of rope-based cradle might be doubly difficult, as there was no rigidity between the two sides until the ropes were tensioned against the weight of the hull.

4. Vessels of any size will distort with service, usually hogging. That is, after a period of service the ship becomes deformed with the keel deflecting upwards into an arc, perhaps half a metre. All the joints are strained by repeated stressing in waves and from loading and unloading, alternating between the empty condition when there is more weight than buoyancy at the ends of the hull to the laden condition when this would tend to be reversed. A decision has to be made, more or less consciously, as to whether the vessel is to be supported, repaired and recaulked in this state; or whether it is to be forced to settle onto a cradle (or onto keel blocks) that will restore the original line of the keel. There is no simple resolution of this problem even when the ship has to be floated into a dry-dock: opinions differed, as revealed in professional discussion that arose in connection with

84. E. Trueba. From a typescript circulating privately ca. 1992, p. 19.
85. R. A. Barker, "Careening Art and Anecdote," *op.cit.*

the design of floating dry-docks that would themselves flex in use.[86] Indeed it would be a difficult matter to accurately establish the curvature of the keel with the ship afloat, ballasted, and with the keel itself obscured below curved keelson and deadwoods, etc. The sources located are practically silent about how the shape of the hull was to be obtained to prepare the cradle for it.[87]

The transfer of loads from the gentle support of water pressure spread over the immersed planking to point support on keel blocks, or two lines of bilge blocks in a cradle, or perhaps worst of all to a single point at the end of the keel if this grounds first during either launching or grounding, imposes large and damaging stresses on the hull. The damage might be to individual frames, suddenly supporting the weight of the ship from the keel for the first time since building; or longitudinal, as a beam, tearing the seams of the planking in shear, and opening scarf joints and butts alike.

It is thus highly desirable that the keel of a ship to be grounded is made much shallower forward than aft, by shifting ballast if necessary, so that the keel is more nearly parallel with the slipway, and it is less likely to ground at one end, with much of the weight of the hull supported there as hauling starts (this also reduces the necessary length of slipway, or makes it possible to ground much larger ships on the same slipway).

To Anacharsis the Scythian is attributed the wry remark (ca. 590 BC) that the safest vessel is the one that is hauled ashore.[88] Provided it may be added that it does not fall over on those hauling or working on it. Others regarded careening a ship afloat as much more appropriate for old and weak ships than grounding them for repairs, let alone hauling them bodily ashore.

Explicit sources for the process of hauling ships ashore are even scarcer than those for launching. Polemics about careening and the (alleged) damage that its (alleged) introduction was doing to *naus* of the Carreira da Índia about 1600 suggest that even very large ships were hauled out for repairs in places like Goa, which had negligible tide for the purpose of repair of large ships, and no dry-docks. One of the earliest accounts located is in fact from Madapollam on the east coast of India about 1680, in which Bowrey briefly describes the local methods employed to haul out a 1,000 ton ship (but see below). The text is as follows (Fig. 13):[89]

86. Ollivier first mentions this, desiring the cradle to fit the shape of the keel as it existed afloat. The consensus of later discussion was that the preferred outcome in dry-docking - in itself a far gentler process - was for the keel to be restored to its original straight form before repair: E. Clark, "The hydraulic lift graving dock," in *Minutes of Proceedings of the Institution of Civil Engineers*, Vol. XXV, London 1866, pp. 292-352; with numerous contributions in Discussion.

87. William Bourne, *Treasure for Travellers*, London 1578 (facsimile Amsterdam 1979), Book 4 Chapter 2, describes a stiff wooden chain, the *lynck ginne*, for taking off lines, but not as for use underwater. The device is still in use: J. e.g. McKee, *Working Boats of Britain*, London 1983, pp. 120/3.

88. Anarcharsis the Scythian, ca. 590 BC. See especially Diogenes Laertius, *Lives and opinions....*, I, ch. 8.

89. R. C. Temple, ed., *A geographical account of countries around the Bay of Bengal, 1669-79*, Hakluyt Society 2nd Series Vol. XII, Cambridge 1905, pp. 100-6 and Plate VIII.

> "..their launching and hauling up the ships is after a most excellent manner, for which they are highly to be commended. I have seen a ship (belonging to the King of Golcondah) a ship of great burthen, built for the trade to Mocho in the Red Sea, and after two voyages thither she was hauled upon the western side of this river a little above the town, to the intent they might sheath and repair her. She could not be less (in my judgement) then 1000 tuns in burthen, and they hauled her up by strength of men with good purchase as follows:- they prepared two very substantial timbers, of 20 foot [6.1 m] long each and 20 to 24 inches [508-610 mm] in thickness [depth] upon which they erected a cradle fitting for the bilge of her, the two main timbers being placed at that distance that the cradle being put under her the foremost was 8 or 10 foot [2.4-3.05 m] abaft the scarf of her stem, the other as much before the heel of her sternpost, with girdlines from the said cradle to her ports or scuppers; to the dogs were fitted good straps and four-fold tackles, the fall of 15 or 16 inch [381-406 mm circumference] coir cable, the which are brought to two very substantial crabs, placed a little above the height they purpose to heave the ship to, and heave first at one end and then at the other 5 or 6 foot at a time, and so on until she is high enough, the dogs running upon good rollers, as in the manner following [key to figure]. The cables straps etc are made of coir, viz the rind of coconuts very fine spun, the best sort of which is brought from the Maldive Isles. They are as strong as any hempen cables whatever, and much more durable in these hot climates, with this provisor, that if they chance to be wet with fresh water, either by rain or by riding in a fresh river, they do not let them dry before they wet them well in salt water, which doth much preserve them, and the other as much rot them...."

Bowrey's sketch shows the hull hauled out broadside-on. In some unspecified way cradles have been placed under the hull, and are secured to the hull with ropes. In this case the ground timbers (Bowrey calls them dogs) extend across the keel, and there are packings and wedges (beds and quoins, together Bowrey's cradle) placed above them to roughly match the hull. These would allow the whole to be ballasted to neutral buoyancy, and moved sideways under the ship in contact with the keel until the cradles made contact - though not necessarily good contact. In fact Bowrey draws the hull inclined to one side with only one side of the cradle actually in contact. How much faith can be placed in this level of detail is unclear: he also draws the dogs sitting clearly above the real line of the keel and unsupported bilges, despite his text description. There is actually a greater dilemma in interpretation here. The dogs are said to be single timbers at each end 20 feet (6.06m.) by about 20 inches (508 mm.) depth, which is consistent with what is drawn for the capstan for example, or the details of the upperworks. There certainly had been Indian vessels of such sizes: but not of 20 feet (6.1m.) beam - 1,000 tons burthen (previously taken on trust by this writer) would require about 40 feet (12.2m.) beam. Looking at the details overall we may suppose an error in the published text, and that the vessel was in fact about 100 tons burthen, say about 50 tons lightweight. Alternatively, the dogs should occupy only half the breadth. Another point is that the text is incomplete in relation to the figure, with no mention of the beds and quoins (or their longitudinal shaping); nor of the poles stretched from end to end; nor of the square fids at each end of the dogs. These latter are virtual proof that the dogs were not single timbers at each end, but a series placed side by side, like European *vasos*, producing much larger and more stable bearing areas for both the hull and the rollers. At this date it is impossible to know whether the dogs and their fids are a copy of European methods, or a local development. The text does not say so, but it is probable that boards were laid on the ground to prevent the rollers digging in - otherwise they are simply crude groundways, will not roll to reduce friction, and 1,000 tons would be very improbable with such limited bearing area.

The next account to consider is by Ollivier, for southern France, about 1736.[90] His text is:

> "The cradle to drag vessels ashore is made in the ports where there is no tide, with three bilgeways, one of which is placed under the keel, and the other two one each side of the keel, like the bilgeways of a launching cradle. The parts of this cradle are the bilgeways, the transoms, the stretchers, the stoppings-up, the dagger planks and the chocks. There are no poppets or lashings in the cradle. The pieces of which it is composed are fastened one to the other with nails. They are assembled on a slipway, so that the underside of the cradle may be in a straight line. One gives to the upper face of the centre "bilgeway" that must touch the keel the same arc that one observes in the keel of the vessel that is to be dragged ashore, and raises the stopping-up and dagger planks above the bilgeways each side as the figure and form of the vessel demand. The cradle thus built is launched into the water; one loads it on the sides with old cannon to make it sink, and leads it just under the vessel, and when one judges from the dimensions taken that the middle of the cradle is to be found under the middle of the keel, the weights with which it is loaded are removed. Then the cradle tending to rise because it weighs less than the mass of water that it displaces comes of its own accord to be applied against the bottom of the vessel, and serves it as a base on the slipway (*cale*) where it is dragged. In the [strongly tidal French Atlantic] ports of the ocean, low tide allows the cradle for the vessel that one wishes to drag ashore to be set up on the *avant-cale*. It is composed of two bilgeways like a launching cradle. One puts the stoppings-up on these bilgeways, supported on chocks, such as the figure of the vessel demands, or [sic: and] one fastens these pieces together with transoms and stretchers, and offers up the vessel on the cradle at high tide, so that when the tide falls, the vessel is supported on the cradle."

Again, the account is incomplete, assuming that we know how, for example, to measure the profile of the hull while it is afloat, to allow for the hogging (since the keel will rest on a shaped "bilgeway"). Nonetheless, despite its late date, this is an authentic description of what must be very old practices, distinguishing the two extreme tidal cases.

A series of descriptions of machines for hauling ships ashore are given by the Academie Royale des Sciences for 1702-3. One of these is for the method actually used at Brest, and most of the other ports of France, according to its author, Blanchart. The other two are alternatives proposed by Blanchart and du Mé.[91] Du Mé's method includes the development of a masonry slipway to contain grooves (three in fact - there was to have been a "bilgeway" under the keel too, as later described by Ollivier, above) in which many rollers were mounted, to reduce the force needed to drag the vessels and cradle. He is describing a forerunner of the "Patent Slip," where the cradle was fitted with wheels, and ran on rails. The slope was to be 10 in 144, so that the vessel did not have to be moved too far (though this is in fact unusually flat). The force was still to be applied with a prodigious assembly of very heavy hawsers and thirteen massive pulley

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90. Ollivier, *Traité, op.cit.*, art.: *berceau,* p. 40-1.

91. Academie Royale des Sciences, Paris, *Machines et Inventions*, Tome 2. Du Mé: No. 70, 1702, pp. 9 ff and plate I fp. 12. Blanchart: No. 89, 1703, pp. 55-6 and plate I fp. 56. Brest: No. 90, 1703, pp. 57-60 and plate II fp 60.

blocks, secured between eight large half-buried anchors for the standing parts of the tackle and powerful geared capstans for the falls. The untarred hawsers were of 9 and 15 *pouce* circumference (77.5 and 129 mm. diameter). The sheaves of the blocks were to have two and a half *pieds* (812 mm.) diameter, and in the sister-blocks, the smaller sheaves, "that is to say those that come towards the narrower end of the shell, diminished always six *pouces*, also of diameter; but they always have the same thickness, which ought to be three *pouces* two *lignes* (85.7 mm.), the hawser that serves them having nine *pouces* circumference." There were four geared capstans in this arrangement. Blanchart's were each worked by 36 men. Du Mé continues:

> "Thus when one wishes to drag a vessel ashore, the ordinary apparatus supposed to be made, that is to say the vessel established upon its cradle, this cradle seized to cables A, B, C, the four capstans will be turned together, which will haul on the four ropes S, R, P, Q, by means of which the vessel will climb the length of the plane: but for that it is necessary to observe that all the ropes may be well handled, and that the manoeuvre may be conducted suitably, because there are many inconveniences and risks in this method of hauling vessels.
>
> 1. One cannot pay too much attention to making the vessel bear upon its cradle, where it is always in danger of turning over.
>
> 2. The different shocks caused by the work, and the different turns that the vessel is given in this situation in relation to its weight, often take it on one side (*de faux côtés*), altering its construction absolutely.
>
> 3. If a hawser should break, it can result in many accidents, both to the vessel and to the workmen.
>
> 4. Finally, in making use of this sort of *capstan à lanterne*, it is true that one increases the force, though losing time proportionately: but also it is to be feared that one of the teeth of the *lanterne* or of the wheel that leads it, may break, which would produce the same effect as if the cordage should break.
>
> Nevertheless these inconveniences are not a [? have no] remedy, since an almost similar manoeuvre is made use of every day for the same purpose."

Blanchart's proposal dispensed with anchors and geared capstans, but used eight simple capstans in their place, each with a lead-block (secured to a buried post at the head of the slipway) to find space for them all. This was conceded to be very similar to Du Mé's arrangement, but safer. In some ways the machine actually in use at Brest is the most interesting account (Fig. 14):

> "The vessel being placed in it cradle, constructed on the lower part of the slip, the piece ED is fixed to the cradle, which [piece] contains in its length the four blocks (*moufle*) V, X, Y, Z, each composed of three pulleys assembled in the shells made within the thickness of the piece, that is bound at its extremitites with bands of iron; and in the intervals that the blocks leave, others of them. To these bands iron rings are fixed. The other piece LM is similar and is fastened at the upper end of the slip to three fixed points N, O, P. One takes a hawser and secures one of the ends to one of the rings of the blocks, then the other end is made to pass through the blocks,

and as they are here four in number in each piece, four capstans S, T, Q, R are also set up, to which the hawsers are fitted. The other capstans I, G serve to receive ropes GFE, IHD, directed by the blocks H, F; these ropes are to maintain the cradle always in the same direction [as seen in effect in the launching described above in the Album of Colbert]. The part of the slip on which the cradle bears ought to be well greased. The things being thus prepared, men are applied to the capstans that they are to turn, and they raise the vessel, as in the preceding machines. The following analogy will give the calculation of advantage of this machine, and this calculation will serve as a rule for all those of this kind."

The calculation that follows related the number of men (216 in all, each pushing with a force of 25 *livres* (12.5 kgs)) and their places on the capstan bars, to the force applied to each part of the apparatus, tracing it back to a total force applied to the cradle, and allowing for the slope of the slipway (1 in 25 here), the weight of the vessel that would be in equilibrium - the capacity of the machine. The critical fault in the process is that no friction is allowed for at any point: not in the axle of the capstan, nor in each sheave of each pulley, nor between the cradle and the slipway. The correct answer is certainly not around 5,158-5,550 tonnes as stated (allowing for misprints and errors in the arithmetic). 900 tonnes would be nearer the mark, which probably does correspond with the launch weight of large ships of the period. Nonetheless, this is the first such published estimate located, and the fact that Academicians were concerning themselves with such matters, when the whole business of shipbuilding and launching was not normally a literary or socially prestigious activity, is an indication of the practical problems States faced in operating large ships.

One point to note in this section is that the use of ships' anchors to secure the standing parts of the tackles for hauling ashore (or for launching) would be a dramatic test of their quality. Failures would be conspicuous, and the broken parts easily recoverable for examination. Design and construction faults in anchors, so important for the security of ships at sea, would be much more readily discerned, and not least by those responsible for their manufacture, than if they failed at sea, perhaps with no witnesses. The same might be said of the ropes and pulleys. Interestingly, similar tackle was widely used in the erection of statues and obelisks, but without a record of conspicuous failures. Stone is of course even more brittle than a ship, and in rare cases just as heavy. Thus we have engravings of the erection of a large obelisk in Rome in 1590;[92] and Catherine of Russia had a monumental granite base reputedly weighing a thousand tons moved in 1782, using iron cannonballs as a form of ball bearing between hollowed "bilgeways" and successive lengths of "standing ways."[93] Fincham makes the same point about ships in general: the loads are far less predictable than for many other constructions and machines.[94] There are examples of large blocks extant, as at the Museu Militar in Lisbon, where a set of four shoe blocks[95] standing 1.5 metres high, each with three, four or five sheaves of 340 mm. diameter, all heavily iron bound. These were actually used for the

92. Illustrated in J. P. M. Pannell, *An illustrated history of Civil Engineering*, London 1964, p. 343. This used forty horse-capstans; it had been brought from Heliopolis in 37AD, but how the Romans lifted it is not known.

93. Illustrated in T. Lentin, "The return of Catherine the Great," in *History Today*, Dec. 1996, p. 16-21. The bearing pressure of the iron spheres on the wood half-cylinder must have been critical.

94. J. Fincham, *An introductory outline of the practice of shipbuilding*, 2nd Edition, Portsea 1825, pp. 1-2, including the observation that as soon as it goes afloat, a ship becomes a "distorted machine"; though he does calculate static bending moments from the intended form.

erection of a statue of approaching 40 tonnes in Lisbon in 1774-5; but are much smaller than those recorded for launching ships earlier in that century.

An unusually detailed record survives for a slipway arranged for hauling ashore at Trieste in the mid-nineteenth century, "Arrippamento di un naviglio."[96] The ways are extended on a foundation of stone blocks, on a cambered surface, with the camber increasing towards the water. There are again no sliding planks over the transverse groundways. The cradle is composed of a pair of heavy bilgeways, with cribs of wedges and rope restraints much as the old launching cradles. Four beach capstans are in use.

A brief description of how the cradle (or sledge as it was termed) was to be fitted under a ship for hauling ashore arises from a new slipway in Palermo: the whole was sunk under the vessel, hauled up close, and then wedges drawn along guides on crosspieces by ropes from above to prop it.[97] This source also states that a slope of 1:13.3 is necessary to slide timbers separated by tallow and grease, but that over a short period of repair (or rest) the initial resistance increases by 5% of weight. The allowance on the hydraulic presses for the slip was thus 20% of total weight to haul a ship up the slip.

It is clear that such devices still exist to be recorded. A cradle, itself quite recent, but of an archaic form, lies on a steep pebble beach in Madeira, associated with substantial fishing vessels. Here there is no trace of groundways, though smaller vessels at the same yard have the benefit of a marine railway. The cradle consists of one long central baulk under the keel and two shorter timbers for the bilge. Two pairs of cross beams and wedges to roughly match the hull form tie these together, and iron bars transmit the drag forces between them.

Slipways

It is unusual to find information about the construction of slipways, or even about the range of techniques that might have been used in their construction. Thus Fernandes provides us with some details of the *grade* in 1616, but limited to a length that is no more than that of the hull: it is not clear what happened in the gap between the building area and the point at or below the low water mark where a large ship could be floated free of a cradle. Ollivier refers to the *avant-cale* that was required for launching in that zone, but his detailed text on the subject, if ever written, is lost.

A number of techniques were certainly available in principle for constructing the slipway beyond the low water mark where necessary. In the Mediterranean, for example, it would be quite impossible to float quite small ships onto cradles without constructing slipways below water; and the only alternative would be to drag a vessel over the natural sea-bed.

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95. Multiple blocks with two sets of 3 and 4 or 5 sheaves sheave pins arranged at right angles one above the other, with a ring at one end only, presumably acting as effective 7- and 8-sheave sets.
96. Kindly provided by the late Mario Marzari, from a contemporary encyclopaedia, unidentified.
97. WWW, abstract of W. Theis on "Repairing slip at Palermo," in *Minutes of Proceedings of the Institution of Civil Engineers*, Vol. XLVIII, 1876-7 pt. I, pp. 297-9. The data is pessimistic in comparison with some other sources.

Caisson construction is an ancient skill, with considerable remains reported and methods reconstructed especially from Caesarea, though this was actually for the construction of harbour moles. Huge timber boxes were constructed, floated into position, sunk and filled with concrete or stone and hydraulic mortar.[98] They are described for harbour works by Vitruvius. Classical methods could equally place individual stone blocks of at least nine tonnes weight.[99]

Cofferdams could be constructed by driving sheet-piling, in suitable ground, and then working inside in the dry to create a permanent structure within them. Ramelli provides details of elaborate cofferdams and the pumps needed to drain them in a work published in 1588, which also shows complex geared capstans giving huge mechanical advantage, but no great strength.[100]

It would have been possible to drive piles in suitable ground, whose heads could be cut off underwater, and used to support and fix in position the timbers of a grid, which would have to be largely pre-fabricated, and probably use divers for placing it.

It is however surprising that the early modern texts on construction of hydraulic works - all much later than our strict period - do not discuss the issue at all.[101] It is perhaps a reflection of the strange fact that most texts on shipbuilding - in any age - simply do not touch on the practicalities of launching the resulting ship. In the sixteenth century it is known that Mathew Baker, Master Shipwright in the Royal dockyards was called upon as a universal Engineer, to advise on the construction of dry-docks,[102] and on harbour works as at Dover.[103] It seems that the tasks of building dock works and in water, and of shipbuilding, may have diverged thereafter. The first text that mentions the matter seems to be Diderot's *Encyclopédie* of 1751, which has an entry for *cale* that is worth giving in full, as an excellent summary of the problem:

> "Still said of a terrace hollowed out to a certain length and breadth in a shipyard, prepared to a gentle slope, and extending just into the sea, to drag the vessels ashore when there is a question of repairing them. For a long time in France it has been mooted whether slips were more advantageous for shipbuilding than dry-docks; but dry-docks appear to have carried the day. The principal inconvenience that is found in slips is that the vessel is in danger of falling onto its side when it is dragged onto the slip, or when it is returned to the water; and when the ship rests on the slip it can only be supported by the bilgeways, which cannot go from one end of the vessel to the other because of the rising forms of the bow and stern, only one part being supported, while the bow and stern that are not supported by any-

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98. J. P. Oleson, "The technology of Roman harbours," in *International Journal of Nautical Archaeology*, Vol. 17.2, 1988, pp. 147-157, is a good summary; the works at Caesarea are illustrated in *National Geographic*, February 1987.

99. H. Frost, *History under the Mediterranean*, London 1969, p. 80.

100. Agostino Ramelli, *Various and Ingenious Machines*, 1588 (facsimile 1976).

101. Bouillet, *Traité des moyens de rendre les rivières navigables*, Amsterdam 1696. R. Castle, "Essay on artificial navigation (1730)," ed. J. H. Farrington, in *Transport History*, Vol. 5, 1972. George Semple, *A treatise on building in water*, Dublin 1776. A more technical survey of old methods is in E. Dobson, *A rudimentary treatise on foundations and concrete work*, London 1850 (and facsimile).

102. MS 2876, Pepys Library, Magdalene College, Cambridge, p. 587 (ca. 1605).

103. From State Papers, personal communciation Stephen Johnston.

> thing suffer greatly. Besides, the slip being narrower than the vessel, it cannot be shored from one end to the other. These inconveniences are not met with in the dry-dock.
>
> So that a slip be as perfect as it may, it is necessary that the bottom is made very solid, and extremely smooth, maintaining a gentle slope equal to about 6 to 8 *lignes per pied* [1 in 18 to 24], so that it becomes extremely long, and can have a length of around 600 *pieds* [195m.], by 25 to 30 *pieds* [8-10m.)] in breadth. It is necessary that it extends under the water to the extent that it has at least 21 *pieds* [6.8m.] of water at the end, so that a ship may bear entirely on the slip, and that the keel touches from one end to the other at the same moment; because a vessel of which one part touches and another is afloat suffers greatly. To render the bottom of the slip solid, it is made of great masonry-filled caissons (*caisses maçonnées*), for which it is necessary to pay great attention to placing them in such manner that the level of the slope is carried forward well. The coffer for the end that is advanced furthest under water is very difficult to sink. A grillage of timber called an *échelle* is put on this base, that serves to make the vessel slide, and sets up there ribbands (*coulisses*) so as to drag the vessel straight and stop it veering. Several capstans are used to drag the vessel onto the slip, and a timber construction that is called a *berceau*. There are necessary for a slip one grillage, three cradles, one for large, one for average and one for small vessels, and several capstans."

An isolated record exists for some of the works in connection with launching from the yards in Bahia in 1717. Three master carpenters and an *adjutante engenheiro* (who assisted in drawing the moulds from the proportions and measures for marking out (*a tirar as formas pelas proporções e medidas de risco*)[104] - perhaps at that stage of construction this meant taking the lines of the hull so that the cradle would fit properly) were engaged for the preparations for launching, some of them for over a month. The construction of the *grade* required many skilled men including master-caulkers, master-white-carpenters, blockmakers, turners, blacksmiths, and others; some religious ceremonials and trumpeters are also implied.[105]

Similarly records are noted for 1755, which include repairs to the site in Salvador, Bahia, before shipbuilding could start. This involved small quantities of stone, sand and lime, but also of tiles, all used by a master stone-mason. Since another entry is for painting the mould-loft (*casa das fôrmas*, an interesting item in itself), it is possible that the repairs were to buildings, rather than the slipway: the works were on the *carreira* which could mean slipway or shipyard, but no details emerge. This was a sufficiently remote site - chosen presumably for the over-riding imperative of suitable ground and slope to a good depth of water - that it was necessary to bring water to the site from a nearby *aguada*, the quay of the *Água dos Meninos*. Surprisingly only seven boat-loads of *tonels* and *pipas* were paid for during the whole course of construction of a large ship, and the barrels were repaired six times. The same source records the customary payments (*propina*) made to the master shipwright on keel-laying and on launching, amounting to about one-quarter percent of the construction cost.[106]

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104. *Risco* was ordinarily the whole plan for the ship, sent out from Portugal: José Roberto do Amaral Lapa, "Memória sobre a nau Nossa Senhora da Caridade," in *Estudos Históricos*, No. 2 December 1963, São Paulo 1965, p. 49. *Sala do risco* was the room in the Arsenal da Marinha, Lisbon, where they were prepared.

105. José Roberto do Amaral Lapa, *A Bahia e a Carreira da Índia*, São Paulo 1968, pp. 123-4.

There must be a suspicion that in an earlier period the slipways really were stopped short at the low water mark, and shipbuilding sites selected with the right slope and firm ground and no other preliminaries.[107] The apparent absence of texts on the matter, and the drawings of Fernandes, Gaztañeta and Colbert might support this slightly surprising solution. This would go some way to explaining why ships had to be dragged afloat.

The fore-poppets

Slipways are critically important for other reasons, including what for this writer remains one of the most intriguing questions of all: why did the fore poppets (in stern launching) not collapse at the point of rotation? The usual modern arrangement for large ships, of great length, is for the hull to be supported in a major structure, still called the fore-poppet, because the stern starts to lift long before the ship is fully afloat. Necessarily, a point is reached where the buoyancy of the stern is sufficient to lift it, transferring the remaining weight to the extreme fore end, and also rotating the hull about that fore-poppet. Many ships actually require internal strengthening at that point to get them afloat undamaged. A modern launch happens so fast and usually so remote from most onlookers, that the critical behaviour at the fore-poppet is not discernible, but failure to make sufficient provision for the geometry and load transfer involved in the rotation would lead to failure. Fore poppets collapsed dramatically at a major launch in the 1990's. The problem is not so severe with the shorter wooden vessels of the historic period, but it certainly came to prominence with longer iron and steel vessels, though this writer is only aware of one quantitative paper illustrating the problem with an analysis of the state of the fore-poppet after the launch.[108]

In the historic period the literal fore poppets were actually a pair of single timber baulks on end. If the ships thus supported rotated as described, there would have been a great risk of either crushing or buckling collapse of the poppet, or of it simply slipping out of place. Damage to the hull might also be expected from such a concentration of load. So why does it not seem to have happened? The risk of bits of the cradle falling away and fouling its passage is as near as we get to a reflection of the problem.[109]

One possible explanation is that in fact the sholes and dagger planks crushed or moved enough to allow a reasonable number of poppets to share the load during rotation, or that the structure of the slipway was flexible enough to contribute to the same effect - a

106. Amaral Lapa, "Memória...," *op.cit.*, pp. 67, 68, 72, 74, referring to MS 3.314-3.318, Bahia, Arq. Hist. Ultramarino, Lisbon.

107. Indeed the writer has heard a description of recent Euro-frigates being launched on temporary ways across sand to preserve a Mediterranean beach (pers. Comm., F. P. Scourse).

108. J. Dickie, "The launch of the cruiser *South Dakota* at the Union Iron Works, San Francisco," in *Transactions of the North East Coast Institution of Engineers and Shipbuilders*, Vol. XXI 1904-5, Newcastle 1905, pp. 77-189+plates. Crushing pieces introduced within the fore poppet, initially all 8 inches deep, were crushed down to variously 7.5 to 0.5 inches (the furthest forward), by the rotation and concentration of load on fewer pieces.

109. This puzzle was one reason for starting research for this paper. This writer had an opportunity to witness details of a frigate launch in 1995, with this very point in mind, though it could never resolve the historic problem.

relative shortening of the poppets furthest inshore during the rotation. Nonetheless it is surprising that there is no more discussion of the point in contemporary texts.
Another possibility is that slipways really were not long enough to allow the ships ever to get to that point of rotation, with the stern lifting. As discussed above, especially in connection with Dutch methods, if the standing ways did not extend far enough, the hull would tend to rotate in the opposite direction as its centre of gravity moved over the end of the ways, the bow rearing. The corollary is that there is a risk of the keel striking the ground as the launch proceeded and the end of the bilgeways dropped off the standing ways. A further corollary is that such a slipway is not well-suited to hauling a vessel ashore, as the keel will tend to be below the end of the slipway. The height of tide will again be significant; coupled with the sea-bed profile off the end of the ways.

Yet again, there is a possible link to bow and stern launching, in the differential behaviour of the slender run and the full bows of typical ships, though the issues are very specific to individual ships and sites.

Cambering the ways, always setting them steeper towards the water's edge, has an interaction with this problem too, and it is conspicuous that many illustrations of early ways do show a marked camber. The potential effects are numerous, from changing or inducing rotational behaviour, and consequently controlling the maximum load imposed on the ways; making the ways shorter for the same immersion on the end of the ways; making it easier to get the keel over the ways in hauling ashore, etc. The literature on these issues for long iron and steel ships is very extensive, and each launch is the subject of elaborate calculation. One difference is that latterly the camber is likely to be of a uniform curvature throughout: that was certainly not the case in yards handling smaller and wooden vessels.

The launch of I. K. Brunel's *Great Eastern*, 1857-8

The reasons for referring to this seeming anachronism are several. It was a national event, for the greatest ship ever seen, with an iron hull weighing 12,000 tons at launch; it was a mixed success (for reasons which are still the subject of bitter partisan dispute), and this combination makes it probably the best-recorded launch in history. It was extensively photographed (collected most completely by Beaver).[110] The components of the cradle and ways were elaborately tested during the design. The details of the launch process and the results of the preliminary tests are reported in Brunel's biography.[111]

There are thus important points recorded that are of relevance in understanding why much smaller ships could become stuck upon the ways. When timber ways, however carefully prepared were loaded (to perhaps several tons per square foot), and slid over each other, three things happened. Firstly there was a force resisting first movement of the two surfaces to be overcome, rather greater than sliding friction: stiction. Secondly, the carefully applied grease was forced out from the sliding surface, and unless the ship attained sufficient momentum in the first few feet it could grind to a halt (indeed Brunel's experiments showed that contrary to received opinion the coefficient of friction

110. P. Beaver, *The Big Ship*, London 1969.

111. I. Brunel, *The Life of Isambard Kingdom Brunel, Civil Engineer*, London 1870, reprinted 1971, pp. 340-391.

between the sliding surfaces actually significantly reduced above about 0.3 metres/second). Thirdly, any imperfections in the surfaces and wild grain in the timber could lead to the grains so interlocking that if a ship stuck on the ways for this reason and the bilge and sliding ways were then cut out, they could only be separated with great difficulty: they had become "wood-bound."[112] No rope tackle would overcome this sort of resistance to movement. Thence Steel's insistence on careful preparation of the surfaces, with no projections to catch, and no weak spots in the ways or their foundations, to cause uneven loading. Brunel was well aware of these risks, and preferred to try the use of iron surfaces, after tests. It might be added that at least iron does not crush at these loadings. Despite Steel's precautions, his glossary indicates clearly enough that groundways were frequently built from decayed timbers. They were large, would have wany edge, shakes, and be quietly warping and rotting in the ground. They probably did present considerable resistance to sliding in many cases, and would crush and bind.

The ship was actually launched sideways, for various reasons, still the subject of debate.[113] The cradles are thus slightly differently arranged from those otherwise described in this paper, but their structure is recognisably descended from earlier carpenters' work (Fig. 15). There were two of them, each 120 feet long (the hull was 692 feet long). They consisted of transverse timbers under the hull, upon which three rows of poppets each side were erected, apparently using the steps between in- and outstrakes in the hull plating as dagger-planks. The daggers are all horizontal, but there are three tiers of them on the outer poppets, heavily bolted together, supported on cleats, and shored longitudinally. There is even a direct imitation of the rope gammonings preventing the poppets moving outwards under the inclined load on their heads: only in this case they were 63 mm diameter iron rods, anchored in the timbers that carried the tension under the hull. The poppets are morticed into these timbers at their heels.

The ship was finally launched with hydraulic jacks, and the resistance was reasonably well known from measurements at the time:[114]

initial lubricated attempt		
	stiction:	0.125
	friction at 0.3 m/sec:	0.088
trials:		
	friction at 0.45 m/sec:	0.083
	friction at 0.6 - 0.9 m/sec:	0.075 - 0.067
reduced lubrication at second attempt, actual ship		
	stiction:	0.15 - 0.167
	friction, just moving:	0.117 - 0.125
	friction, 0.15 - 0.2 m/sec:	0.108

112. I. Brunel, *op.cit.*, p. 344.

113. D. A. Forbes, "The launch of the *Great Eastern* and the aftermath,," paper for *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, Vol. 136, 1992/3, pp. 45-60.

114. I. Brunel, *op.cit.*, pp. 348, 385-9. It should be noted that these figures as reported are not coefficient of friction, but the resistance to motion along a plane at 1 in 12, divided by the weight, acting vertically. These figures broadly match the best obtained in conventional launching, wood sliding on wood and tallow, where 7.5% slope will just slide a ship, 5% extra is allowed for initial stiction; and so to haul ashore the total force required would be 20% of the weight of hull and cradle. (This data is also in the source of note 97 above). It does however illustrate the penalty on lubrication if the launch initially fails.

The conclusion was that the critical feature was initial lubrication, for the cradle to start moving; which corresponds to the regular provision of drivers for the first impulse in old methods. Stiction had nonetheless to be overcome, and any imperfections in the sliding surfaces would also hinder the initial increase in speed that would ensure a freely sliding launch.

The key point is that, even at the height of Victorian Engineering confidence, the whole process was perceived as exceptionally difficult. Equipment and calculation alike were stretched to the limit in determining the size of cradles; and eventually the largest concentration of hydraulic jacks ever seen was assembled. Many of the leading Engineers of the day gathered to watch and learn, fully aware of the significance of the events. No comparable quantitative accounts have been found for earlier launchings of exceptionally large ships, but they occurred in all periods. The increasing size of India *naus* in Portugal from 1500 onwards must have presented just the same challenges to their builders.

Archaeology

There is only very limited published archaeology of actual launching ways. This arises in part from the total reconstruction of older dockyard sites, such as Deptford, the continual deepening of most permanent sites for larger ships over time or the encroachment of sites over older foreshores, and partly from the very ephemeral nature of slipways on smaller sites. Excavations at Woolwich Dockyard produced a long report[115] including parts of a building slip, but it is fragmentary and the site was confused by redevelopments. Buckler's Hard has produced a much more intact eighteenth century site for large warships, but the last report seen was preliminary to final excavations.[116] It is known that other work has been done, for example in Amsterdam for seventeenth century sites; equally that a lot of foreshore work has been done in China for still earlier sites (possibly fifteenth century), which might include dry-docks (though the results in the only report seen by this writer[117] are open to interpretation). Much reporting of dock features has been poor in the past, as discussed elsewhere. There is of course a substantial bibliography of work on classical shipsheds and slipways, and overland hauling, though Coates remarks that original excavations of slipways at Piraeus in the 1880's were not extended to measurements below water, significantly reducing the value of that work to archaeology.[118]

Publication is also awaited of a group of papers on related themes from the IX ISBSA meeting in Venice in 2000, which include two for Dutch and three for classical topics.

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115. T. W. Courtney, "Excavations at the Royal Dockyard, Woolwich, 1972-3," in *Post-Mediaeval Archaeology*, Vol. 8, London 1974, pp. 1-28+plates; Vol. 9, 1975, pp. 42-85+plates.
116. J. Adams, ed., Buckler's Hard: Beaulieu River Project, Report No. 1, University of Southampton 1994.
117. Chao Lei, "Découverte des cales sèches d'un chantier naval de 2,200 ans," in *Archéologia*, Vol. 118, Paris 1978, pp. 70-1. Two structures claimed to be dry-docks lie at different slopes and without any dividing structure, at unstated depth. They have not been explained, and the details are unconvincing as dry-docks.
118. Coates, *op.cit.*, p. 107.

It should also be apparent that many of the details described will have left a trail of bolt and nail holes where launching apparatus has been fastened to the hull, which can be expected to appear in underwater archaeology; much as the carpenters' surmarks[119] and ribband-fastenings from frame assembly that have already been found; or the pegs marking load-waterline that were called for in 1604.[120] It is understood that nail holes for dagger planks have been determined in the Red Bay ship of 1565.[121] Steel for example refers (p. 49) to nogs placed to prevent the heads of shores slipping on the hull (the term more usually referring to treenails fixing the feet of shores to the slip). These will probably be treenails in blind holes, and since they worked in shear may be of large size and un-wedged; they may be at many levels, and in frames alone, or placed after planking. Groups of former bolt holes might be found through all from the spurs fore and aft in especially English eighteenth century methods.

Conclusion

The paper has shown that launching a large ship was a complex and difficult operation at any time, just as subsequent repair of that ship below the waterline was a major problem either in a home port, or at the far side of the world.

We have seen how galleys and small coasters were relatively easy to manoeuvre on rollers and greased planks, but also that when during the sixteenth century ships were more commonly built to a thousand tons and more, they had become a major problem, with no ready answer available to the shipbuilder. Such ships caused great difficulties in launching them, and the process often took many days, unless momentum took over as the ship started to move.

It seems possible that the importance of longitudinal sliding planks above the groundways had not been recognised in Southern Europe, and the articulated *vasos* of the old galley tradition were binding on the transverse timbers of the slipway.[122] Yet no English or French writers of the sixteenth to eighteenth centuries comment on the discrepancy between the originally southern method using cradles then prevalent for large ships in both England and France, and the continuing existence of some of the manifestly older methods based on sliding on the keel and bilge; nor on the actual introduction of sliding planks to the transverse system in the eighteenth century - which omission remains an unresolved curiosity. It is only in the late eighteenth century that we can be certain that sliding planks were commonly used above the groundways, other than in

119. R. A. Barker, "Design in the Dockyards, about 1600," in *Carvel Construction Technique*, ed. R. Reinders and K. Paul, Oxford 1991, pp. 61-9.

120. Quirino da Fonseca, "O Problema das Tonelagems e Formas de Querena dos Navios de Vasco da Gama," in *Memórias da Academia das Ciências*, Lisbon 1935/6, Tomo I (Letras), p. 313, cites a *Regulamento sôbre não carregaram em demais as naus da índia*, dated 1604, which calls for conspicuous wooden pegs to be placed by the shipbuilder at the four quarters to mark the intended maximum draught.

121. Pers. Comm.: B. Loewen.

122. The original rollers ceased to be valuable on a large scale. They notionally remove all friction, but perfect rollers on perfect slipways concentrate loads intensely and will crush and distort the timber correspondingly; and must be exactly perpendicular to the keel and to motion, so that the benefit is lost in practice. They would be difficult and dangerous to place, and almost impossibly so under a large ship that was to be grounded.

Northern Europe. The timbers tended to squeeze out the grease and to tear each other to bits and become wood-bound, rather than slide the ship freely in its cradle.

Nonetheless, there was a steady improvement in the design of cradles during the seventeenth century, reducing the bulk of the cradle, and increasing its efficiency. This extended to methods of getting ships ashore for repair, and may perhaps be reflected in the change from launching ships bow-first to launching them stern-first.

The other striking aspect is the absence of early accounts of adequate slipways into deep water: there is no description until the mid-eighteenth century. Several sources have drawings that almost refute their existence, as we have seen. This too must have been critical to the launching process, and to the need to drag ships afloat.

The inheritance of methods suitable for rope and muscle, and of difficulties anticipated, extended to influence the launching of the early leviathans of the age of iron and steam. The problem for the builders of India *naus* should not be underestimated.

This brief survey of the sources lacks contemporary evidence to answer some of the riddles: there is considerable scope for more research into such practical matters. Not least that of when and under what circumstances large ships were first launched stern-first in Portugal. What were the foundations of slipways in dockyards, were they extended far below low tide, were they straight, or just following the natural camber? At what stage did longitudinal structure start to appear? Does the hypothesis that the great advance in European launching methods stemmed from the late adoption of longitudinal ways stand up to wider examination? - does Dutch evidence and that from further north and east fit the pattern?

A tentative chronology for the sequence leading to the large cradles of around 1800 might be:

Stern-first launching:

> Portuguese: possibly 16th century, but very uncertain, and based on iconography. Fernandes 1616 appears to use bow-first. Barlow's sketch of 1663 is explicit. Witsen 1691 is the first actual text distinguishing the Portuguese method.
>
> Spanish: Gaztañeta 1688 still uses bow-first.
>
> French: Colbert 1677 still has bow-first; Ollivier 1736 has it as optional. (Chapman, while ostensibly representing a stern-launch in 1692 is suspect, and it is probably 1750's).
>
> Sweden: Rålamb, 1691, is bow-first.
>
> Denmark: model of 1730 is still bow-first.
>
> English: large ships often from dock, and represented stern to water (the earliest of such may be the Pett portrait of 1610).

Freely sliding launch:

> England: Pett speaks of an accident with a ship sliding prematurely in 1604; Sutherland, 1711 shows massive dog-shores to prevent sliding, and no tackle, indicating free-sliding, and his drawing *may* show sliding planks, too.
>
> Sweden: Rålamb, 1691 shows massive dog-shores to prevent sliding, and no tackle.
>
> Portuguese: examples taken at face value indicate that sliding was achieved as routine between 1711 and 1721.
>
> Denmark: model of 1730 shows drivers and tackle anticipating at least a starting problem.
>
> French: Ollivier 1736 and Ozanne 1765 both suggest that sliding was still very unreliable. (Chapman, taken as 1750's, fits this pattern).

Longitudinal standing ways:

> English: before 1768 (Chapman). Text in Falconer, 1769; possible illustration in Sutherland 1711.
>
> French and Iberian: no record seen from before 1783.
>
> Older longitudinal methods survive, based on sliding the bilge directly on a longitudinal plank, as in late seventeenth century Dutch texts, and in Chapman 1768; also as listing in twentieth century England. Older, simpler, examples exist, as from Flanders, and were probably widespread for smaller vessels.

But to confuse the issue an English Navy Board model, identified as the *Neptune* of 1683, has been seen recently that includes a slipway and cradle - a very unusual feature for such a model.[123] This has a longitudinal structure to slide the bilgeways (and unlike any text description seen for English yards), vertical shores with longitudinal daggers, but no stopping up: a mixture from other known methods (Fig. 17). Clearly it is not a complete structure (there is no transverse tie or bracing, nor dagger planks) but is the slipway contemporary with the ship model? If it is, it does not fit the chronology above. This yarn is not complete.

123. Merseyside Maritime Museum. John Franklin (*Navy Board Ship Models, 1650-1750*, London 1989, p. 59) refers to the model, though not by name, as having a series of raking shores supporting the hull. This evidently corresponds with an archive photograph, kindly provided by Alan Scarth, which does show shores raking transversely into the floor of the dock, but with the bilgeways still in their correct location in the background; though the model is now correctly assembled with the range of "shores" as poppets vertical on the bilgeways.

Further studies

This study has been in hand for twenty years, and has amassed a great range of material. There remain parts of Europe hardly covered by this paper, however, and this is more likely to be a reflection of the languages searched in than of the material available. The classical period has been largely omitted here, and there are whole geographic areas - such as China - where large ships have been used in the periods considered and similar problems must have been overcome, but for which there is very little information available in European languages.

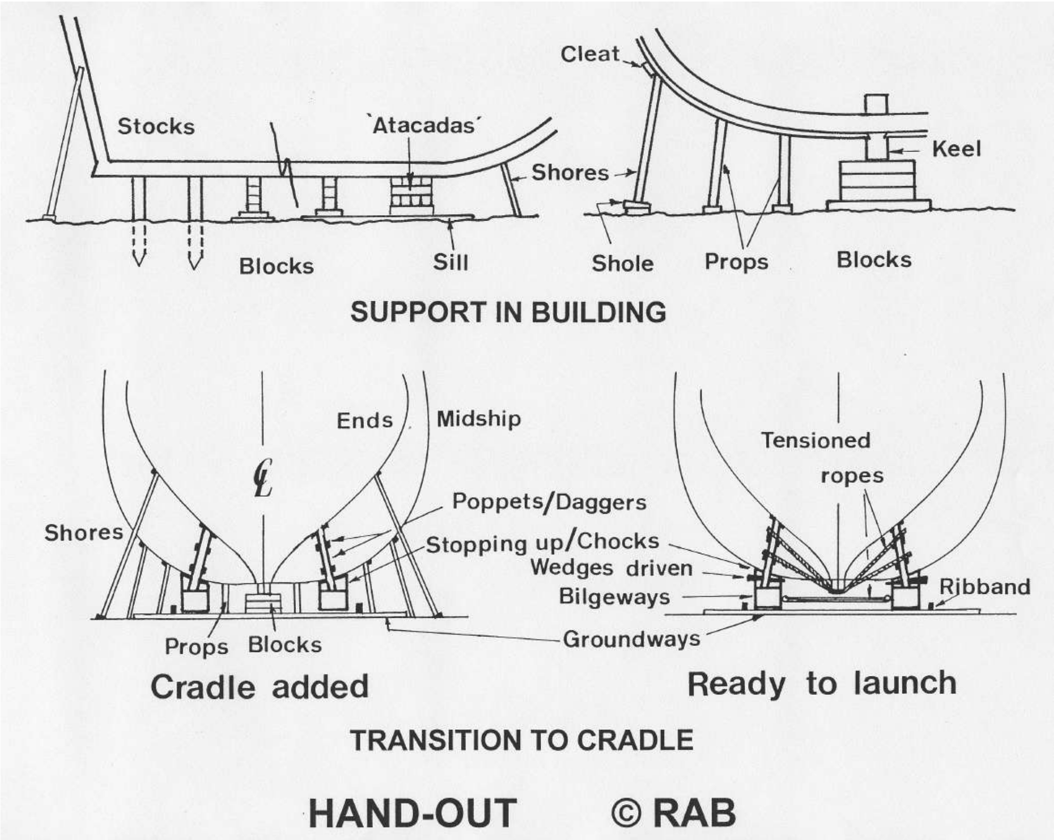
It is intended to extract significant material from post-1800 sources for a future paper, not to record a history of launching as such, but to use technical material from the age of iron and steel to further illustrate the problems of an earlier age. The key topics include:

> the problems associated with natural lubricants
>
> growing awareness of shear strength issues, both longitudinal and transverse
>
> early experiences and observations with iron hulls
>
> and, more for amusement, some of the bizarre launchings on record.

As ships increased in length (both absolute and relative) different issues came to prominence in technical discussions:

> the issue of camber and foundations
>
> the rotation of the hull, and the critical nature of support at the fore poppet(s), and internal reinforcement, temporary or otherwise
>
> the introduction of steam machinery and floating docks created a new awareness of longitudinal problems especially.

All of these have implications for both launching and structural issues in wooden hulls generally, some already touched on in this paper and elsewhere.



Hand-out: Support in building and transition to cradle - schematics and terminology.

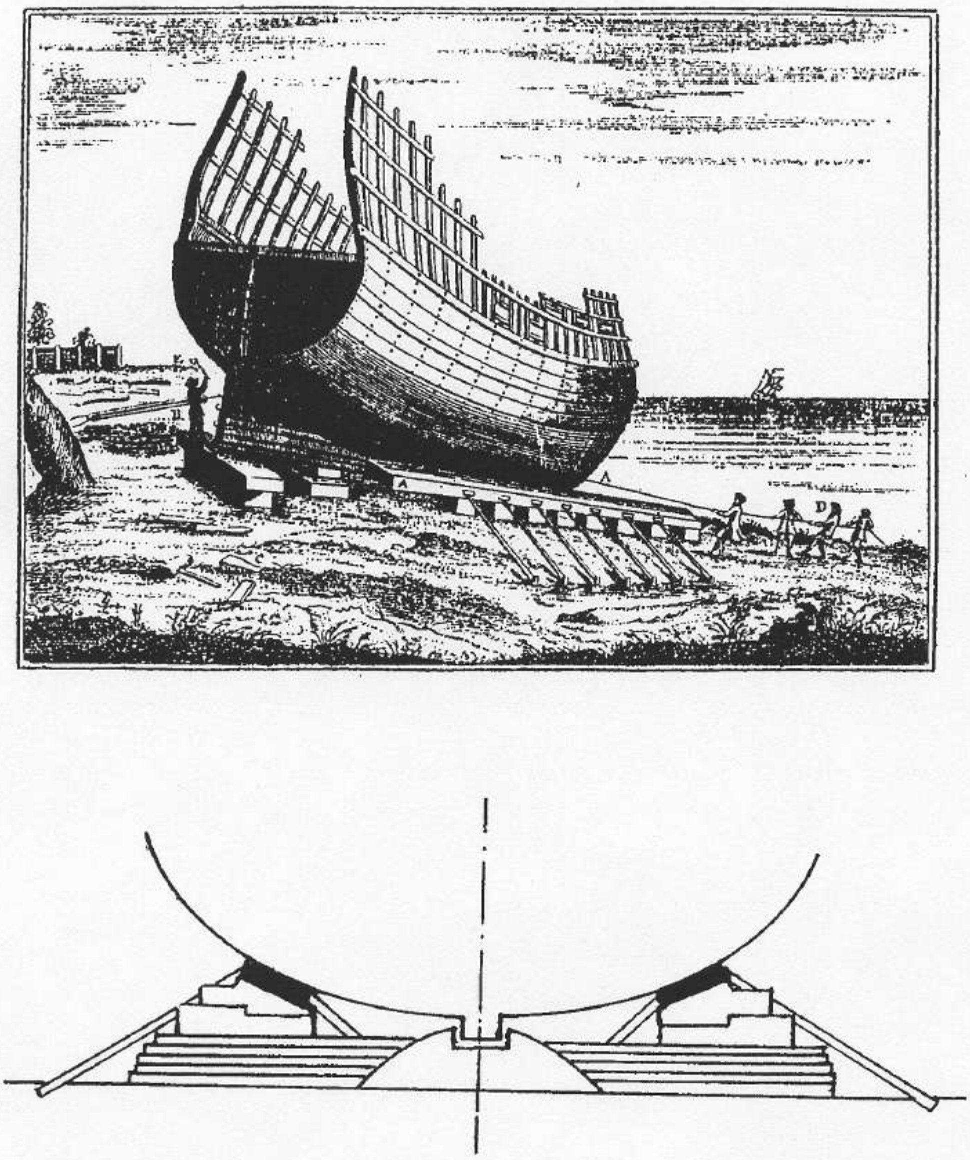


Fig.1 DUTCH METHODS

a (top): Van Yk b (bottom): Chapman

© RAB

1-a. Seventeenth century Dutch launching, from Van Ijk, 1697, plate facing page 100 (as copied by Toms).

1-b. Section of the launching ways in the Dutch method. Redrawn from Chapman, 1768.

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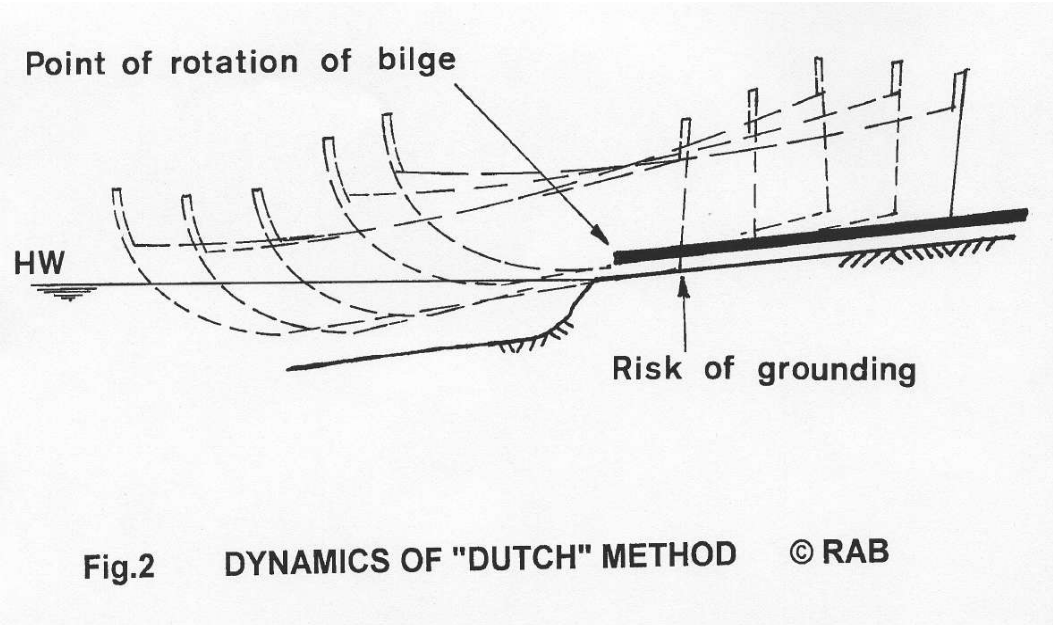
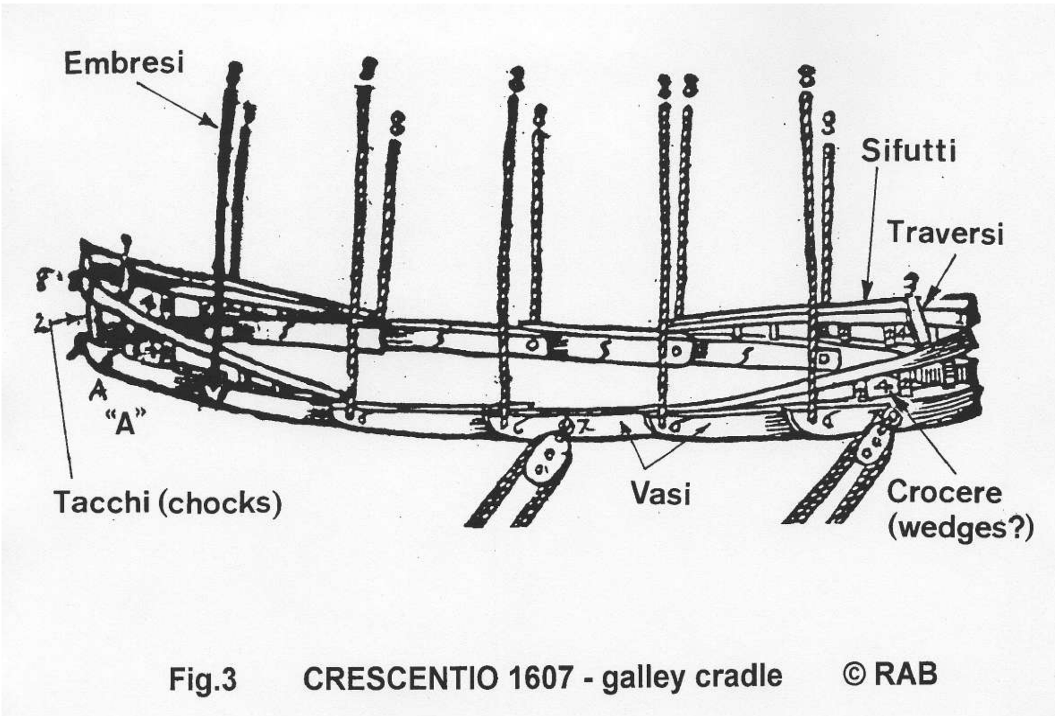
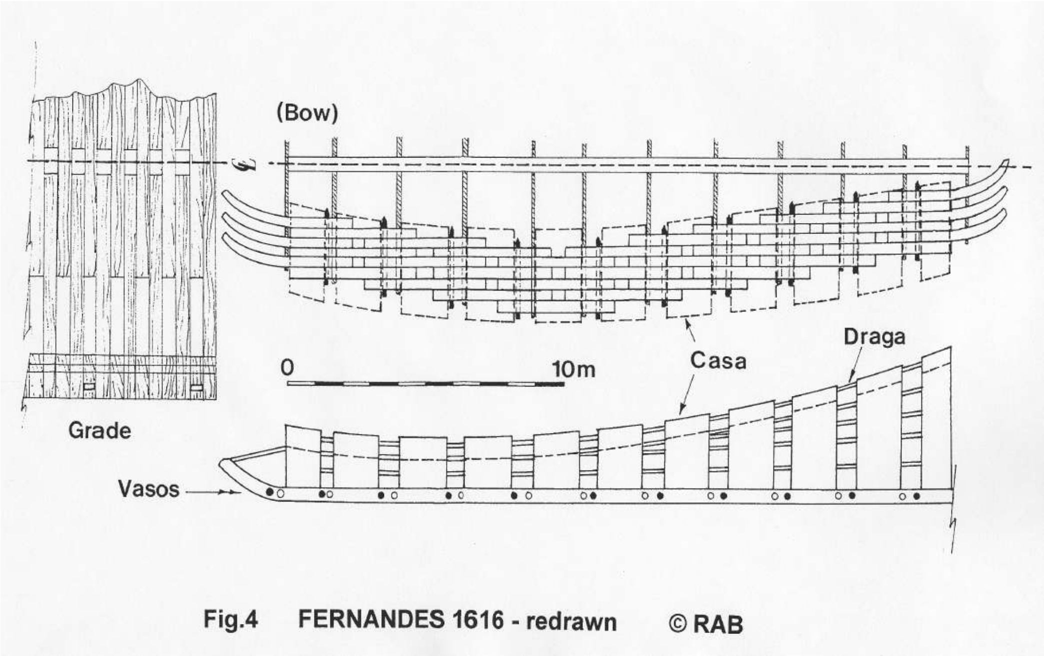


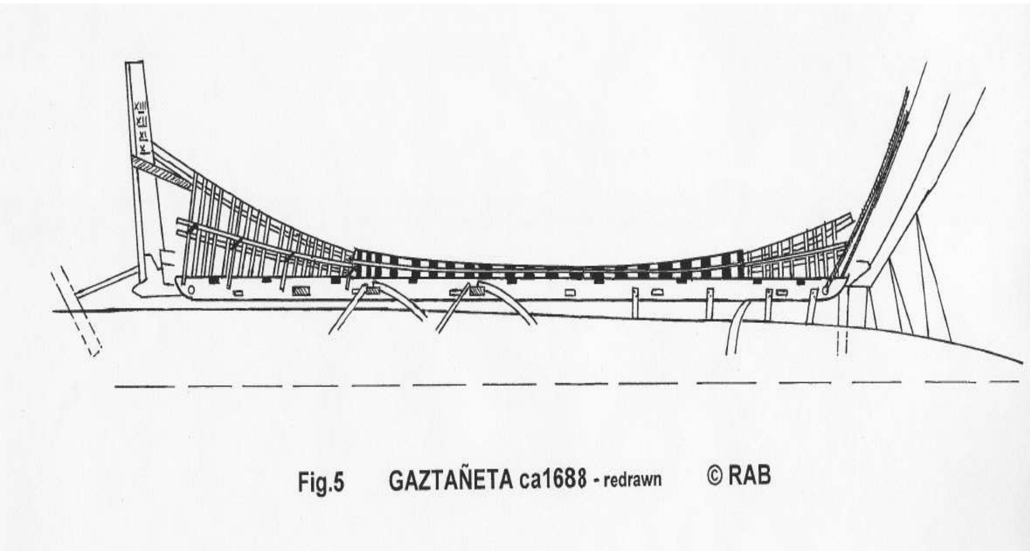
2. Illustration of the dynamics of the Dutch method for launching small vessels.



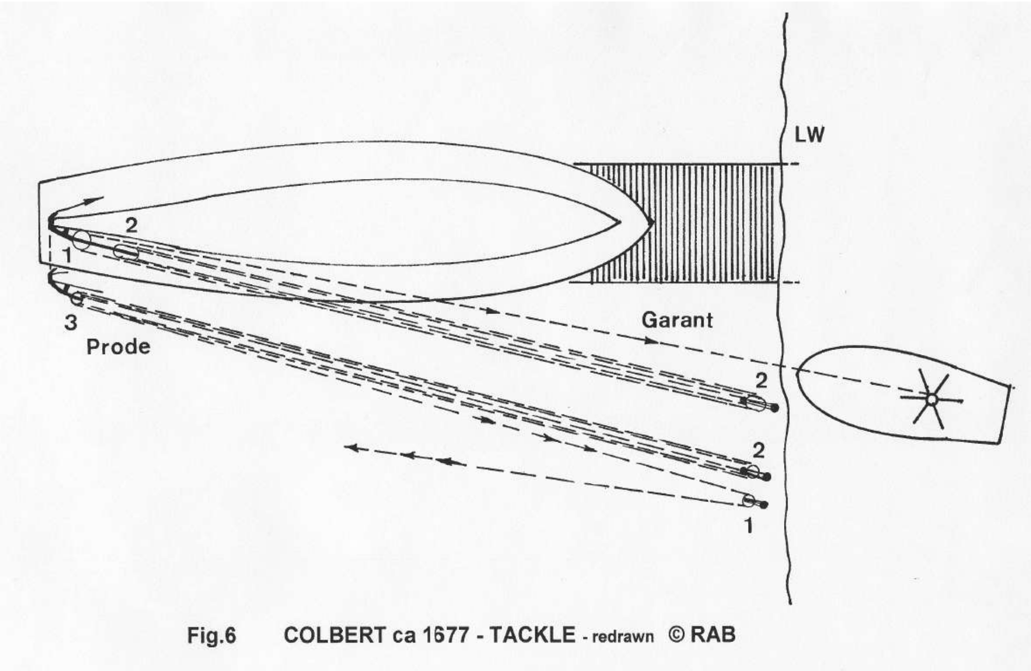
3. Galley cradle from Bartolomeo Crescentio, published 1607.



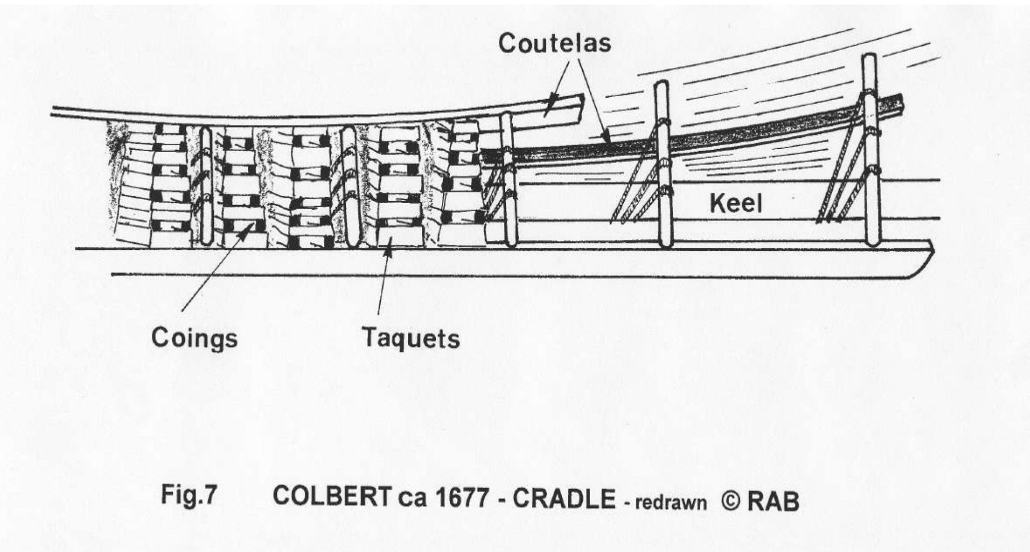
4. Launching cradle and *grade* from Manuel Fernandes, *Livro de Traças de Carpintaria*, 1616. Redrawn.



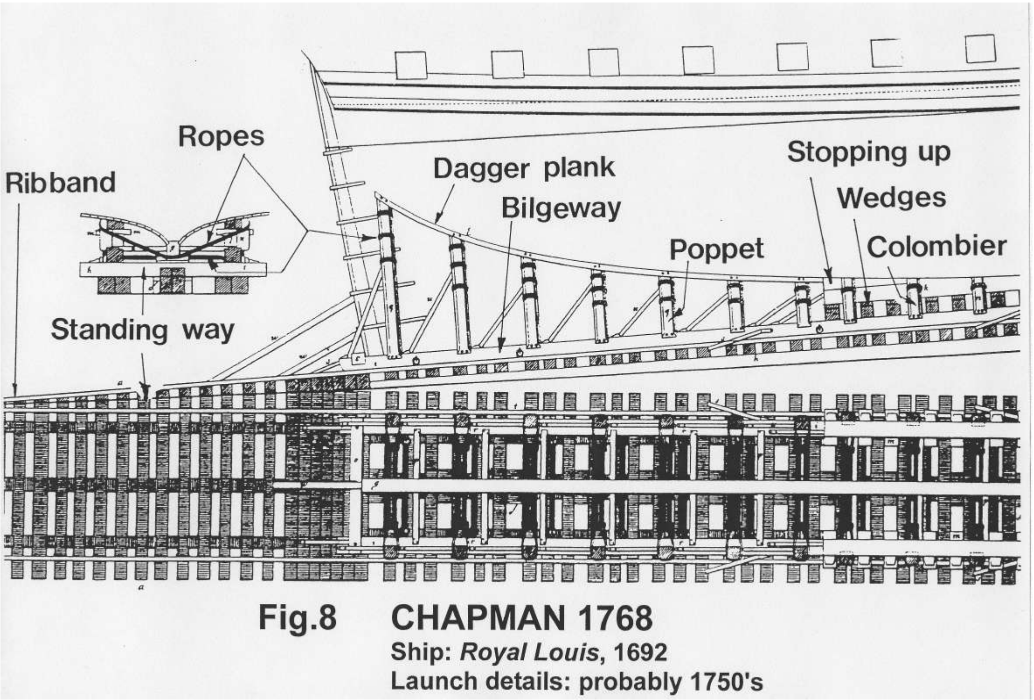
5. Launching cradle from Gaztañeta, *Arte de Fabricar Real*, ca 1688. Redrawn.



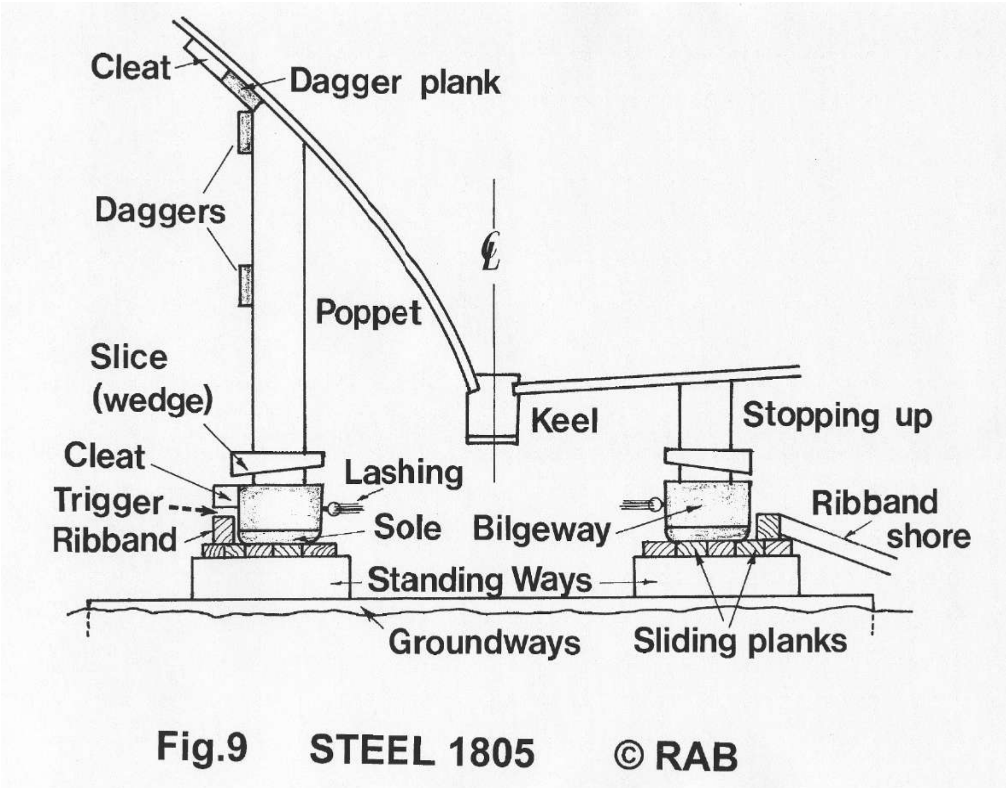
6. Arrangement of the hauling tackle for launching, illustrated in the Album of Colbert, ca. 1677. Redrawn schematically.



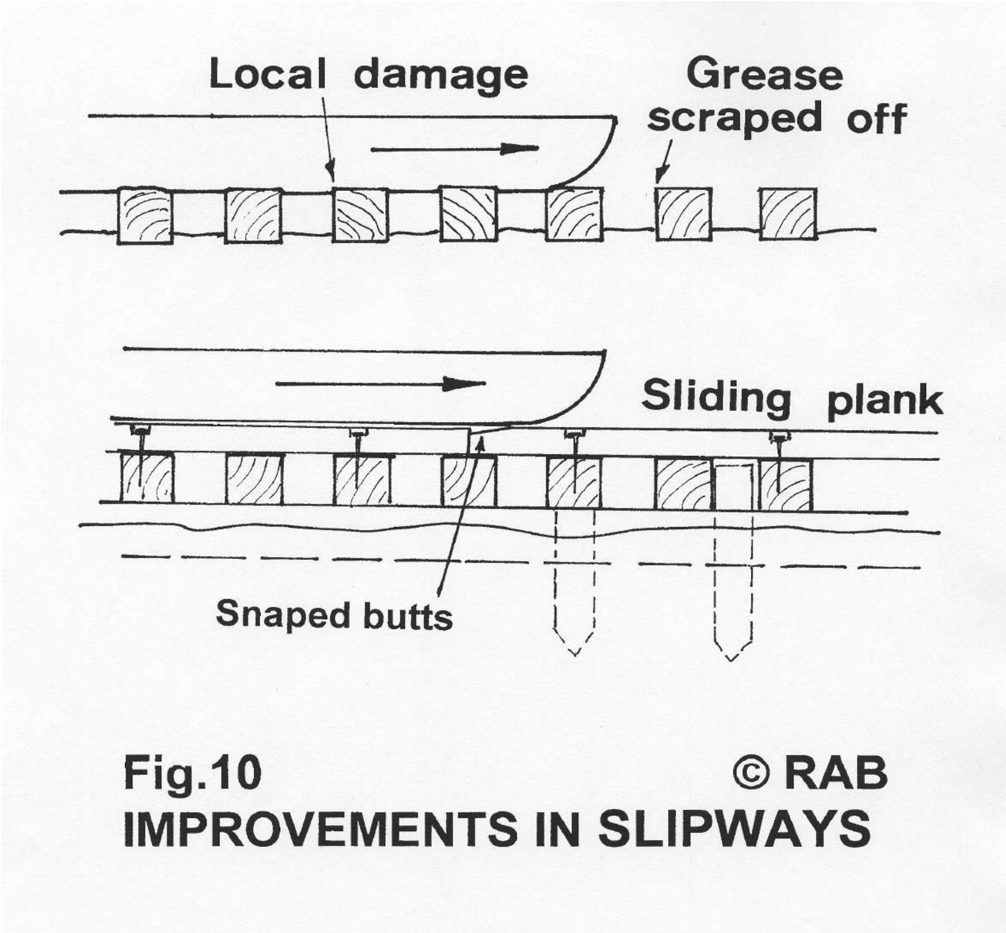
7. Launching cradle from Album of Colbert, ca. 1677. Detail of forward end only, redrawn.



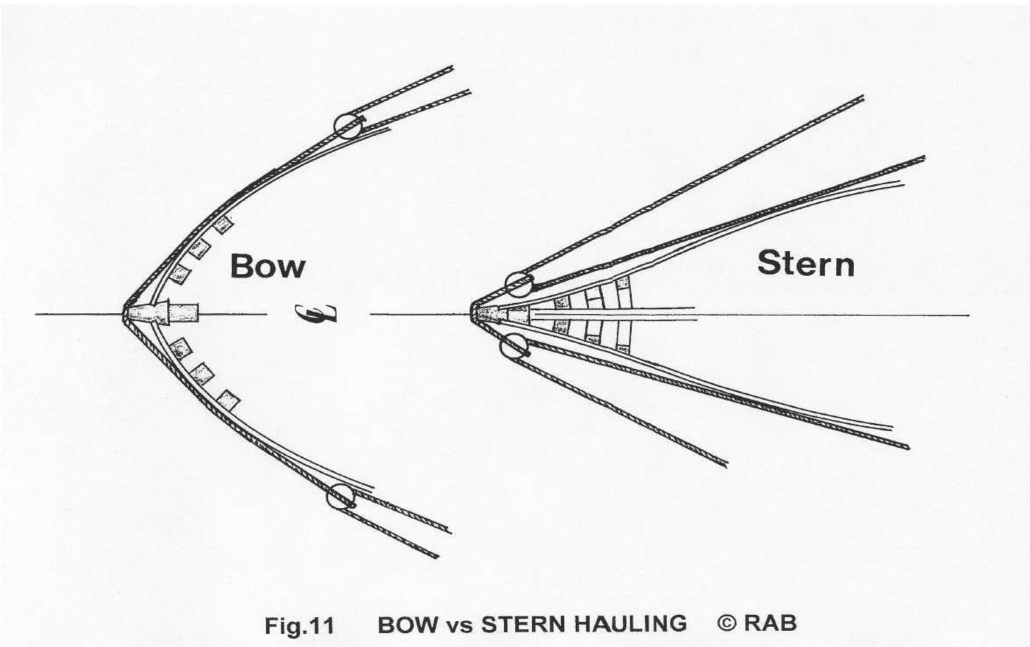
8. Launching cradle and slipway for the *Royal Louis*, taken from Chapman 1768. Detail of the stern only. Chapman's caption has the date 1692, but while this applies correctly to the ship, the launching arrangements are probably from his visit to Toulon in the 1750's.



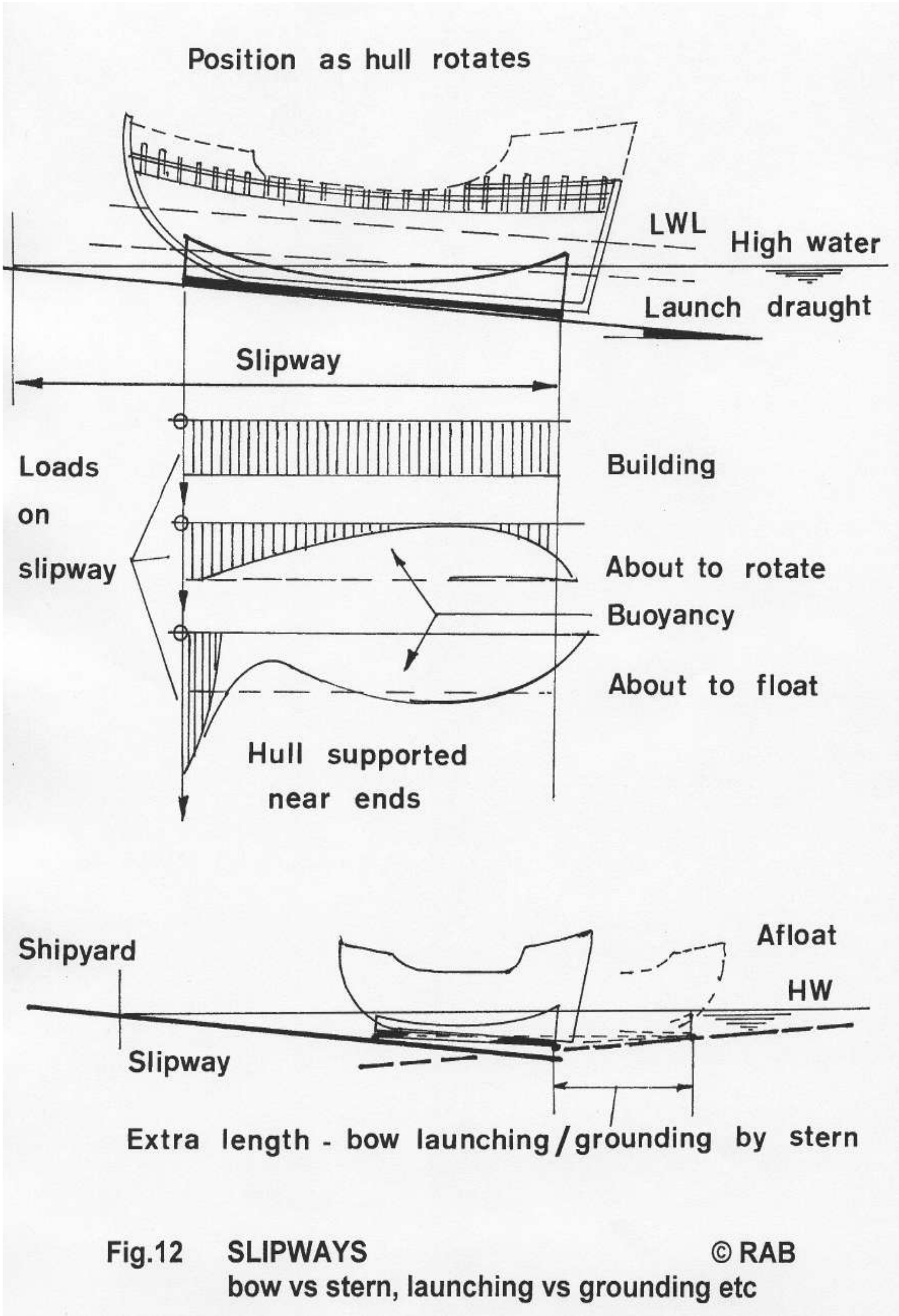
9. Sections of launching cradle at ends and midships as described by Steel, 1805. Redrawn.



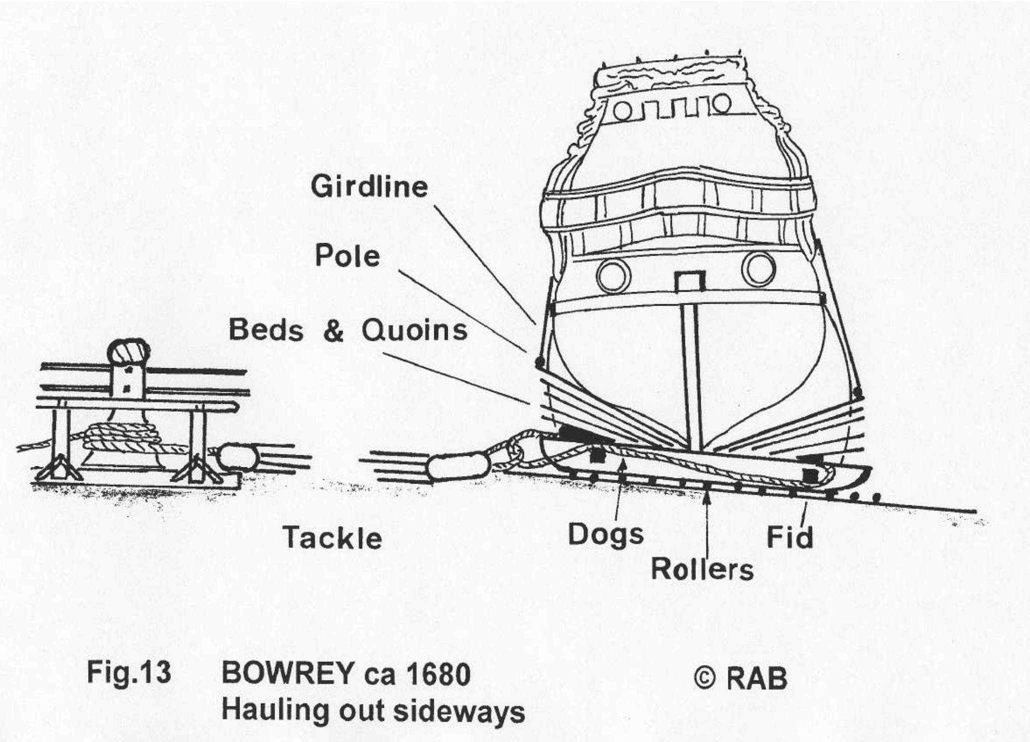
10. Improvements in slipways. Above: bilgeways directly on transverse groundways. Below: sliding plank introduced with details described by Steel, 1805. Schematic.



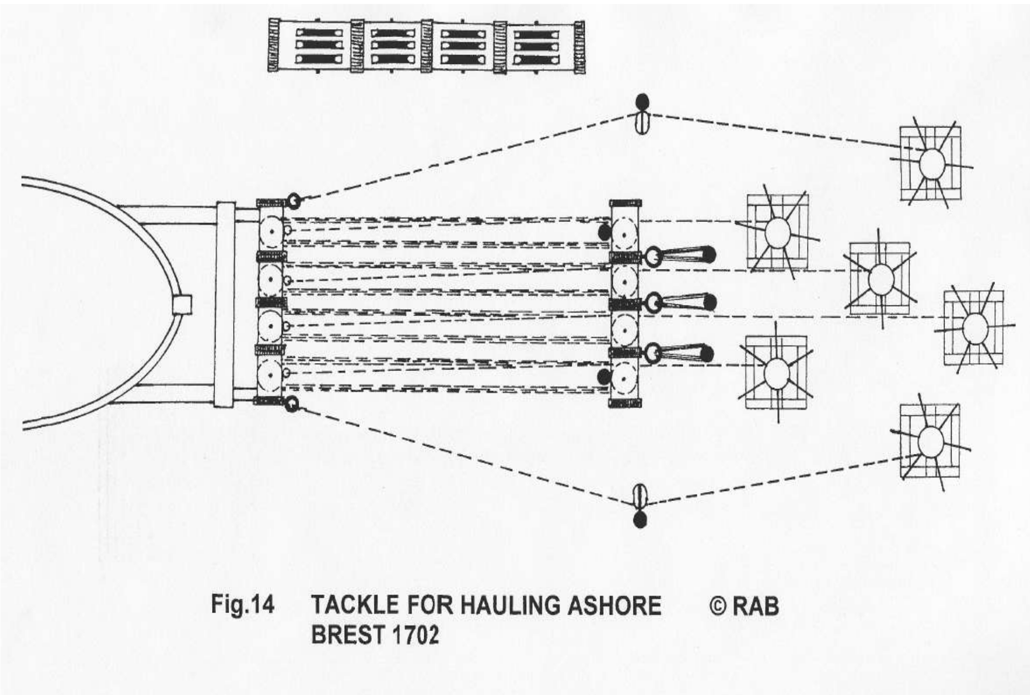
11. Illustration of the difference between hauling on the sternpost and on the stem. Schematic.



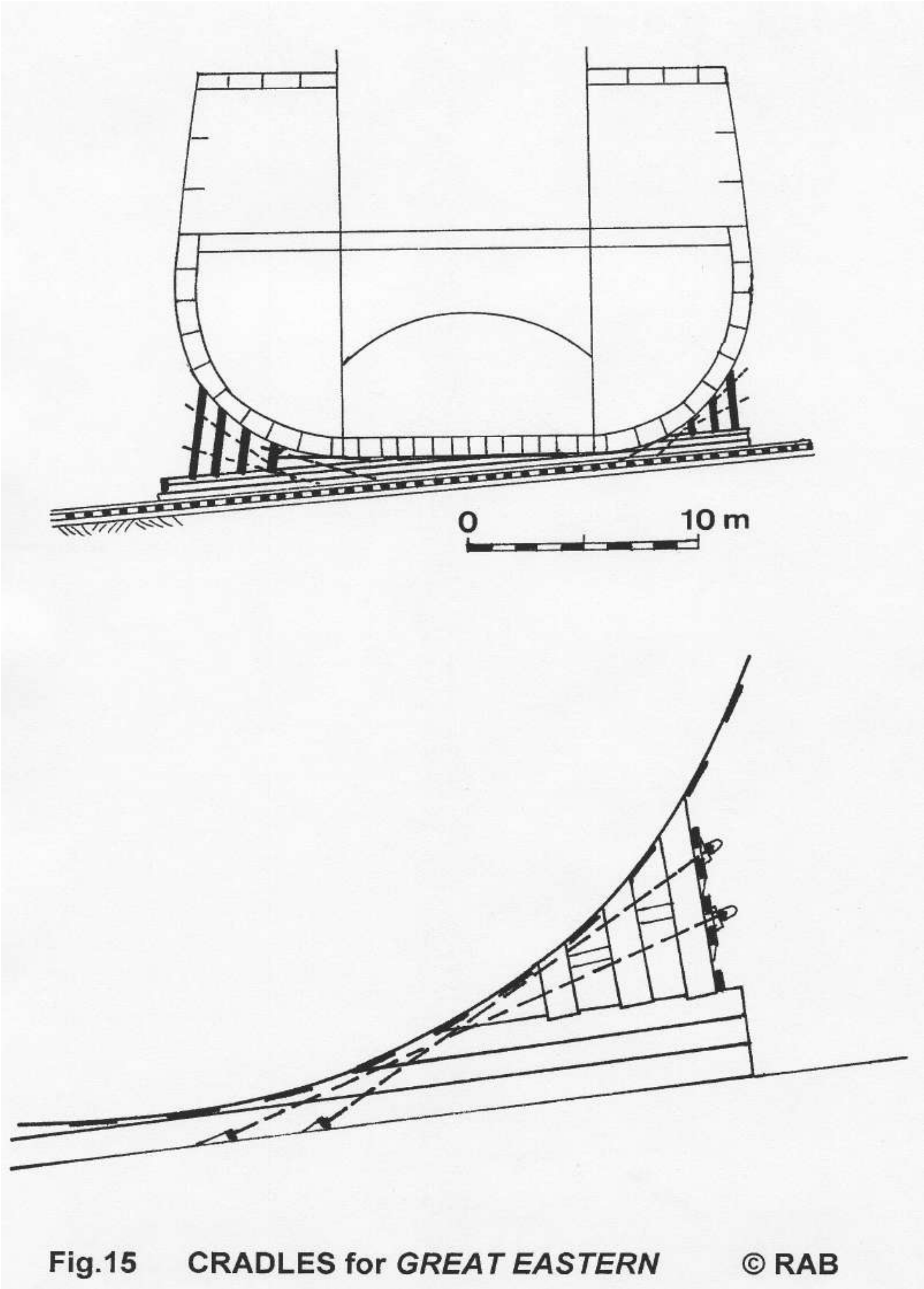
12. Illustration of the process of floating or grounding a vessel at the end of a slipway, and of the difference between bow-first and stern-first. Schematic.



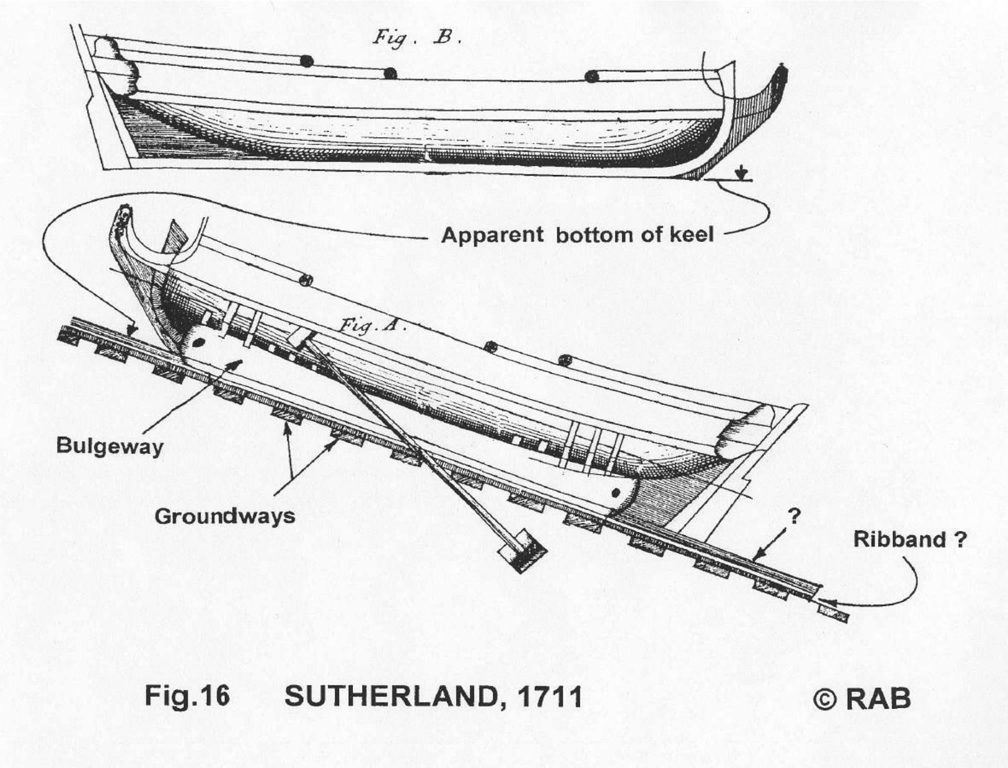
13. Arrangements for hauling ashore broadside-on, at Madapollam, India, ca. 1680, redrawn from Bowrey.



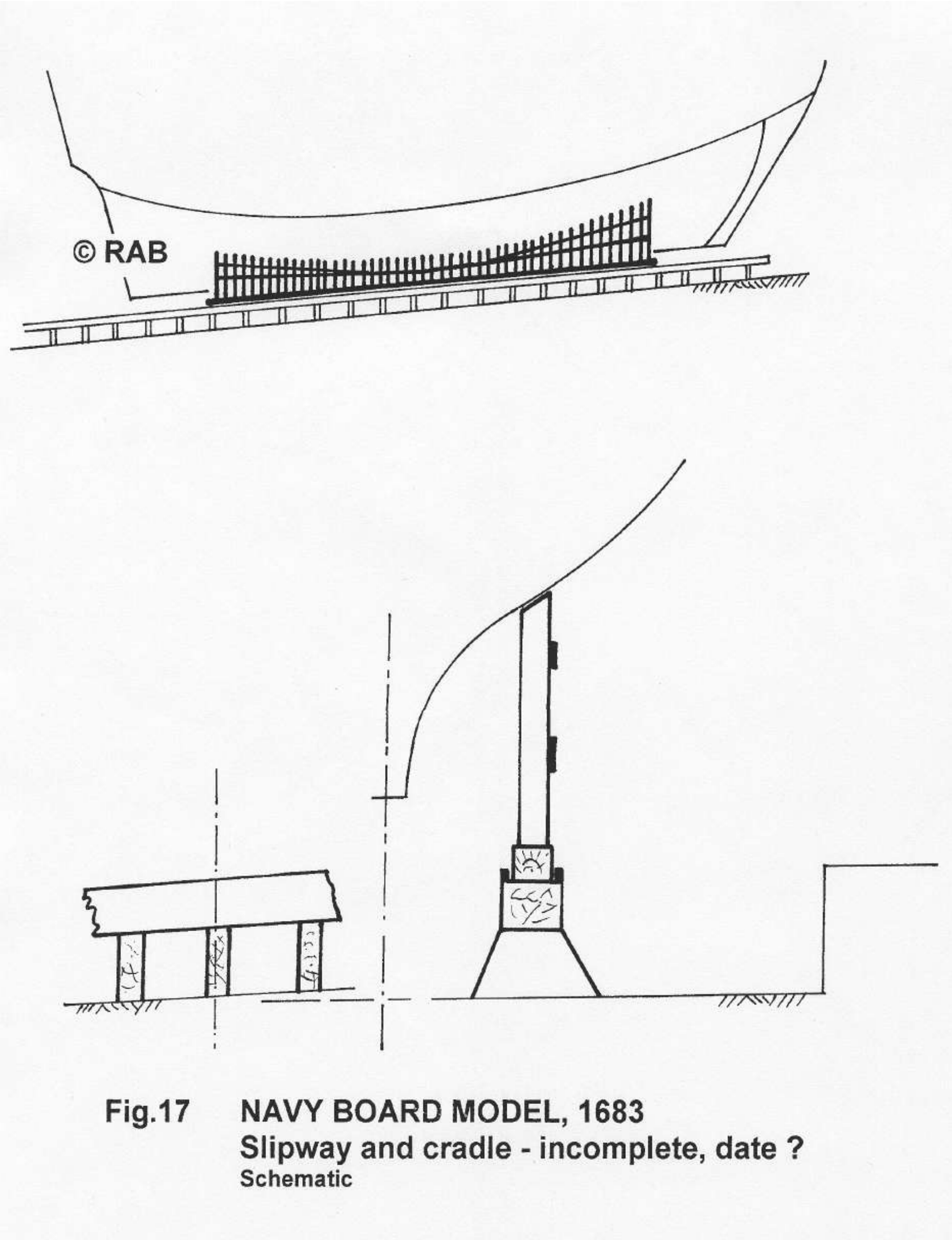
14. Arrangement of tackle for hauling ships ashore, in use at Brest, 1702. Redrawn from *Machines et Inventions*.



15. Section and detail of the launching cradle for the *Great Eastern*, 1857. Redrawn from Brunel.



16. English launching, redrawn from Sutherland, *The Shipbuilders Assistant*, 1711.



17. Schematic arrangement from an English model, ostensibly dated 1683.

Launching addenda

Felipe II of Spain wrote a letter to his daughters from Lisbon, dated 19 February 1582, which has tantalising remarks on the launching of the great Portuguese galeão *São Felipe*. It was first published by Gachard, but more recently by F. J. Bouza Álvarez, *Cartas de Felipe II a suas hijas*, Madrid 1988, pp. 59-61. It was kindly brought to my attention by Augusto Salgado.

> "I do not know what work is said there to be made here, except the castle of São Gião [below: São Julião] which is being extended, but which I have not seen since I went to Sintra. Yet another is being made in Setúbal, which I have still not seen; if I have time I will go to see it but I do not know when I will be able and, now, with the weather as it is - it is strange how it rains, it is not possible. For that reason, they took three days last week to launch a galeão into the sea. They had begun it a little before I came here, in the square of this house, where it could be seen very well, from a veranda here and was finished; they thought to launch into the water on Thursday, and we were waiting all morning; but it so great and weighs so much that it was not possible. On Friday the same happened, and we even went without Mass to see it, but it was so little possible. On Saturday also they [were] delayed (*demoraram*) a good while and we already had misgivings, but this time they launched it. It is pushed by hand, with a kind of *chapin* beneath it on which it slides. It is a thing worthy of being seen, but it would be very long to describe it here. They are beginning another, on the same site."

Chapin is not a nautical term, but a woman's clog with a cork sole, often very high. Felipe uses it at least twice in other letters (pp. 63, 84) in that sense. It suggests a structure of the kind illustrated by Manuel Fernandes in *Livro de Traças de Carpintaria* of 1616, which was an almost solid mass of timber ranged along the length of the bilge.

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In May 1575, Simão de Miranda made a sketch (now in the State Archives of Turin) of the Ribeira in Lisbon. This shows a ship under construction (or possibly repair), which is stern to the water. A poor reproduction was published by A. de Carvalho, "Três temas sobre as relações artísticas entre Portugal e Espanha, nos séculos XVI e XVII," in *As relações artísticas entre Portugal e Espanha na época dos decobrimentos*, ed. P. Dias, Coimbra 1987, pp. 233-257, Fig. 10. A large image has been displayed at the Museu da Cidade, Lisbon. A complete but very small image is in *De Olisipo a Lisboa. A Casa dos Bicos*, CNCDP Lisbon, p. 24, and a good partial detail in N. Senos, *O Paço da Ribeira 1501-1581*, Lisbon 2002, Fig. 12.

****

An unusual record of launching ceremonies appears in the archives of Aragon (Capmany, 1787), for 1505. D. Fernando prepared a fleet against the Kingdom of Naples. This included 9 named galleys, constructed in the arsenal of Barcelona. There is an inventory item for the powder consumed in proof firing of the single heavy *bombarda* for each galley and another larger one for the city, and firing 333 shots from *morteretes* and *servatanas* at the blessing and launching into the water of the nine galleys. Each master shipbuilder and master caulker received a silver-gilt cup of one mark each, which was stated to be customary. This is a relatively early record of what was later a more widespread practice.

Questions and Comments, Richard Barker: "Launching Large Ships to about 1800 – Different Practices and Developments" and "Cradles of Navigation – Re-Visited"

Horst Nowacki

25 June 2002

This contribution to the Workshop, particularly in its elaborated form of the article "Cradles of Navigation – Re-Visited," is a rich source of information and a colourful account of the earlier history of ship launching. A thorough survey of the current state of the art in launching technology and on the modern level of advanced physical analysis is given in Chapter XVII, "Launching," by C. M. Leavitt in "Ship Design and Construction," ed. R. Taggart, ISBN 0-9603048-0-0, SNAME, Jersey City, NJ, 1980. This may be a useful reference for any comparisons.

Launching has been recognized as a critical, potentially perilous event in a ship's life from antiquity and is still bearing considerable risks today, which may sometimes require new, sophisticated methods of analysis. Let me illustrate that by a few further episodes.

Although we have no direct archaeological evidence of launching technology in antiquity, it is evident from the literature that the difficulties and risks involved in launching large ships were fully appreciated. Plutarch's report on Archimedes single-handedly launching a large, fully loaded galley of King Hieron's fleet in Syracuse by means of a system of windlass (capstan?) and pulleys certainly smells a bit of legendary exaggeration, but does suggest a certain level of technological sophistication. Another classical writer, Athenaios of Naukratis in Egypt (ca. 300 AD) attributes to the early Hellenistic Period also the invention of the drydock. Athenaios reports that King Ptolemy IV Philopator of Egypt who reigned from 221 to 205 BC, among many other spectacular ships, also built a fortier galley, i. E. a ship of 40 oarsmen per half-cross section, each starboard and port, of about 420 ft length. About this ship Athenaios says (quoted from L. Sprague de Camp, "The Ancient Engineers," Ballantine Books, New York, 1974):

> "At the beginning [the fortier] was launched from a kind of cradle which, they say, was put together from the timbers of fifty five-bank ships, and it was pulled into the water by a crowd, to the accompaniment of shouts and trumpets. Later, however, a Phoenician conceived the method of launching by digging a trench under the ship near the harbour, equal in length to the ship. He constructed for this trench foundations of solid stone seven and a half feet in depth, and from one end of these foundations to the other he fixed in a row skids, which ran transversely to the stones across the width of the trench, having a space below them six feet deep, and having a sluice from the sea, he let the sea into all the excavated space, filling it full; into this space he easily brought the vessel, with the help of unskilled men; …when they had barred the entrance which had been opened at the beginning, they again pumped out the sea water with engines. And when this had been done, the ship rested securely on the skids aforementioned."

Despite all necessary caution relative to such a claim without physical evidence and technical documentation, the text clearly suggests that the idea of the drydock was understood in antiquity.

As an example of the level of sophistication reached in modern launching calculations let me mention a recent paper by Stefan Krueger: “Stability of Ships on a Resilient Slipway during Launching,” presented to the German Soc. of Shipbuilding Technology (STG) in May 2002. This paper deals with a large ship being launched on a single set of groundway/sliding way in the ship’s centerplane, which has certain advantages, but incurs the risk of the ship tipping sideways during the launching process. Thus the resilient, elastically and in part plastically deformable material of the ways must provide enough restoring moment to exceed any tipping moments. The resilience of the blocks in the groundway and sliding way had to be taken into account in the launching analysis using realistic nonlinear material property laws.

These comments and episodes are intended only to underscore the timeless nature of the human struggle to ensure safe launching technology.

Now for a few questions:

1. Launching Analysis before Calculus?

The most significant risks in launching large ships which are taken into account in modern launching calculations comprise:

- ¥The risk of tipping over the edge of the dock when the CG of the hull passes over the end of the groundways if by that time the buoyancy force acting on the partially immersed ship’s end is not sufficient to lift the ship and to pivot it about the fore poppet.
- ¥The risk of capsizing during or just after launching due to insufficient stability.
- ¥The risk of structural damage to the incomplete hull structure in the sagging deflection mode when the ship is partially launched.

These risks are carefully analyzed in modern launching calculations. This requires reliable estimates of weight distributions and buoyancy forces at each stage of the launching process. How were these risks accounted for in historical shipbuilding? When were launching analyses first performed? Presumably not before numerical integration based on calculus became feasible? Without such calculations, what other precautions were taken to minimize such risks?

2. Side Launchings

Side launchings are favoured where feasible because they avoid certain precarious situations. They were very popular in some regions, not only where the widths of the waterways were restricted, but also e.g. on the Great Lakes. Where and when were side launchings first performed? Are there regional or national patterns to their origins?

Response to: Questions and comments, Horst Nowacki on "Cradles of Navigation”

Richard Barker, 25 June 2002

Ancient dry-docks and launching.

Dry-dock is one of the most abused terms in the field! Any hole in the ground can be so described, it seems. (See some examples in papers such as *Caravelas, tides and water*). Evidence is indeed scanty from the classical world, despite the text of Athenaeus. That has similarities to proposed solutions for the loading of the great obelisks onto barges on the Nile.

I wonder whether John Coates might feel there was good evidence for launching problems of classical galleys, from the infrastructure. His complaint has been the lack of interest of land archaeologists in the rather important issues of the extension of the shipshed slipways below water! But yes, how the rather larger grain ships were built, launched and subsequently repaired is of interest, and there seems to be no evidence. If Archimedes' launching of a galley was the limit of technology, how did they launch a large grain ship? With a lot of people and some difficulty, in short.

Calculations and precautions for launching

The first actual calculations and experiments discovered were those of Brunel in the 1850's, and the net result seems to have been to scare him into what were actually disastrous precautions. Before that, it all seems to have been very empirical - but sizes did not increase that much over a long period, and each regime would develop its own solutions. As noted in the paper, the English favoured dry-docks for large ships - though these suffered almost as many problems as launching in practice.

The record is full of horror stories about what went wrong - ships sticking, falling over (capsizing seems to be a more recent problem, possibly because launch weight had to be minimised so carefully in the past). Some of the methods collected (not by any means all in the present paper - waiting for Part II) seem utterly cavalier.

Side launching

There seem to be two circumstances where this is adopted routinely: narrow waterways, and vessel types that have little longitudinal strength. Canal narrow boats, and Great Lakes steamers fit that category. In the past, American wooden river steamers did too, with very high L/D ratios - they were sometimes just floated off in seasonal floods. One might observe that in places like the Clyde and Tees there was very little river width, but they seem to have preferred traditional methods. Perhaps the length of available waterfront was more critical.
Origins? - down to anecdote. Bowrey hauls out sideways c.1680; various old images of Lisbon show ships broadside on in the sixteenth century; new inland waterways proliferated in the eighteenth century. Systematic information seems to be lacking.

La tecnica d'impostazione in cantiere delle barche altoadriatiche

Gilberto Penzo

La classificazione dei metodi costruttivi navali in "a guscio" o "a scheletro" conosce, grazie alla ricerca etnografica e a quella archeologica, sempre nuove forme intermedie tanto da rendere vieppiù difficile una netta distinzione fra le due concezioni.

Desideriamo quindi segnalare anche i metodi utilizzati nell'alto Adriatico per l'impostazione in cantiere di barche e navi, metodi che mostrano, a nostro parere, alcuni interessanti procedimenti. I nostri carpentieri navali, pur disponendo di metodi grafici e geometrici che permettono loro di tracciare e fabbricare tutto lo scheletro dell'imbarcazione, iniziano sempre la costruzione come se si trattasse di realizzare un guscio da riempire successivamente con le ordinate.

Fig. 1. Impostazione di un *sàndolo* nello *squero* Bovo di Burano, Venezia. Si noti come il primo corso di fasciame sia modellato solo fra asta specchio di poppa, ed un'unica ordinata centrale.

Ricordiamo brevemente che in tutta l'area adriatica, come nel resto dell'Italia con piccole variazioni di lessico e di strumenti, nella progettazione e realizzazione di un natante di qualsivoglia grandezza non si usa il disegno su carta con le tre viste ortogonali classiche e la successiva trasposizione in sala a tracciare, ma solo l'uso dei *sesti*, cioè di dime che permettono di tracciare in scala naturale tutte, o quasi, le costole della nave.[1] (Fig. 1)

I sesti permettono di tracciare scafi di qualsiasi forma, dai più semplici con fondo e fianchi piatti, a quelli più elaborati dai fianchi curvi e dal fondo stellato sia concavo che convesso. I vantaggi sono facilmente intuibili: economia, rapidità d'esecuzione, maggiore precisione, possibilità immediata di modificare alcuni o tutti i parametri dello scafo.[2]

Questo procedimento, pur attestato nei manoscritti di costruzione navale di tutte le epoche, è stato ignorato o sottovalutato da quasi tutti gli studiosi perché lontano dalla supposta razionalità e scientificità dei disegni tecnici, ma soprattutto, presumo, per la mancata frequentazione dei cantieri navali e quindi la non dimestichezza con i reali,

1. Ho cercato sempre, per quanto possibile, di raccogliere informazioni di prima mano direttamente dai costruttori o consultando i loro appunti segreti; questi costruttori e informatori sono citati e ringraziati nella prima parte della bibliografia.
2. Per una descrizione dettagliata di questi metodi si veda, i miei: *Il bragosso*, Il Leggio editore, Sottomarina (Venezia), 1992. *Barche veneziane. Catalogo illustrato dei piani di costruzione*, Il Leggio, Sottomarina (Venezia), seconda edizione 2002. *La gondola. Storia, progettazione e costruzione della più straordinaria imbarcazione di Venezia*, Il Cardo, Venezia, 1999.

complessi problemi legati alla costruzione. Sicuramente anche perché non visualizza la nave che si vuole costruire e non permette tutti quei calcoli, sicuramente indispensabili per grandi costruzioni, ma assolutamente superflui per la flotta tradizionale.

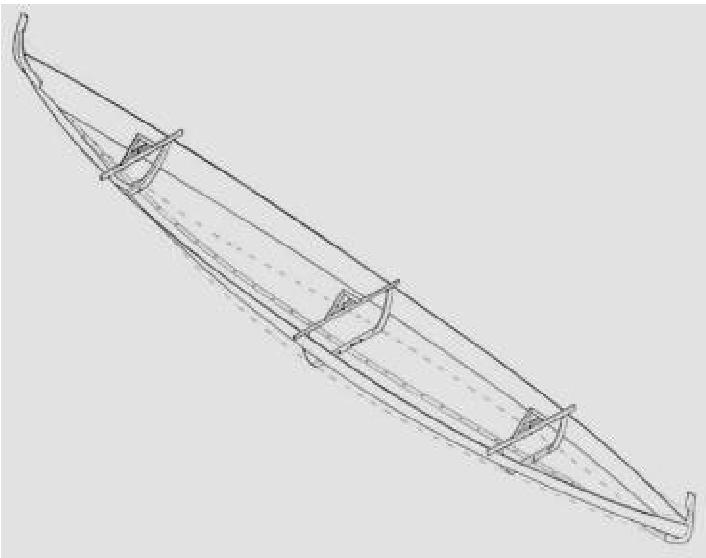

Fig. 2. Impostazione di una gondola, con il primo corso di fasciame, *sércio*, fissato fra aste e le tre ordinate di riferimento o *maistre*. Dis. Gilberto Penzo.

Per questo motivo è difficile datare con esattezza l'introduzione e la diffusione di questi metodi, o la loro importazione da altre realtà geografiche. Di certo metodi consimili sono dettagliatamente spiegati nei manoscritti dei costruttori navali privati o che lavoravano all'Arsenale di Venezia in tutte le epoche fin dal XV secolo. [3]

Sono metodi di progettazione o costruzione? Sicuramente nella pratica questa dicotomia non si poneva, chi costruiva era anche il progettista e modificava di volta in volta la linea delle barche, sulla base delle sue personalissime teorie sicuramente non "scientifiche" nel senso che si intende attualmente, ma sicuramente empiriche, basate cioè sulla continua sperimentazione. Sottoposte per essere confermate o smentite dal *feedback* continuo degli utilizzatori che ritornavano regolarmente in cantiere per nuove commesse o per la regolare manutenzione.

Fig. 3 - 4. Ordinate di poppa e prua di gondola già assemblate prima dell'inserimento fra le ordinate di riferimento.

Il costruttore in pratica, traccia, taglia e assembla tutte le ordinate e le accatasta in ordine, (Fig. 3, 4) ma per la fase più critica, quella che dà inizio alla costruzione, modella il primo corso di fasciame il *sercio* (cerchio in veneto) utilizzando solo tre di queste ordinate (Fig. 2, 5) e in alcuni casi addirittura una sola posta al centro. (Fig. 1)

3. Sulla persistenza di questi metodi costruttivi si veda i testi citati in bibliografia e in particolare il mio *A Comparison Between the Earliest Testimonies of Venetian Construction Techniques and the Testimonies of the Present Day,* in Proceedings of IX International Symposium on Boat and Ship Archaeology, Venezia, 2000. In corso di stampa.

La modellazione del *sércio*, o *magèr de boca* nella terminologia antica, è molto difficile e non ammette repliche perché il legno non viene ammorbidito a vapore, ma a fuoco vivo che lo brucia e non permette successivamente che piccoli aggiustaggi. Si pensi alla difficoltà di manovrare tavoloni di sedici metri, grossi cinque centimetri, tagliarli a misura, adattarli e inchiodarli alle batture delle aste, senza possibilità d'errore e simmetricamente per entrambi i lati.

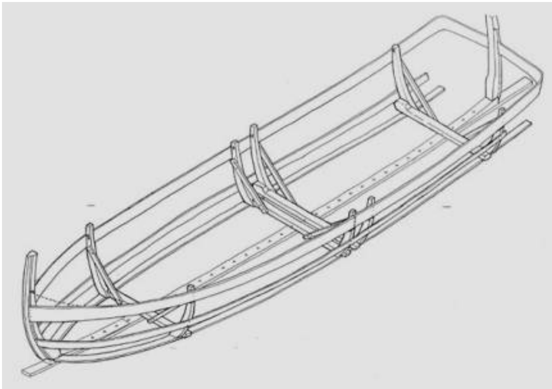

Fig. 5. Impostazione di un bragosso. Anche in questo caso si collocano solo tre ordinate principali, il *sércio*, e alcune *maìstre* ausiliarie sul fianco e sullo spigolo del fondo. Dis. Gilberto Penzo.

Non si creda che sia un metodo usato solo per piccole barche, sono fatti così il *sandolo* raffigurato lungo otto metri, le gondole quasi undici metri, su su fino ai *bragossi* di 12 o 16 metri e *tartane* di 18. Barche talmente grandi da avere il *sercio* fatto in due o più pezzi, con i tutti i problemi aggiuntivi d'allineamento e avviamento che questo comporta.

La forma finale del *sércio*, poi, non è il semplicistico prodotto della naturale flessione delle tavole ma viene plasmata con puntelli che dall'interno, gli *sbagi*, dall'esterno, le *ponte*, allargano o restringono il fianco. In casi particolari si usano come guida, anche delle *forme* o *sagome* poste di piatto sopra le estremità della barca, in modo d'avere un controllo perfetto delle curve. (Fig. 6)

Fig. 6. Gondola impostata con il metodo "moderno," si noti il triplice supporto del fondo, lo scheletro completato e i due *sérci* appoggiati sopra pronti per essere fissati sui fianchi. Cantiere dei Rossi, Giudecca, Venezia.

Solo compiuto questo rito, con tutto il corollario di bestemmie proporzionato alla difficoltà dell'operazione, il costruttore completa l'*imboscaura*, cioè la posa e il fissaggio di tutte le ordinate intermedie. Al termine, mentre il fumo si dirada e si placa la sete e la tensione con un buon numero di bicchieri di vino, si può finalmente osservare la fuga

armoniosa delle ordinate e approfittare per chiedere al maestro la ragione di questa sequenza d'operazioni.
Purtroppo la risposta che ci danno è sempre la stessa, in tutti i cantieri (anche dai rari carpentieri astemi) e per tutti i quesiti veramente intriganti, ammettendo: "*abbiamo sempre fatto così*."

Le ragioni quindi possono essere trovate solo per via ipotetica, possibilmente non astrattamente ma ripercorrendo le operazioni e immedesimandosi il più possibile con i mezzi disponibili e con le problematiche reali della costruzione. Spiegazioni che non bisogna ritenere né definitive né alternative le une alle altre, ricordandosi di lasciare sempre la porta aperta a comportamenti che ci appaiono illogici solo perché non disponiamo di tutti le informazioni necessarie o non abbiamo avuto la possibilità di sperimentare l'infinita varietà di problematiche che bisogna fronteggiare operando dal vero. Una delle ipotesi è che si tratti di un atavismo, cioè della persistenza del metodo più immediato ed elementare per impostare un'imbarcazione prototipo, anche quando il modello di nave si sia stabilizzato al punto di diventare ripetitivo.
A favore di questa congettura, riferiamo che i nuovi costruttori sia di gondole che di altre barche si sono anch'essi posti il nostro stesso quesito e hanno deciso unanimemente di lasciare il metodo antico e di adottare la costruzione a scheletro puro. Preparano e fissano tutte le ordinate al *cantièr*, il lungo trave che fa da supporto alla nave, e poi le cingono con il fasciame. (Fig. 7)

Fig. 7. Sagome e *forme* per modellare le estremità di poppa e prua di una *peata*, una barca veneziana da carico di 16 metri di lunghezza e 37 tonnellate di portata. Cantiere Antonio Amadi, Burano, Venezia.

Questo cambio di metodo, a dire la verità, non ha dato grandi economie né di tempo né di materiale, perché bisogna pur sempre bloccare tutte le ordinate con delle cinte provvisorie interne o esterne. Questo sistema si è imposto più che altro perché non richiede manodopera dotata di "occhio" e di sicurezza. Può sembrare strano, ma non per chi frequenta i cantieri tradizionali, constatare che un maestro ottuagenario - dotato di pochi mezzi materiali ma ricco di quella rara abilità artigianale che non si può insegnare con i trattati - sia ancora più rapido, versatile, ed elegante di molti giovani che hanno un approccio "razionale" e "scientifico" alla costruzione navale.

Anche per le grandi navi progettate su disegno, si procedeva allo stesso modo, collocate chiglia e aste, s'installavano in sequenza: *maestra* centrale, *cai de sesto* o ordinate maestre di poppa e di prua, poi le *corbe da onza* - una ogni cinque campi - legando il tutto con una serie di forme o maistre cioè con dei correnti flessibili posti in particolari punti critici del contorno delle ordinate (Fig. 8). Solo per ultimo si collocavano tutte le ordinate intermedie o *di riempimento* e si sostituivano le maestre con il fasciame definitivo.

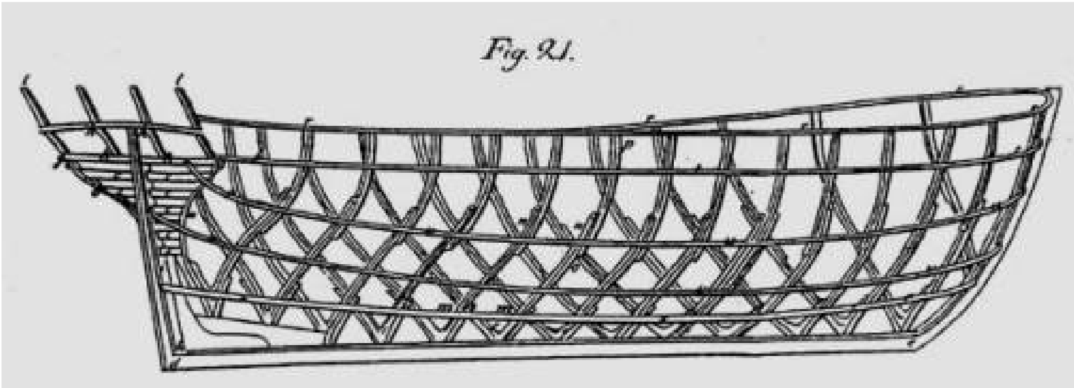

Fig. 8. Impostazione di una nave, si notino le corbe da onza e le cinque *maestre* guida. Da TONELLO Gaspare, *Vocabolario dei principali termini di marina,* Tip. G. B. Merlo, Venezia,1835.

Come si vede pur avendo tutto il corredo di costole già assemblate, si procedeva nell'installazione per suddivisioni progressive del volume totale della nave, procedura di costruzione e di progetto effettivamente ridondanti, visto che si poteva disegnare, e lo si faceva, le ordinate intermedie prendendo una serie di misure trasversali dalle maestre.

Questa sequenza di costruzione attiva fino ai nostri giorni, ricalca perfettamente i passi dei manoscritti di costruzione navale cinquecenteschi, dove scrittore e costruttore definiscono la forma della barca per passaggi successivi fino a che il volume della barca si concretizza e ritaglia la sua porzione dallo spazio attorno a sé.

Ma siccome non c'è atavismo o tradizionalismo che regga l'incongruenza o lo spreco bisogna convenire che se si continua per così lungo tempo, e in luoghi distanti fra di loro, ad operare in questo modo, vi debbono essere dei vantaggi effettivi. Un piccolo vantaggio è che si possono prendere i quartabuoni direttamente dal vero ma il principale crediamo sia che in questo modo si riduca la possibilità d'errore nel disegno e nella messa in opera delle ordinate, dando al costruttore il controllo continuo dell'avviamento dello scafo.

Procedendo per installazioni e suddivisioni progressive si mediano gli errori dovuti alle necessarie tolleranze di costruzione e di posizionamento sul *cantièr* o sulla chiglia, utilizzando la naturale elasticità di ordinate e fasciame per farli combaciare perfettamente. Procedendo in sequenza invece le tolleranze si possono sommare e arrivare, dopo poche costole, ad irregolarità non più correggibili.

In conclusione il maestro, senza l'ausilio di una visualizzazione grafica, preferisce mantenere il pieno controllo del corretto avviamento delle forme, mediante la sola guida esperta del proprio sguardo sulle linee guida del fasciame o dei listelli provvisori, pur disponendo già dell'intero set di ordinate ma temporaneamente accantonate in un angolo del suo cantiere.

Bibliografia

"Nella bibliografia cito non solo le tradizionali pubblicazioni, ma anche gli insegnamenti impartitemi da altri attraverso le loro voci e i loro gesti, le loro sagome per la costruzione di imbarcazioni ed infine i loro taccuini d'appunti. Mi scuso con coloro che hanno svolto l'opera da insegnante con me e che ho inavvertitamente dimenticato in questa lista. Strettamente parlando questa non è una bibliografia ma una "antropografia."

A Venezia:
Angelo Marella, Nedis e Roberto Tramontin, Gastone Nardo, Giovanni Giuponi, Roberto dei Rossi, Gianfranco ("Crea") Vianello, Mario e Marco ("Botte") Vianello, Duilio Cavalier, Giampaolo Proto, Daniele Bonaldo, e Aristide Battistin. Gli squeri Cucchin, Cucco, Casal, and Celli.

A Chioggia:
La mia famiglia Bullo ("Niere"), partendo da mio bisnonnor, *parón* Giovanni, i suoi figli Lionello ("Nello"), Angelo, Luigi, e Giuseppe; Aristide e Gino Bertotto, la famiglia Cimolin, Bullo Antonio e Carlo, Olindo Ranzato, la famiglia Poli.

A Burano:
Antonio, Piero e Guido Amadi; Agostino Amadi; Vittorio Amadi, Nerio Molin, Rino Molin, e i fratelli Bovo.

A Murano:
La famiglia Astolfo; lo squero "Pericle."

A Pellestrina e Portosecco:
Attilio e Giovanni Schiavon; Pompilio Menetto, Piero Menetto; gli eredi del ("Detto") Schiavon.

Al di fuori della laguna veneta:
Dino e Luigi Rondolini, Pesaro, Italia.

Altre importanti fonti d'informazioni: Silvano Voltolina, Paolo Bonaldo, Sambo ("Nino") Violante.

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Le *canovete* ossia i mezzi-modelli utilizzati nei cantieri adriatici

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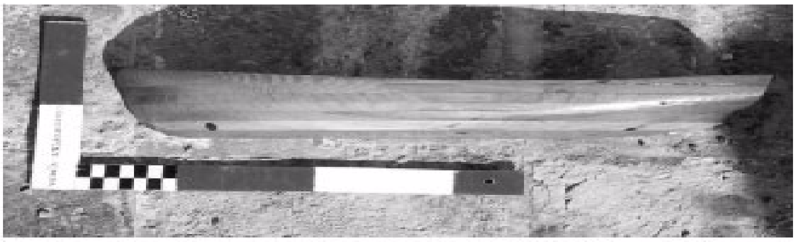
Il metodo per eccellenza di progettazione di barche e navi è quello di realizzarne un modello in scala ridotta, con il quale si può, con poca spesa e fatica, visualizzare la forma futura dello scafo in gestazione. E' un metodo intuitivo, il solo che permetta un controllo tridimensionale del volume, con la puntuale verifica dell'avviamento delle forme mediante i due strumenti infallibili di ogni costruttore: l'occhio e il tatto. Non si sottovaluti questo metodo pensando che fosse applicabile solo a piccoli scafi dove si potevano tollerare approssimazioni di forma: con i modelli si sono sempre costruiti in tutto il mondo vascelli, galere, navi di ogni tipo fra cui *yacht* da regata ed enormi *clipper* oceanici.

Fig. 1 Mezzi modelli fotografati nel cantiere Olandese Van der Werff di Workum. (Le foto, ove non specificato diversamente, sono dell'autore).

Per questo motivo, se si vuole realmente capire i procedimenti usati nella costruzioni tradizionali, si deve cercare di immedesimarsi il più possibile con la mentalità e i mezzi a disposizione degli artefici, perché ogni testimonianza etnografica è una fonte inesauribile d'informazioni preziosissime a patto che la si sappia interrogare con curiosità, modestia, senza idee e teorie preconcette considerandole soprattutto nel contesto originario dove sono state prodotte.



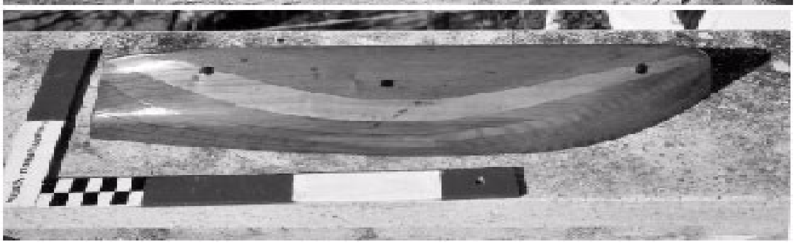


Fig. 2 Mezzo modello di *passera lussiniana*, coll. Carlo Sciarrelli Trieste.
Fig. 3 Lo stesso modello visto da sotto si notino i vari strati che lo compongono e le caviglie che li tengono bloccati.

I modelli erano a volte interi ma più spesso a metà visto che bastava modellare un fianco essendo l'altro perfettamente simmetrico al primo, naturalmente gondola e altre barche veneziane escluse.

La costruzione di un mezzo modello è universalmente nota tanto da non richiedere ulteriori spiegazioni. Ricordo solo i tre principali tipi a cui farò riferimento: il più semplice è il mezzo modello massiccio tratto da un unico blocco di legno (Fig. 1), quello più raffinato ma posteriore fatto con strati sovrapposti smontabili (Fig. 2-3), e quelli definiti in inglese *hawk's-nest* o *crow's-nest* cioè con sezioni ritagliate da sottili tavolette, riunite da listelli flessibili (Fig. 4).

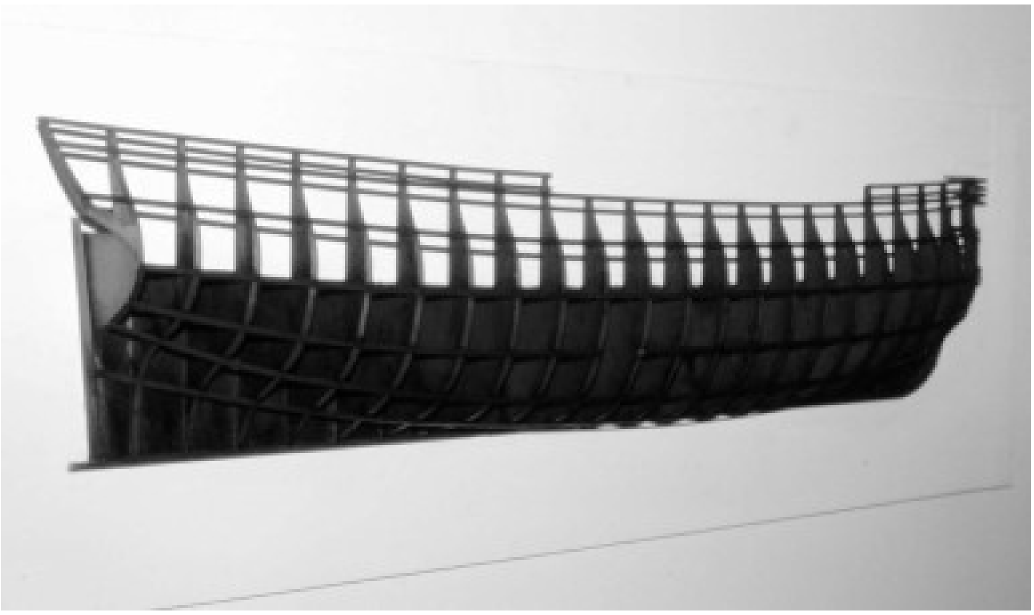


Fig. 4 Mezzo modello *crow-nest* di vascello conservato Museo Storico Navale di Venezia. Questo potrebbe essere uno dei modelli elencati dal Casoni.

Eviterò anche di fare estese generalizzazioni e, come mia abitudine, parlerò solo di argomenti che ho potuto controllare di persona, trattando quindi solo dell'uso che se ne faceva nella costa italiana altoadriatica.

Fonti storiche

Non è possibile attestare con sicurezza la nascita di questa tecnica, questi modelli come i sesti e le sagome dei cantieri sono andati, nella stragrande maggioranza, distrutti.
Non è possibile sapere tra l'altro se è un sistema nato contestualmente all'affermarsi della costruzione su scheletro, prima dell'affermarsi del disegno tecnico convenzionale, per definire la forma delle ordinate

.

Fig. 5 Mezzo modello di motoveliero proveniente dal cantiere Benedetto Schiavon di S. Pietro in Volta, Venezia.

Va sempre ribadita la difficoltà di reperire informazioni in un campo che non ha lasciato tracce se non quando diventava di interesse statale, pertanto ogni ricostruzione storica, basata necessariamente solo su ciò che si è fortuitamente conservato, rischia spesso di non essere obbiettiva.

Si pensi alla scarsità di documenti lasciati dagli innumerevoli cantieri privati diffusi su tutta la costa adriatica e in Venezia, rispetto a quelli relativi al solo Arsenale di Venezia, dal quale proviene una delle rare attestazioni antiche che conosciamo, relativa ai mezzi-modelli conservati all'interno della Sala dei Modelli. Ben diverso è il panorama dei cantieri privati. Nessuno dei numerosi cantieri visitati, compreso quello della mia famiglia, ne ha conservato qualcuno. I pochi esaminati sono del XX secolo, appartenenti a collezioni private[1] (Fig. 5-6).

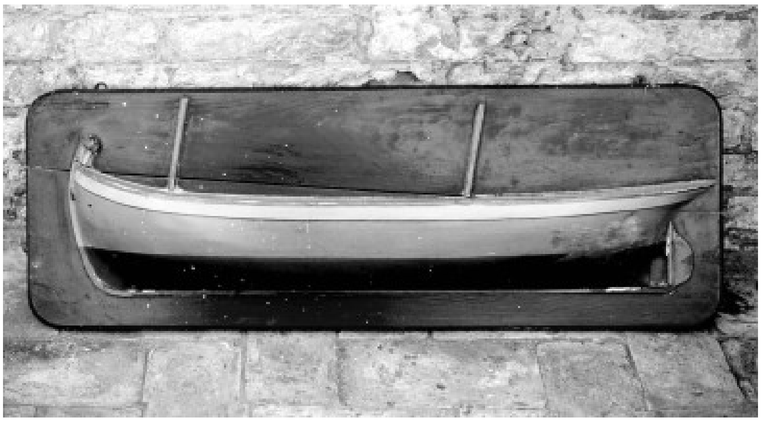


Fig. 6 Mezzo modello di *trabaccolo* con poppa ellittica proveniente dal cantiere Benedetto Schiavon di S. Pietro in Volta, Venezia.

1. Si tratta delle collezioni della famiglia Schiavon di Venezia e del noto progettista navale di Trieste, Carlo Sciarrelli.

Giuseppe Casoni nel suo elenco manoscritto dei modelli dell’Arsenale conservato al Museo Correr di Venezia elenca:[2]

Giuseppe Cason [i]
Li 10 gennaro 1796 more veneto

NOTA OSSIA CATALOGO DI TUTTI LI DISEGNI E MODELLI DI BASTIMENTI, CITTA, FORTEZZE, MACCHINE ESISTENTI NELLA SALA DELLA REGGIA CASA DELL'ARSENAL.

1	Mezzo modello detto in caneveta della fregata grossa *Fama* e della *Gloria Veneta* e dell'altre due esistenti sopra li cantieri in Novissimagrande. Il disegno esiste presso l'eccellentissima consulta.
1	Altro mezzo modello in canevetta del sopradetto [fregata leggera da undeci portelli].
1	Mezzo modello in caneveta [di bombarda]
1	Mezzo modello in caneveta [di siambecco piccolo]
1	Altro mezzo modello in caneveta di lancia cannoniera.
3	Tre mezzi modelli di vecchie fregatine di autori anonimi.
1	Altro mezzo modello in caneveta del sud.to [cotter].
1	Altro mezzo modello di galeazza pure di autor anonimo.
1	Modello in caneveta di galera bastarda del fu proto de marangoni Cristofolo Zampin dell'anno 1749 con due progetti per la costruzione della voga.
1	Mezzo modello in caneveta di gallera di capo di mar del sopradetto Zampin.
1	Mezzo modello in caneveta di galera *zaccala* stabilito per campion dall'eccellentissimo Senato.
1	Mezzo modello in canevetta di galeotta ossia siambecchin originale *dell'Esploratore* eseguito dal sopradetto ammiraglio Paresi.
3	Tre modelli in caneveta di galeotte di banchi 20, 18, 15 proposti dal fu primo architetto naval Giulio Cesere [*sic!*].

Un totale quindi di 17 modelli con spesso le indicazioni del nome dell'imbarcazione e del proto o architetto che le aveva progettate. Molti di questi potrebbero essere quelli conservati al Museo Storico Navale di Venezia (Fig. 4).

2. MCVe, Cod. Cic. 2975

Il nome

Il nome tradizionale riportato dal Casoni è *caneveta*, nome ancora ricordato dai vecchi maestri d'ascia nostrani con qualche variante come *canoveta* o *canaveta*. Purtroppo i vocabolari marini o dialettali consultati non ci hanno fornito alcuna definizione né di questi né di *mezzo modello*. Non deve stupire quest'assenza nei vocabolari di marina, essi sono il risultato di collazioni d'altri testi e documenti e molto raramente di ricerche sul campo. Inoltre la lingua italiana marinaresca è nei casi migliori un *collages* di vari dialetti locali ma più spesso è frutto di vere e proprie invenzioni.

L'unico sul quale è stato possibile reperire qualcosa è il Boerio[3] che alla voce *Caneveta*, indica: *cantinetta o salvafiaschi, arnese in legno in forma quadra, dove si custodiscono e si portano le bocce piene di vino e di ogni altro liquore*. Potrebbe darsi, ma è solo una mia ipotesi, che si definisse così i modelli a *crow-nest* per similitudine con gli scomparti di questi contenitori.

Mezzi modelli e *sesti*

I mezzi modelli pur essendo conosciuti dai costruttori, non avevano in pratica un uso diffuso perché, come spero di avere chiarito in altri lavori,[4] nei canteri adriatici come in tutti i cantieri tradizionali, la costruzione avveniva per mezzo di *sesti*, il metodo che permette di tracciare tutte le ordinate di uno scafo mediante lo "scorrimento" di una o più sagome.
Quindi non c'era la necessità di testare su un modello la forma della nave da costruire, anzi non lo si poteva fare perché le curve ricavate da un modello non potevano essere convertite in sesti ma in curve libere da ingrandire in sala tracciato.

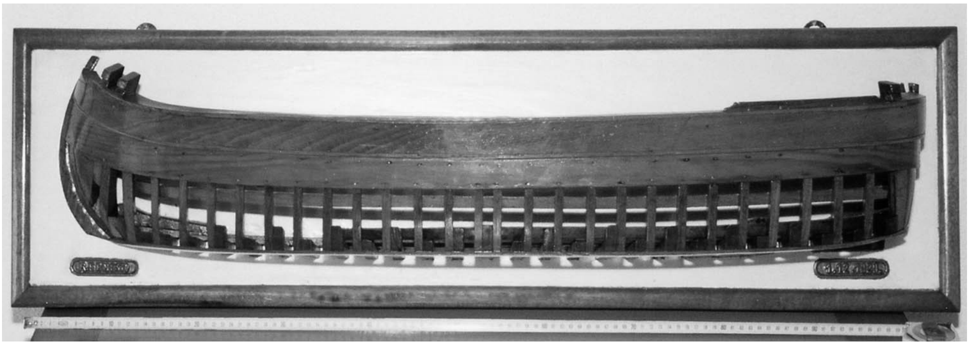


Fig. 7 Mezzo modello da cantiere di un *bragosso* da pesca, costruito nel 1929 da Ernesto Ranzato, nato nel 1889 a Chioggia.

3. BOERIO Giuseppe, *Dizionario del dialetto veneziano*, Cecchini Editore, Venezia, 1856 (ristampa anastatica, Giunti Martello, Firenze,1983).
4. Si vedano i miei *Il bragosso*, *La gondola*, *Barche veneziane*.

Forse era necessario costruire un modello quando si doveva impostare un nuovo tipo di barca o modificarne uno esistente, cercando conferme alle proprie intuizioni e, perché no, discuterne con il committente. Penso soprattutto al caso di scafi con sezione tonda o a calice, che richiedono più attenzione nell'"avviamento" delle estremità. Ed è forse per questo che ho trovato più tracce di *canovete* da Trieste in giù sulla costa orientale dell'Adriatico dove si usano solo barche con chiglia e fianco tondo, come *passere* e *brazzere*[5] mentre su quella veneziana solo barche a fondo piatto, se si esclude il *trabaccolo*. Il modello di bragosso che illustriamo (Fig. 7-8) è quindi un'eccezione, fatto quasi sicuramente per un'esposizione o per diletto dal maestro d'ascia.[6]

Fig. 8 Il rilievo dello stesso.

Modelli d'uso e di rappresentanza

Lo studio e l'interpretazione dei pochi mezzi modelli sopravissuti, deve partire innanzitutto da alcuni quesiti fondamentali, per prima cosa indagare su quale sia stato l'obiettivo che si prefiggeva il costruttore. Non tutti i modelli sono, infatti, propedeutici alla realizzazione di una barca, molti sono posteriori alla costruzione eseguiti come ritratto da donare all'armatore, (Fig. 9) altri sono didattici per illustrare agli allievi le forme degli scafi.

Fig. 9 Modello di *topo* chioggiotto eseguito dall'autore. Si tratta di un modello costruito successivamente alla barca, per controllare l'avviamento dello scafo dopo il suo rilievo.

5. La diversificazione di tipologie navali è stata il prodotto dell'adattamento alla morfologia costiera, quella veneziana bassa e sabbiosa, mentre quella dirimpetto rocciosa e profonda.
6. Un modello simile di bragosso è conservato nel Museo Navale di Imperia.

I modelli d'uso si distinguono facilmente da quelli celebrativi, perché non sono rifiniti, a volte si possono smontare, non hanno la tavola di supporto (o è stata aggiunta successivamente), mancano di dettagli nelle sovrastrutture, portano segni e appunti di costruzione o modifiche da apportare.[7] Inoltre in quelli "veri" c'è solo il volume dello scafo "interno fasciame" e mancano i dritti e la chiglia.

Quelli celebrativi al contrario si presentano meglio, possono essere dipinti, hanno la tavola di supporto, targhetta con il nome e il costruttore, soprastrutture, accenno dell'armo, a volte sono "fuori fasciame" ecc. Questo non vuol dire che i secondi siano inattendibili, anzi spesso lo sono di più dei primi, però non hanno assistito e partecipato alla progettazione della barca, ma ne sono solo il ritratto finale (Fig. 10).

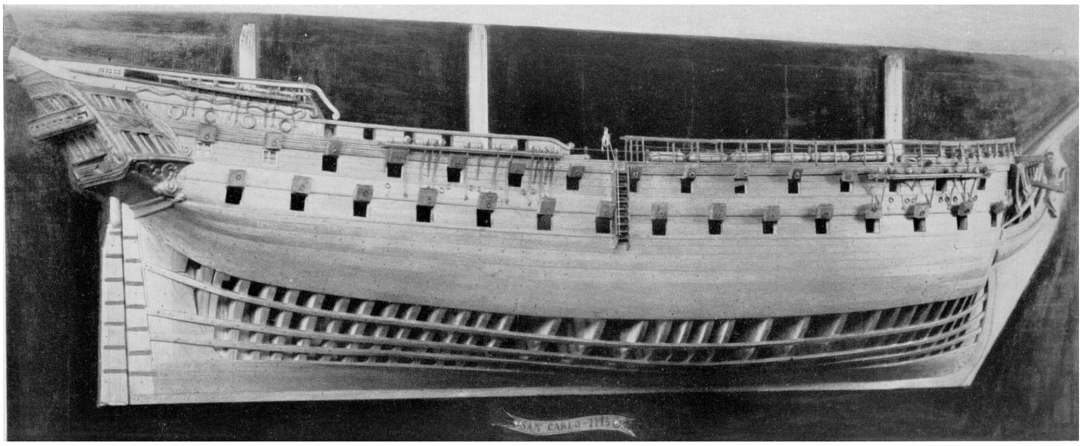


Fig. 10 Mezzo modello della nave S. Carlo, 1715. Tratto da: PATRONE Giacomo, *Modelli navali italiani dal XVI al XIX secolo.*

Trasferimento della forma dal modello alla scala reale

I metodi per trasferire, ingrandendoli, i profili delle sezioni dal modello alla scala reale, sono anch'essi noti, mi limiterò quindi ad un breve accenno. Si tratta di rilevare le sezioni in corrispondenza di intervalli regolari e paralleli, in genere ortogonalmente alla chiglia in modo da poterli poi ingrandire adeguatamente.

Nel caso di modello massiccio, si possono prendere i profili in modo distruttivo sezionando fisicamente il blocco, facendo aderire una barretta di piombo, creando un calco negativo con ripetuti tagli di un foglietto di cartoncino, o con dei pantografi che percorrano la carena e trasferiscano curve o misure su carta.
Nel caso di modelli smontabili o *crow-nest* si prendono gli *offset* in corrispondenza dei vari livelli orizzontali e li trasformano nelle consuete viste ortogonali del piano di costruzione o li si memorizzano in tabelle che poi saranno trasferite nel pavimento della sala a tracciare.

Si può anche ipotizzare anche che il passaggio fra la *canoveta* e la barca vera non passi né attraverso il disegno, né attraverso la sala a tracciare ma direttamente sulle ordinate

7. Esteticamente sono spesso ammaccati e sporchi quindi non hanno "appeal," e non sono richiesti dai collezionisti.

o sui sesti. Il costruttore cioè smonta la *canoveta* e trasferisce gli *offset* direttamente sulle sagome con le quali taglierà il legname per le ordinate.

Conoscendo però il modo di procedere dei costruttori, dotati di una sensibilità estrema per il loro mestiere tanto da impostare vascelli dalle linee elegantissime ed efficientissime solo sulla base di poche risicate misure, non mi sento di escludere che utilizzassero il modello solo come schizzo o "cartone" per "sentire" il volume dello scafo per poi procedere senza misure dirette a tracciare le ordinate.

Purtroppo non ho potuto, per ragioni d'età, e non finirò mai di rammaricarmi, investigare di più questo mondo, voglio solo ricordare che un figlio di un apprezzato *squerariolo* di Chioggia[8] si angustiava che neanche suo padre lo facesse salire sul soppalco ricavato nell'edificio dei cantiere, per assistere alla tracciatura dei sesti o del piano dei quinti. Si pensi quanto questa operazione fosse tenuta in considerazione e quanto forte fosse la paura che ne trapelassero i metodi di riduzione matematica e tracciatura che evidentemente erano il patrimonio più prezioso del cantiere, tanto da essere nascosta non dico agli operai ma anche al proprio figlio, forse non ritenuto all'altezza o non ancora pronto per l'insegnamento.

Scala

Uno dei problemi in cui ci si imbatte spesso, per non dire sempre, quando si esaminino modelli originali[9] è la loro mancanza di scala o piuttosto di proporzioni. Sono immancabilmente tozzi, molto più larghi e alti di quanto dovrebbero essere in proporzione alla lunghezza. Per questo e per il loro grado approssimativo di finitura sono frettolosamente liquidati come modelli naif o votivi, e presi in considerazione solo come esempi d'arte popolare o nel caso opposto, con risultati ben peggiori, rilevati e presi a modello per ricostruire le barche vere (Fig. 11).

Fig. 11 Modello di galea del sec XVI (?) Museo Storico Navale di Venezia. Tratto da: PATRONE Giacomo, *Modelli navali italiani dal XVI al XIX secolo.*

La mia esperienza mi ha portato a ritenere che siano piuttosto da interpretare, perché realizzati non in una sola scala di riduzione ma con scale diverse.

8. Si tratta di Ginetto figlio di Aristide Bertotto (classe 1883), di cui ho potuto fortunosamente salvare i quaderni d'appunti dove si segnava tutte le misure delle barche costruite.
9. Questo vale anche per le raffigurazioni come dipinti e sculture.

Ho esaminato moltissimi di questi modelli[10] tutti sicuramente realizzati da maestri d'ascia, e in molti casi ho assistito direttamente alla loro costruzione, che avveniva con la stessa sequenza delle barche reali impostando la, o le, ordinate di riferimento poi il primo corso alto di fasciame ecc.

Orbene quando dimostravo a questi artigiani che non rispettavano le proporzioni mi osservavano increduli affermando che esse erano corrette come potevo vedere direttamente con i miei occhi. La controprova si aveva quando sottoponevo un modello costruito secondo le misure della nave vera che mi avevano fornito, il commento era l'opposto: sì il modello era bello ma sproporzionato, per l'esattezza troppo sottile e basso!

La mia ipotesi è che i costruttori applichino ai modelli lo stesso metodo di proporzione di quando devono fare delle barche vere ma di diverse taglie: riducono la lunghezza, l'altezza e la larghezza in scale diverse in modo da ottenere sempre un risultato correttamente proporzionato e funzionale. Infatti una barca di venti metri, non è larga e alta il doppio di una di dieci, così per la stessa logica una barca di 50 cm non deva essere 20 volte più stretta di quella reale.

In pratica il costruttore decide con la sua estetica le proporzioni relative e non assolute, come fa un artista che per abbozzare una statua ha bisogno di conoscere la grandezza finale, poiché non è la stessa cosa plasmare un piccolo soprammobile o un colosso, caso per caso bisogna alterare le proporzioni del capo e degli arti in modo da conformarle al punto di vista dello spettatore.
Concludendo il metodo dei mezzi-modelli o *canevete* era conosciuto e utilizzato nella marineria adriatica, ma allo stato attuale non è possibile valutarne origini e grado di rilevanza nella progettazione e costruzione di barche da lavoro e da guerra.

10. Conservati in: collezioni private, Museo Storico Navale di Venezia, Museo della Laguna Sud, Museo della navigazione fluviale di Battaglia Terme, Museo diocesano di Chioggia, Museo della Regina di Cattolica, Museo delle navi di Bologna, altri a Cesenatico, Trieste, Milano ecc.

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Appendices

Appendix I

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Appendix II

Workshop Program

Monday, November 26 (7:00 PM)

Presentation: Matteo Valleriani, Franco Rossi
Digitalization of the *Archivio Proprio Giacomo Contarini*
(International Co-operation between MPIWG and State Archive of Venice into the frame of the ECHO Project: http://echo.mpiwg-berlin.mpg.de)

Tuesday, November 27 (10:00 AM)

Session I: Hull Geometry

Jean Dhombres
Connection between line drawings, Wooden Models and Geometric Calculations before and after Calculus

Eric Rieth
A Similar A tlantic and Mediterranean Ship Design Method: The Case of the French Royal Dockyards at the End of the XVII Century

Horst Nowacki
Practices and Methodologies of Hull Geometry Definition

Brad Loewen
Comparing Shipwrecks and Shipbuilding Treatises, Iberia and England, XVI - XVII Centuries

Fred Hocker
Early Drafting Equipment

Gilberto Penzo
Designing Ships by Means of Half-Models

Session II: Shipbuilding Materials and Ship Structural Design

Fred Hocker
The Effect of Shipbuilding Materials on Hull Form

Wednesday, November 28 (10:00 AM)

Session II: Shipbuilding Materials and Ship Structural Design (cont)

Richard Barker
Aspects of Careening

Eric Rieth
From Wreck to Shipyard: the Example of the Port Berteau II Wreck, France (VII c. AD)

Brad Loewen
Shipbuilding Practices, XVI - XVII centuries

Session III: Shipbuilding practice and theory in the Mediterranean

Carlo Beltrame, Mauro Bondioli
Genesis of the Skeleton First Shipbuilding Conception: a Hypothesis based on the Observation of the Serçe Liman Wreck

David McGee
Michael of Rhodes: The Manuscript Resurfaces

Gilberto Penzo
Venetian Shipbuilding: Comparing six Centuries of Design and Construction Techniques

Mauro Bondioli
Fabris Peritia and Marina Architecura. A Comparison between two Naval Craftsmen: Vettor Fausto and Nicolò Palopano

Eric Rieth
First Archaeological Evidence of Mediterranean Whole Moulding Ships Design Method: the Example of the Culip VI Wreck, Spain (XIII-XIV Centuries)

Christian Lemée
Examples of Shipbuilding Practices in Northern Europe Between 1580 and 1630

Session IV: Academic teaching, treatises and ship building practice

Larrie Ferreiro
Structures of the Scientific Revolution: the dissemination of naval architecture knowledge prior to the professional society

Thursday, November 29 (9:00 AM)

Session V: Hydrostatics and Stability

Larrie Ferreiro
Inventing the metacenter: stability accidents, weight estimates and the practical application of the metacentric theory to ship design

Richard Barker
Launching Large Ships to about 1800 - Different Practices and Developments

Horst Nowacki
Approaches to Hydrostatic Stability of Floating Bodies and Ships Taken by Archimedes, Bouguer and Euler

Jean Dhombres
Interaction between Volume Evaluation by Calculus and other Methods and Shipbuilding Practice in European Textbooks (End of XVII and XVIII Century)

Session VI: Ship motions, maneuvering and propulsion

Larrie Ferreiro
Deriving the derive: development of laws for the derive (leeway) and relation to the development of vector laws

Larrie Ferreiro
A shock to the system: the rise and downfall of the solid of least resistance

Appendix III

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