Ships and Shipbuilding

Navires et construction navale

Recent Advances in Ship History and Archaeology, 1450–1650: Hull Design, Regional Typologies and Wood Studies

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Résumé

Des recherches récentes s'appuyant sur des écrits et des épaves modifient nos connaissances sur trois questions relatives à la construction navale de la Renaissance : la conception des carènes, les typologies d'épaves et le bois en tant que matériau archéologique. À propos de la conception des carènes, deux synthèses divergentes, puisant à des sources atlantiques et méditerranéennes, ont été publiées. En matière de typologies, les archéologues distinguent désormais des signatures régionales pour lesquelles ils avancent des explications historiques. Quant au bois comme matériau archéologique, la dendrochronologie en révèle aussi aujourd'hui la provenance géographique. D'autres recherches indiquent que de jeunes arbres destinés à la production de membrures ont été forcés en cours de croissance d'adopter une morphologie spécifique, ce qui réduit les nouveaux modèles de carènes à des styles régionaux.

Abstract

Combining the study of texts and shipwrecks, new research is changing our knowledge of Renaissance shipbuilding on three subjects: hull design, shipwreck typologies and wood as an archaeological material. On hull design, diverging syntheses have been published using Atlantic and Mediterranean sources. On shipwreck typologies, archaeologists now recognize regional forms for which historical explanations are advanced. On wood as an archaeological material, methods of tree-ring dating now also reveal the geographic origin of timbers. Other research indicates that frame timbers were "trained" as samplings to attain a specific shape, thus limiting new hull designs to regional styles.

In the last two decades, the study of ships and shipbuilding before Jean-Baptiste Colbert, Anthony Deane, Antonio de Gastañeta and Nicolaes Witsen[1] has grown exponentially and is transforming our knowledge of a period that was formerly understood only in the most general terms. In this paper, we are interested in the research gains, approaches and current issues that have seen significant progress in the last few years. We shall concentrate on three research issues. The first concerns hull design, which combines manuscript and archaeological sources and has resulted in a new interpretation of Renaissance shipbuilding. The second issue concerns the typology of shipwrecks, which has identified regional characteristics of ships from the period circa 1450 to 1650. The third issue concerns the study of wood as an archaeological material, and describes what inferences researchers are drawing from this approach. In conclusion, we shall evaluate the contribution of these issues to a larger picture of maritime history.[2]

Hull Design and Construction

The study of ship history has always been interdisciplinary. The strategy of combining manuscript and archaeological evidence is especially apparent in the gains that have been made in understanding the obscure shipbuilding treatises of the Renaissance and in applying this new knowledge to the study of archaeological ship remains. The treatises form a relatively small corpus of texts dating to about 1410 to 1620, and may be divided by date and

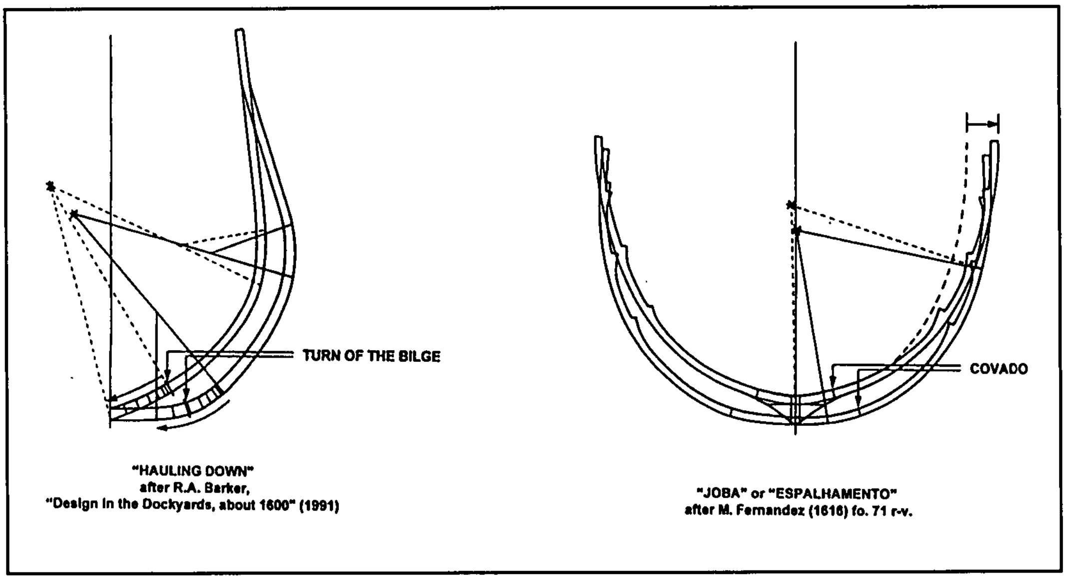


Fig. 1
Based on the shape of the master frame, the frames fore and aft were modified in three ways, beginning with the "rising" and the "narrowing" of the floor. Next, two alternative methods existed for modifying the upper frame. In English texts we find a method called "hauling down the futtock," while Iberian texts speak of espalhamento *or* joba.

provenance into three groups. The oldest group derives from Venice and consists of four rather elliptical texts dating to circa 1410 to 1594.[3] Subsequently, two contemporaneous groups of of texts appeared in Iberia and England in the period from circa 1570 to circa 1620. The Iberian group consists principally of four Portuguese[4] and six Spanish[5] texts, while the English group also contains six principal manuscripts.[6] There is also a later group of ten related texts in French and Spanish, from 1680 to 1783, that are more accessible in style and have been used to shed light on the earlier texts.[7]

The essential information contained in these texts, whatever their origin, is similar and seems to suggest a common origin. Three major steps made up the ship carpenter's process of designing a hull. First, he worked out the four basic dimensions of the hull: its breadth, its keel, its length from stem to sternpost and its depth of hold. These dimensions mirrored those used by ship surveyors to gauge a ship's tonnage and, in practice, allowed a carpenter to convert to a merchant's desire to build a ship able to carry a certain tonnage of goods into real measures.

Second, within the parameters of the breadth and the depth of hold at midship, the carpenter worked out the shape of the master frame, using as his fundamental elements a series of five tangent lines and arcs: the floor line, the bilge arc, the futtock arc, the arc at the greatest breadth and the tumblehome line. He then devised a master mould from this shape, and marked off the points on the mould at which his lines and arcs touched.

Third, using the master mould, he worked out the shape of frames fore and aft of the master frame by means of three systematic adjustments to the master mould, namely: the rising of the floor, the narrowing of the floor and — here the English and Ibero-Mediterranean texts differ in the details — adjusting the aspect of the frame from the bilge upwards. While the English method achieves the modification of the three tangent arcs by adjusting the length of adjacent cords, known as "hauling down" and "hauling up" the arcs, the Ibero-Mediterranean method was based on tilting the frame outward from a pivot point at the bilge, a method called *legno in ramo* in the Venetian manuscripts.[8] The English and Ibero-Mediterranean variants appear, however, to converge over time. The English shipwright Matthew Baker mentioned "linoramo" as a novelty in England about 1580 while the Ibero-Mediterranean texts used a limited version of "hauling down" the bilge arc in order to fair out the kink left at the bilge by the outward tilting of the futtock mould.[9] In the later French manuscripts, the two methods appear to have fused into one.

The appearance of the English and Iberian manuscripts in such a short period of time raises questions about their role within the shipbuilding establishments. All of the texts were generated by individuals close to the royal courts of their countries, in an era of increasing state interest in shipbuilding and navigation. After an initial surge of interest in shipbuilding at the turn of the sixteenth century in all the Atlantic states, including France, a second wave of royal involvement gathered momentum during the third quarter of the century in Portugal, Spain and England.[10] One effect of the appearance in the sixteenth century of permanent shipyards, both private and state, with large work forces and stockpiles of material, was to separate the tasks of designing and building ships. Schooled sons of privileged families took over the role of design from the artisanal carpenters who had risen in their trade by following a traditional professional development from apprentice to journeyman to master. The cleavage generated legal resistance by carpenters and polemic affirmations by designers.[11]

Some of the self-styled "architects" who left works on ship design were the sons of prominent carpenters, such as Matthew Baker and the Coulombe family of Toulon, while many such as João Baptista Lavanha, Fernando Oliveira, Diego Garcia de Palacio and John Wells were attracted to the mysteries of hull design only after shipbuilding became an avenue of professional advancement in the state hierarchy. These authors embedded their work in the trappings of classical architecture including references to Greek and Latin writers, discussions on the relation between hull design and the laws of nature as observed in the shape of fishes, and symbolic imagery such as the architect's compass displayed in their right hand and the architect's square and the illustrated pages of a learned treatise exposed on a desk.[12] In a similar Renaissance spirit, Baker began his *Fragments* with a voyage to Greece and Venice while Oliveira ennobled his *Livro* by referring to current Italian writers. Snatched from its medieval guild context of visual and oral knowledge, hull design became a modern paper subject, reproduced in text and two-dimensional representations. Without doubt, the birth of "naval architecture" once attributed to the great builders of the seventeenth century — the aforementioned Colbert, Deane, Gaztañeta and Witsen — can now be placed in the context of the Renaissance shipbuilding treatises.

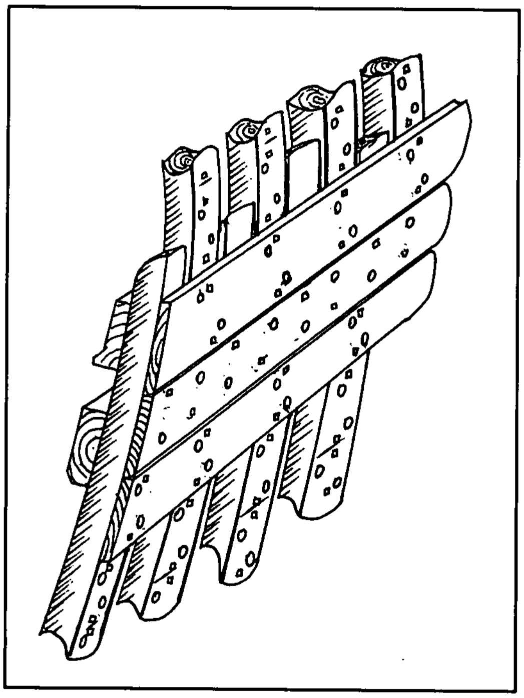


Fig. 2
This drawing illustrates the overlap of the "floating futtocks" at the lower deck, as well as the typical fastening pattern of Biscayan ships. Two iron nails (square) and two treenails (round) fastened each joint of a plank and a frame. Where the frame timbers overlapped, they counted as one frame.

More troubling are questions relating to the apparently common origin of the information contained in the treatises, and it is here that archaeology has contributed to the debate by demonstrating the prior existence in shipyards of these concepts. Underwater archaeologists, once confined to raising manageable artifacts and drawing a plan of in situ architectural remains, now regularly disassemble shipwrecks for surface recording. The design of the frame timbers can thus be learnt and compared to information gleaned from the Renaissance treatises. The best known application of this method was at Red Bay, Labrador, where a Biscayan whaling ship that sank in circa 1565 was reconstructed at a 1:10 scale and studied in detail.[13] Other wrecks at Red Bay, Cala Culip (Catalonia), Bermuda, Cavalaire-sur-Mer (Provence) and Matagorda Bay (Texas), have also been dismantled with a view to contributing archaeological evidence to the debate on the origins of Renaissance ship design. Built by anonymous hands as much as a century before the earliest treatise, these naval structures confirm the widespread use of all the design concepts recorded by the first ship "architects." While the prior existence of these design methods can not be doubted, the problem of their origin remains. Some see a sole Mediterranean source that spread into the Atlantic in the fifteenth century with the advent of carvel planking, while others see the design variants contained in the English texts as a vestige of an Atlantic or Nordic tradition that was in place well before the arrival of carvel planking.

Shipwreck Typologies

The question of origins in ship history has led archaeologists to develop tools that are geared to place anonymous shipwrecks in a specific cultural and geographic context. In the 1980s, archaeologists working simultaneously on several sixteenth-century wrecks, all with a presumed "Iberian" origin, began noticing a series of structural features that were common to all, thus giving rise to a preliminary "Ibero-Atlantic" shipwreck typology.[14] This recognition tool has since been refined by explaining several of the characteristics through historical research and associating several of them with the more precise geographical basin of Biscay, one of the early cradles of Atlantic shipbuilding.[15] Other researchers have used the typology to define a series of contrasting features that appear on Mediterranean sites.[16]

The most important characteristic of Ibero-Biscayan shipwrecks is the abundance of oak, used for the frames, the planking of the hull, ceiling and decks, the treenails and for all major timbers such as the keel, the stem, the stern post, the knees, the keelson, the rudder and even sometimes for the masts. On the Basque coast, laws governing oak plantations specialized in the production of naval timber date to the Middle Ages, and sixteenth-century state programs encouraged the planting and cultivation of oaks in Biscay as a part of Spanish naval policy.[17]

The second characteristic is the use of both oaken and iron hull fasteners. The treenails are about 25 mm in diameter and the iron nails are about 10 to 12 mm square in section. At each joint of a frame timber and a plank, two iron nails and two treenails are typically found. The use of both iron and wooden nails distinguishes Biscayan shipwrecks from more northerly wrecks, such as the *Mary Rose*, which have only treenails and from more southerly wrecks, especially from the Mediterranean, which have only iron nails. J. B. Lavanha stated, around 1610 to 1620, that treenails were used in countries whose ships sailed in cold waters, while iron nails were favoured in countries whose ships sailed in warm seas, where wooden nails were quickly tunnelled by the taredo worm and thus, each treenail became a leak.[18] In Biscay, a land of oak plantations and iron working, both materials were readily available as fasteners and their combination helped speed up construction. Analysis of the Red Bay ship has shown that the iron nails were used first to quickly assemble the planks and frames, and later, the treenails were installed to solidify the hull. The head of each fastener is typically surrounded by a countersink made with a small adze, which served to start the drill and keep it from slipping or splitting the wood. Later, when a waterproofing agent based on pitch and whale oil was applied to the hull, the cavity around the head collected the agent and protected the fasteners from sea salt and the taredo.[19]

The typology of Ibero-Biscayan wrecks puts a great emphasis on timber measures, or scantlings. The floor timbers are typically 19 to 20 cm square in section, while the futtocks decrease in section from 19 to 20 cm square at the floor to about 14 cm square at the upper deck. There is little difference between the scantlings of large and small ships, suggesting that the timber supply was relatively uniform. The width of the hull planks falls in a range of 33 to 38 cm. Their thickness is about 5.5 to 6 cm below the water line, and about 4.5 cm in the upper hull. The deck and castle-wall planks measure 17 to 19 cm in width and from 3 to 3.5 cm in thickness. The maximum length of all the plank types is in the range of 10 to 11 metres, which seems to represent the original length of the planking stock that arrived at the shipyard.

These frame and plank dimensions correspond to the metrology used historically to measure timber in the forestry trades of coastal Biscay.[20] Surveyers gauged timber after sawing, in order to calculate the sawyers' pay, in three different ways depending on the type of timber, all of which are reflected in sixteenth-century shipwrecks. First, the *codo de maderamiento*, or the cubit of framing-timber, equalled 8 *pulgadas* (19.1 cm) square by 1 *codo* (57.5 cm) in length. Second, the *codo de tabla*, or cubit of planking, measured 16 *pulgadas* (38.3 cm) wide, 1 *codo* long and 1/8 of a *codo* in thickness. Third, the castle planks, ledges and other smaller pieces were gauged according to the formula *dos por uno*, or two for one, because they were only half as great as the major pieces (9.5 cm for the timbers, 19 cm for the planks)

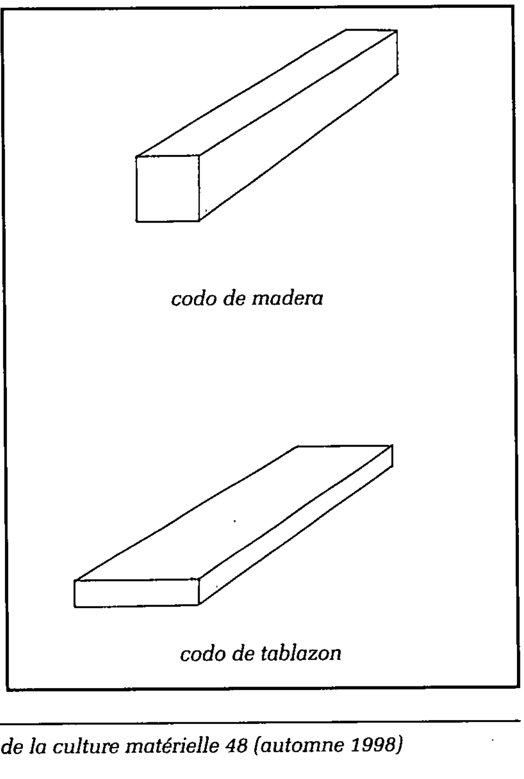
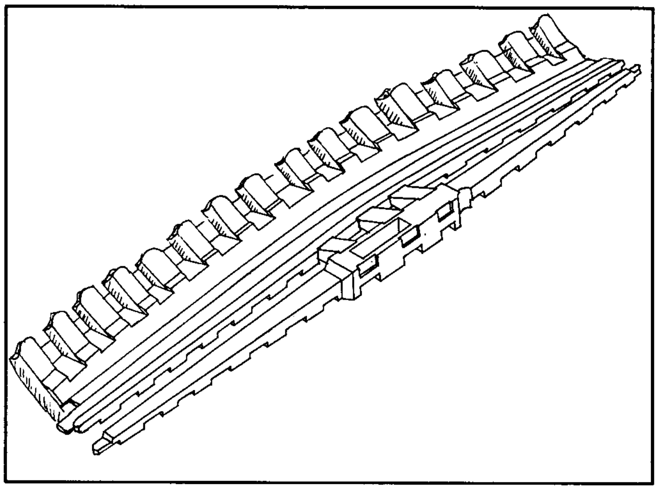


Fig. 3
Typical timber dimensions in Basque shipwrecks reflect the wood-volume units of Biscayan forestry. The codo da madera, *or frame-timber* codo, *measured 8* pulgadas *square (19.1 cm square by 57.5 cm). The* codo de tablazon, *or planking* codo, *measured 16 by 3* pulgadas *in section (38.3 cm by 7.2 cm by 57.5 cm).*

Fig. 4
The characteristic Atlantic keelson, showing the "swollen" central area with its mast step cavity, the buttresses on either side and the semi-circular pump well. Beyond the keelson are the runs of ceiling planks, the last of which is the elaborately-carved albaola *with its crenelated appearance and small inserted planks to deflect moisture and refuse onto the ceiling.*



and thus required twice the amount of sawing. In the shipwrecks, the surfaces of the planks are adzed to a smooth finish after the sawing, which had the effect of reducing their thickness and breadth to something less than the standard dimensions.

Another characteristic of sixteenth-century wrecks is called the "lateral assembly" of selected frames. The floor timbers and first futtocks of a limited series of frames including the master frame are joined by a dovetail mortice-and-tenon joint. In the case of the Red Bay ship, this assembly occurs on 14 frames, 6 forward and 7 aft of the master. Generally, the number of assembled frames is greater aft than forward of the master. The dovetail morphology of the mortice is the only shape found so far on Basque ships from this period,[21] however it also occurs in some Mediterranean shipwrecks. Archaeologists distinguish the Biscayan assemblage by the presence of both iron nails and treenails securing the joint, while in the Mediterranean, only iron nails have been found.[22] It has been hypothesized that this central group of mortised frames corresponds to the "calculated frames" (*maderas de cuenta*) described in the shipbuilding treatises of the period.[23] Fore and aft of the mortised frames are non-assembled frames in which the various timbers are not directly linked. The floor timbers, first futtocks, second futtocks, etc., are independent and fastened only to the hull planks and the internal longitudinal structures such as the ceiling planks, deck clamps and waterway wales. Archaeologists refer to this feature as the "floating futtocks."

A few other typical features have been catalogued, but still lack an historical explanation. For example, the keelson is a massive timber that is swollen in the middle in the area of the main mast step and buttressed on each side against the bilge clamps. As well, just aft of the mast step, on one or both sides of the keelson, a semi-circular cavity is notched into the timber where the pump was seated. Several pumps have been recovered and they too have a typical style.[24] Another diagnostic feature is the morphology of the outermost ceiling plank, known in Spanish records by its Basque name of *albaola*, which was elaborately carved and complemented with insets to ensure a watertight joint between the hull, the futtocks and the ceiling.[25]

The typology has known several avatars since it was first described by the American archaeologist as "Ibero-Atlantic." French archaeologists have concentrated on its "Atlantic" character, and have used it as a basis for developing a contrasting "Mediterranean" typology. Canadian archaeologists have refined the "Basque" association of these archaeological features based on their research at Red Bay. In truth, little data from other Atlantic regions, in Iberia or elsewhere, has been systematically compared to the corpus of wrecks that makes up the typology. Some English sites excavated before the 1980s, for example, are believed to contain some comparable features, while recent Portuguese findings are bound to generate valuable comparative data. Eventually the parameters of the typology can be better understood.

Wood as an Archaeological Material

The archaeological interest in materials, such as ceramics, metals or glass that are commonly well preserved in various sub-soil contexts, has spurred ship archaeologists to approach their subject from the point of view of wood as a material. Our interest here is to provide a resumé of two approaches that are based on the anatomical study of the wood itself. The first approach, called dendrochronology, is able in certain circumstances to date the year of the tree's felling and to narrow down the geographical area of its growth, sometimes to within a single watershed. The second approach compares several indices to discover the forestry practices related to the production of naval timber.

The current wave of interest in dating archaeological objects by dendrochronology dates to the 1970s. Anomalies in radio-carbon dating results had been detected by American researchers on the basis of comparison with wood from extremely old bristlecone pines, whose age could be precisely known by counting the annual growth rings. Tree-ring researchers in Northern Ireland and in Germany reacted to the announcement of the unexplained anomalies by proposing to duplicate the study using European oak samples. Instead of vainly searching for trees of great age, they developed methods of transferring their ring count from one tree to another, and thus progress backwards over time. Called "interdating," these methods were quickly recognized by archaeologists as having immense potential for dating wooden findings. As suspected, it was soon confirmed that "interdating" worked only between trees that had grown within a limited geographic area ranging, according to regional climatic gradients, from less than twenty to a couple of hundred kilometres in radius. This constraint has been seized by ship archaeologists as a method of ascertaining the provenance of wrecks discovered far from their point of construction.[26]

Several case studies illustrate the impact of dendrochronology on ship archaeology, which has often forced researchers to take surprising new data into account. In the mid-1980s, the tree-ring patterns from the Dutch ship *Amsterdam*, a well-documented wreck of 1748, were analysed in order to discover the origin of the timbers. Initial comparisons were fruitless, but as more local chronologies were published, the origin of the timbers could eventually be situated in the lower German Rhine.[27]

In another research question, it was hoped that the felling date of the timber from the Red Bay wreck could help narrow down the identity of the vessel. It was thought to be the *San Juan* that sank at this place in 1565 until it was discovered that a second Basque whaler of similar size and description, the *Magdaleine*, was lost in the same harbour in 1574, although in different circumstances.[28] A tree-ring chronology built from the hull planking was compared to Basque chronologies constructed from the wood of sixteenth-century buildings, but no relation was found. Related research helped understand the reasons for this initial failure. On the one hand, the steep climatic gradients on the Biscayan coast prevented "cross-dating" from one narrow valley to the next.[29] On the other, ship's timbers were typically cut in the same valley where the construction took place, and within a radius of about ten kilometres from the rivermouth. Usually, two or three private forests measuring a few hundred yards across supplied all the frame timbers and planking for one ship.[30] This information has obliged tree-ring studies on the Basque coast to become more precise and more patient, but the knowledge gained meanwhile of the repercussions of sixteenth-century naval forestry practices upon dendrochronology has been immense.

In a third case, a precise datation was possible. The Cavalaire-sur-Mer (Provence) wreck had been dated initially to the later fifteenth century by associated ceramic and cannon finds, and typological analysis situated the construction of the wreck on the Atlantic coast, probably in Biscay. However, the growth patterns of its oaken timbers and hull planks did not match any available tree-ring series from the Mediterranean or the Atlantic. Only a short ceiling plank, a recent repair made of fir that included the bark, matched several series from Savoy and its ultimate ring could be dated to 1470, making this anonymous ship the earliest Atlantic wreck to be found in Mediterranean waters.[31]

Finally, tree-rings studies on the timbers of the *Mary Rose*, another well-documented wreck, have been used to establish which timbers dated from the orginal construction in 1509–1511 and which ones were added in a major refit in 1536.[32] Sophisticated research strategies such as these are bringing ship archaeology increasingly closer to the scientific standards of land archaeology.

Another approach to wood as a material has yielded initial results that place hull design and forestry in intimate proximity. The approach is based on comparing three kinds of data. First, the age of the frame timbers is calculated by counting the growth rings. Then, the researcher evaluates the correspondance between the tree's grown shape (curvature and diameter) and the finished shape and dimensions of the frame. Finally, the shape of the frame timbers as a group is analysed, to discern the use of common arcs and a systematic progression of shapes, in order to ascertain the use of a mould in shaping them. These data can reveal relationships between forestry practices such as planting and pruning, and the ship carpentry practices of designing and moulding frames.

The approach grew out the Red Bay project led by Parks Canada, and its conception may be worth recounting. During the excavation, preliminary tree-age information for the frames was gathered as a means of choosing timbers for dendrochronological study, which resulted in the systematic rejection of futtock timbers because their typical age, about thirty-five to forty years, was well below the target age for the study. Attention was diverted to the planks, whose greater age made them suitable for sampling, and the tree-age information on the futtocks languished. However, when later research revealed the highly localised provenance of Basque framing timbers, the information acquired a new significance, as the uniformity of the tree-ages suggested that the frame-timber trees had been planted and harvested as a single crop. Subsequently, it was remarked that the futtock timbers, whose shape varied considerably according to their location in the hull, nonetheless exhibited a high degree of correlation between the morphologies of the tree and the finished frame, that is, the curvature and the diameter of the tree closely matched the final shape and dimensions of the futtock. Moreover, the arcs found in the frame timbers do not naturally occur in the trunks of oaks. A hypothesis was thus developed concerning the training of a crop of trees to their required curvature; however, because the timbers had meanwhile been reburied at Red Bay, comprehensive tree-age data could not be obtained to validate the hypothesis.

Instead, the hypothesis was tested on the futtocks of the Cavalaire-sur-Mer wreck, built a century before the Red Bay ship and apparently also on the Basque coast. The test results were unequivocal.[33] First, tree-ring counts, whose overall precision was estimated at ±5 years because of the occasionally-degraded condition of the timbers' ends, revealed that a large proportion of tree-ages at the time of felling clustered in the range of 65 to 70 (±5) years, and nearly all in the range of 60 to 75 (±5) years. Second, the correspondance between the tree-trunk and finished-frame morphologies was extremely close, as one tree produced only one frame and the final sapwood was regularly visible as "waniness" along the corners of the frame timber. Third, analysis of the futtock shapes revealed that the timbers had been sculpted on the basis of a single model, indicating the presence of a formal moulding process. Thus the practice of training a crop of trees to a shape established by ship designers and harvesting them at a uniform age, hypothesized from the Red Bay data, seems to be corroborated already for the period 1400 to 1470.

Conclusion

A correlation between timber growing practices and hull design has far-reaching implications for the study of shipbuilding. First of all, it opens a whole new range of historical sources, namely forestry records, to the historian interested in ship design. However it also sheds new light on the degree of creativity that was open to ship carpenters who had to work with timber that was grown to a specific shape and harvested as soon as it reached the required dimensions. Local hull design was locked into a conventional form, determined by foresters thirty-five to seventy years earlier, thus ensuring the longevity of regional ship-types. A carpenter was obliged to design all his ships, irrespective of their size, for an invariable timber supply; possibly, a single set of moulds could be adapted for ships of various sizes.

These possibilities are evoked here in part to suggest ways in which we may need to rethink the history of shipbuilding, but also to illustrate the efficient, yet rigid technological context in which Renaissance hull design operated. Instead of innovating, carpenters perfected. This stable context provided ample time for the woodworking trademarks that make up our regional shipwreck typologies to become ingrained. When change came, it was all-pervasive. As the case of Biscay reveals,[34] the accelerated construction and the larger hulls in the second half of the sixteenth century put strains on local timber resources but, in so doing, they also pushed traditional hull design beyond its intended limits. The eclipse of the master carpenter as the author of his design and the rise of the "naval architect" are played out against this background of historic change.

GLOSSARY

(italics refer to other terms in this glossary)

Arc. A segment of a circle.

Basque Country. The modern name for *Biscay*, translated from the Basque language.

Beam. One of several heavy transversal timbers that form the principal support for each *deck*, resting at each end on a lengthwise timber called a *clamp* or "shelf."

Bilge arc. The *arc* described by the *master frame* at the bilge, that is, where the *master frame* turns upward and the *floor timber* and *first futtock* overlap.

Biscay. The historic name for a region on the Atlantic coast of Europe, straddling the border of France and Spain, with a strong maritime industry dating to the later Middle Ages, and homeland of the Basque people. For Renaissance mariners, the principal ports of Biscay lay from Bilbao to Bayonne. See *Basque Country.*

Breadth. The breadth of the hull at its widest point, at midship near the water line.

Carvel. An adjective used to describe hull planks laid edge-to-edge, as opposed to having the plank edges overlap which is called *lapstrake* or clinker planking.

Castle. The raised structures at the forward and aft ends of the ship, commonly used as shelter.

Ceiling. The ship's interior, lengthwise planking, often limited to the lower part of the hull.

Clamp. An interior lengthwise timber upon which the *deck beams* are rested. Also called a "shelf."

Cord. The straight line between the two end-points of an *arc.*

Deck. Each of the ship's interior "floors," called "lower" (sometimes "orlop"), "main" and "upper" (sometimes "weather") in a three-decked ship.

Depth of hold. The height inside the hull from the *ceiling* to the main *deck.*

Floor line. The straight line, horizontal in many sixteenth-century representations, described by the *master frame* from the *keel* to the *bilge.*

Floor timber. A lowest component timber of each *frame*, resting immediately upon the *keel.*

Frames. Often compared to "ribs," these are the heavy, curved timbers that lie across the *keel* and arch upwards to the top of the hull, and to which the hull planks are fastened. One *frame* is composed of several timbers named, from bottom to top, *floor timber, first futtock, second futtock, third futtock*...and *top timber.*

Futtock. One of several rising component timbers of each *frame*, extending above the *floor timber* on each side of the hull. From bottom to top, the futtocks are called "first," "second" and "third" *futtocks.*

Futtock arc. The *arc* described by the *master frame* where it flares outward from the *bilge* to just below the water line, in the area where the first *futtock* is situated.

Hull fasteners. The *treenails*, iron nails and iron bolts which fasten the hull planks and internal structures to the *frames.*

Keel. The lowest timber of the ship, oriented lengthwise, upon which all the other timbers are built.

Keelson. A heavy, lengthwise timber placed over the floor timbers, parallel to the *keel.*

Knee. A heavy, angled timber made from the joint of a trunk and a branch, used to reinforce the joint of a horizontal deck beam and a near-vertical frame. Knees are also used in a horizontal position to reinforce the joint of two of the ship's walls, at the stern or the bow.

Lapstrake. An adjective used to describe hull planks whose edges overlap. Also called clinker as opposed to *carvel* planking.

Ledge. One of several light transversal timbers, laid between the heavier *beams*, that support the deck *planking.*

Master frame. The *frame* at midship, from which the hull *narrows* fore and aft. The shape of this frame corresponds to that of the *master mould.*

Master mould. The template, often in several pieces, used by the carpenters to give the correct shape to the hull timbers. The master mould has the same shape as the *master frame.* The component pieces of the master mould are systematically modified to produce the shape of the *frames* fore and aft of the *master frame.*

Midship. The section of the hull at its widest point, usually at the *master frame.*

Narrowing of the floor. The reduction in the breadth of the *floor timbers* from the *master frame* fore and aft. See *rising of the floor.*

Rising of the floor. The rising of each end of the *floor timbers* from the *master frame* fore and aft, as these timbers progress from a relatively "flat" shape at the *master frame* to a V-shape at the quarters of the hull and to a Y-shape at the stern and *stem.* See *narrowing of the floor.*

Rudder. A long, flat piece attached to the *sternpost* with hinges, allowing it to be angled left or right in order to steer the ship.

Scantlings. The dimensions of timbers used in shipbuilding.

Stem. The upward-curving timber or timbers attached to the forward end of the keel, forming the leading edge of the ship as it passes through the water. See *sternpost.*

Sternpost. The upward-oriented timber attached to the aft end of the *keel*, forming the aft extremity of the hull. The *rudder* is attached to the sternpost. See *stem.*

Treenail. A wooden dowel used to fasten planks to *frames.*

Tumblehome. The line described by the *master frame* where it angles inward above the water line.

Wale. A hull or ceiling plank of a thicker-than-normal dimension, used to reinforce the hull at certain levels.

NOTES

1. *L'Album de Colbert* (1670), Service historique de la Marine, Pavillon de la Reine, Château de Vincennes (Paris), Ms 140-1 513; fascimile Omega (Nice, 1988); cf. M. Vergé-Franceschi and E. Rieth, *Voiles et voiliers au temps de Louis XIV* (Paris: Du May, 1992); J.-C. Lemineur, *L'Orient Arsenal, XVII-XVIII^e siècles*, catalogue de l'exposition du 3 au 28 juin 1983, Service historique de la Marine, Lorient, 1982, pp. 13–42. Anthony Deane's *Doctrine* is at the Pepys Library, Magdelene College (Cambridge), Ms 2910, reproduced and presented in B. Lavery, *Deane's Doctrine of Naval Architecture, 1670* (London: Conway, 1981). The *Arte de Fabricar Reales* by Antonio de Gastañeta Yturribalzaga was published in facsimile by F. Fernandez Gonzalez, et al, eds. (Barcelona: Lunwerg, 1992). Finally, Nicolaes Witsen's *Aeloude en Hedendaegse Scheepsbouw en Bestier* was republished by Canaletto (Alphen aan de Rijn, 1979); cf. A. J. Hoving in *Model Shipwright*, nos. 58, 60, 69, 70.
2. The author discussed some related research issues in "Codo, Carvel, Mould and Ribband: The Archaeology of Ships, 1440–1620," *Mémoire vive* (Montreal 1994): 6–21.
3. The four manuscripts, along with their commentated editions, are **(i)** "Fabrica di galere," ca 1410 (Florence, National Library, Magliabecchiano, Ms 7, XIX), cf. A. Jal, *Archéologie navale*, vol. 2 (Paris, 1840), mémoire n° 5, pp. 1–106, and R. C. Anderson, "Jal's mémoire n° 5 and the manuscript Fabrica di Galere," in *Mariner's Mirror* 31 (1945): 160–167; **(ii)** Z. Trombetta de Modon, "Libro," ca 1445 (London, British Library, Cotton, Ms Titus A 26), cf. R. C. Anderson, "Italian Architecture about 1445," in *Mariner's Mirror* 11 (1925): 135–163; **(iii)** "Ragioni antique spettanti all'arte del mare et fabriche de vasselli," late fifteenth century (Greenwich, National Maritime Museum, Ms NVT 19), cf. G. Bonfiglio Dosio, ed., reprint with commentary (Venice, 1987), and A. Chiggiato, "Contenuti delle architetture navali antiche," in *Ateneo Veneto* 178 (1991): 141–211; and **(iv)** B.Q. Drachio, "Visione," ca 1594 (Venice, Archives of the State of Venice, Contarini, Ms 19, arsenal, 1), cf. L. T. Lehmann, *Baldissera Quinto Drachio, la Visione del Drachio* (Amsterdam, 1992). For an overview, see S. Bellabarba, "The Ancient Methods of Designing Hulls," in *Mariner's Mirror* 79 (1993): 274–292, and E. Rieth, *Le maître-gabarit, la tablette et le trébuchet* (Paris, 1996), 133–148.
4. The four Portuguese manuscripts are: **(i)** F. Oliveira, "Ars nautica," 1570 (Leiden, Library of the Rijksuniversiteit Leiden, Ms Vossianus Latinus F41); cf. E. Rieth, "Remarques sur une série d'illustrations de l'*Ars nautica* (1570) de Fernando Oliveira," in *Neptunia* 169 (Paris, 1988): 36–43; **(ii)** F. Oliveira, "Livro da fabrica das naos," ca 1570 (Lisbon, National Library, reserve Ms 3702, reproduced and commented by F. Contente Domingues and R. A. Barker, Lisbon, 1991); **(iii)** M. Fernandes, "Livro de traças de carpintaria," 1616 (Lisbon, Library of the Palace of the Ajuda, Ms 52.XIV.21, reproduction Lisbon, 1989); and **(iv)** J. B. Lavanha, "O Livro Primeiro da architectura naval," ca 1600–1620 (Madrid, Library of the Royal History Academy, Salazar, Ms 63), transcribed in J. da Gama Pimentel Barata, "'O Livro Primeiro da architectura naval' de João Baptista Lavanha," in *Ethnos* 4 (1965): 221–298.
5. The six Spanish texts are: **(i)** J. Escalante de Mendoza, *Itinerario* (Seville, 1575; reproduced in C. Fernandez Duro, *Disquisiciones Nauticas*, vol. 5, Madrid, 1880), pp. 413–515; **(ii)** D. Garcia de Palacio, *Intruccion Nauthica* (Mexico, 1587; repr. Madrid: Ediciones Cultura Hispanica, 1944; tr. and ed. E. Bankston, Bisbee, New Mexico, 1988); **(iii)** A. de Aroztegui, "El Rey ...," 1607 (Museo Naval, Madrid, Collection Fernandez de Navarrete, vol. 23, document 47); **(iv)** T. Cano, *Arte para fabricar y aparajar naos* (Seville, 1611; reprint E. Marco Dorta, ed., La Laguna, 1964); **(v)** M. de Aroztegui, "El Rey ...," 1613 and **(vi)** "El Rey...," 1618 (Cambridge, Mass., Harvard University, Houghton Library, Palha, Ms 4794, vol. 2, unpaginated), transcribed in G. de Artiñano y Galacano, *Arquitectura Naval Española en Madera* (Madrid, 1920), appendix 9. For an overview of the Portuguese and Spanish texts, see Loewen, "Codo, Carvel, Mould and Ribband."
6. The six English manuscripts are: **(i)** A Construction Plan for the Early Sixteenth-Century Ship *Mary Gonson*, cf. R. C. Anderson, "The *Mary Gonson*," in *Mariner's Mirror* 46 (1960): 201–202; **(ii)** M. Baker, *Fragments of Ancient English*

Shiprightry, ca 1580 (Cambridge, Magdelene College, Pepsyian Library, ms 2820), cf. R. A. Barker, "Fragments from the Pepysian Library," in *Revista da Universidade de Coimbra* 32 (1986): 161–178; **(iii)** anonymous, ca 1600 (Cambridge, Cambridge University Library, Mss Add 4005, Part 12), reproduced in R. A. Barker, "Design in the Dockyards, about 1600," in K. Paul, R. Reinders, eds., *Carvel Construction Techniques,* 5th ISBSA Proceedings, Amsterdam, 1988 (Oxford: Oxbow Monograph no. 12, 1991), 61–69, and in R. A. Barker, "A Manuscript on Shipbuilding, Circa 1600, copied by Newton," in *Mariner's Mirror* 88, no. 1 (1994): 16–29; **(iv)** "A most excellent briefe and easie treatise," anonymous, ca 1600 (London, Royal Institute of Naval Architects, Scott, Ms 798); **(v)** a circa 1608–1610 text on shipbuilding and rigging by Thomas Herriot, ca 1608–1610, commented in J. V. Pepper, "Harriot's Manuscript on Shipbuilding and Rigging (ca 1608–1610)," *500 Years of Nautical Science, 1400–1900* (London, 1981), 204–216; and **(vi)** John Wells, *A Treatise on Shipbuilding* (1620), Admiralty Library, London, ms 9; published in W. A. Salisbury, ed., Society for Nautical Research, Occasional Publication no. 6, 1958. For an overview see R. A. Barker, "Many May Peruse Us: Ribbands, Moulds and Models in the Dockyards," in *Revista da universidade de Coimbra* 34 (1988): 539–559 and "Design in the Dockyards, About 1600," op. cit.

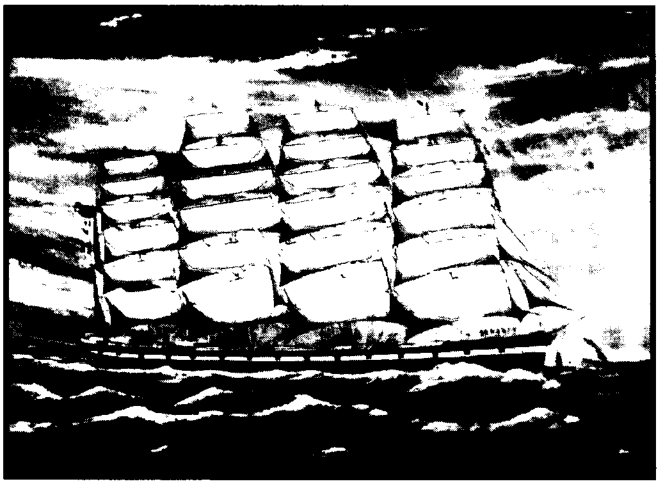
7. The ten texts in the later group are: **(i)** P. Arnoul, "Remarques faictes par le Sieur Arnoul sur la marine de Hollande et d'Angleterre ...," 1670 (Paris, Bibliothèque Nationale, Ms Cinq Cents de Colbert 201); **(ii)** A. de Gaztañeta Yturribalzaga, "Arte de fabricar reales," 1687–1691 (Mutriku, Archives of the Casa de Arrietakua), reproduced and commented by C. Apeztegui Cardenal in F. Fernandez Gonzalez, et al, eds. (Barcelona: Lunwerg, 1992); **(iii)** "Traitté de la construction de galères," ca 1691 (Vincennes, Service historique de la Marine, Ms SH134), transcribed and commented in J. Fennis, ed., *Manuel de construction des galères, 1691* (Amsterdam, 1983); **(iv)** Barras de la Penne, "La Science des galères," 1697 (Paris, Musée de la Marine, Ms B1125); **(v)** La Madeleine, "Tablettes de Marine," ca 1712 (Paris, Musée de la Marine, Ms R711); **(vi)** B. Ollivier, "Traité de construction ...," 1736 (Vincennes, Service historique de la Marine, Ms SH310; repr. Nice, 1992); **(vii)** P. Bouger, *Traité du navire, de sa construction, et de ses mouvemens* (Paris, 1746); **(viii)** H.-L. Duhamel du Monceau, *Élémens de l'architecture navale* (Paris, 1752); **(ix)** Duranti de Lironcourt, *Instruction élémentaire et raisonnée sur la construction pratique des vaisseaux en forme de dictionnaire* (Paris, 1771; repr. Nice, 1986); and **(x)** G. Juan, *Examen maritime théorique et pratique* ... (tr. from Spanish with additions by M. Levêque, Nantes, 1783). For an overview see E. Rieth, *Le maître-gabarit, la tablette et le trébuchet* (Paris, 1996).
8. The outward tilt is called *espalhamento* in Portuguese, *joba* in Spanish and *trébuchement* in French.
9. The smoothing-out of the kink is called *cancomo* in Portuguese, *desfaldar* in Spanish and *recalement* in French.
10. M. L. Freire Costa, "The Role of Shipbuilding in the Making of the Modern State: The Portuguese Littoral and the Atlantic Routes," *Proceedings of 'As navigações portuguesas no* Atlantico *e o descobrimento de América,'* Coimbra, 1992.
11. This development, in the case of the Basque province of Guipúzcoa, has been detailed in the 1570s in B. Loewen, "Le baleinier basque de Red Bay, Labrador (XVI^e siècle): étude du clouage dans les murailles de la coque," *L'aventure maritime, du golfe de Gascogne à Terre-Neuve, Actes du 118^e congrès national annuel des sociétés historiques et scientifiques, Pau, octobre 1993* (Paris: Éditions du CTHS, 1995), pp. 145–158. Royal dockyards on the Thames and the Tagus, dating to the turn of the sixteenth century (and even earlier at Rouen and Portsmouth), had an ambiguous relation to private builders and timber growers, sometimes fertile, sometimes closed and even secretive.
12. M. Baker, op. cit. (ca 1580), fo. 2r. M. Fernandes, op. cit. (1616), frontispiece. Rembrandt van Rijn, "The Shipbuilder and His Wife" (1633), Buckingham Palace collection, London; cf. J. Bruyn, et al, *A Corpus of Rembrandt's Paintings*, Vol. 2, no. A77 (The Hague, 1986), 367–377.
13. P. Waddell, "Marine Archaeology in Red Bay, Labrador: The Diving," *Proceedings of the Canadian Association for Underwater Science, Toronto, March 1985*, pp. 21–32 and "The Disassembly of a Sixteenth-Century Galleon," *International Journal of Nautical Archaeology* 15, no. 2 (1986): 137–148.
14. T. J. Oertling, "The Few Remaining Clues ...," in *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference*, ed., J. Barto Arnold III (Baltimore, 1989), 100–103.
15. The sites included in the revised typology are the *San Esteban*, built at San Sebastian and sunk at Padre Island, Texas in 1554; three Basque whalers at Red Bay, including the presumed *San Juan of Pasajes*; the Molasses Reef and Highborn Cay sites in the Bahamas; the Cattewater wreck in Dorset; the Western Ledge Reef wreck in Bermuda; and the ca 1470 wreck at Cavalaire-sur-Mer, Provence. See J. B. Arnold and R. Weddle, *The Nautical Archaeology of Padre Island* (New York: 1978); J. Rosloff and J. B. Arnold, "The Keel of the *San Esteban* (1554): Continued Analysis," in *International Journal of Nautical Archaeology* 13, no. 4 (1984): 287–296. R. Grenier, "Excavating a 400-year-old Basque Galleon," *National Geographic* 168, no. 1 (1985): 58–68 and "Basque Whalers in the New World: the Red Bay Wrecks," in G. Bass, ed., *Ships and Shipwrecks of the Americas* (London: Thames and Hudson, 1988): 69–84. T. Oertling, "The Molasses Reef Wreck Hull Analysis: Final Report, *IJNA* 18, no. 3 (1989): 229–243; and "The Highborn Cay Wreck: The 1986 Field Season," *IJNA* 18, no. 3 (1989): 244–253; R. Smith, D. Keith, D. Lakey, "The Highborn Cay Wreck: Further Exploration of a Sixteenth-Century Bahamian Shipwreck," IJNA 14, no. 1 (1985): 63–72. M. Redknap, *The Cattewater*

Wreck: The Investigation of an Armed Vessel of the Early Sixteenth Century (Oxford, Greenwich: BAR British Series 131, 1984); and "The Cattewater Wreck: A Contribution to Sixteenth-Century Maritime Archaeology," in C. O. Cederlund, *Postmedieval Boat and Ship Archaeology* (Oxford: BAR International Series 256, 1985), 39–59; G. Watts, "The Western Ledge Reef Wreck: A Preliminary Report on Investigation of the Remains of a Sixteenth-Century Shipwreck in Bermuda," *IJNA* 22, no. 2 (1993): 103–124. B. Loewen and M. Delhaye, "The Fifteenth-Century Ship Found at Cavalaire-sur-Mer (Var): A Precursor to the Red Bay (Labrador) Vessel?", paper read at the Society for Historical Archaeology, Corpus Christi, Texas, January 8, 1997.

16. E. Rieth, "Signatures architecturales," paper read at Aix-en-Provence, October 1995.
17. G. de Artiñano y Galacano, *Arquitectura Naval Española en Madera* (Madrid, 1920); cf. M. Barkham, "Spanish Basque Shipbuilding: The Port of Zumaya: An Historical Economic Geography of a Merchant Capitalist Industry" (M.A. thesis, Memorial University of Newfoundland, Centre for Newfoundland Studies, 1985).
18. J. B. Lavanha, "Primeiro livro da arquitectura naval" (ca 1620), op. cit.
19. B. Loewen, "Le baleinier basque de Red Bay," op. cit.
20. P. B. Villareal de Berriz, *Maquinas hidraulicas de molinos y govierna de los arboles y montes de Vizcaya* (Madrid: Antonio Marin, 1736); A. de Gastañeta Yturribalzaga (c. 1686), op. cit.
21. The ca 1535 Studland Bay (Poole, Dorset) wreck exhibits a simple lap scarf.
22. M. Guérout, E. Rieth, J.-M. Gassend, *Le navire génois de Villefranche* ... (Paris: CNRS, 1989).
23. R. Barker, "Design in the Dockyards, About 1600," in Carvel Construction Techniques, 61–69.
24. P. Waddell, "The Pump and Pump Well of a Sixteenth-Century Galleon," *IJNA* 14, no. 3 (1985): 243–259; T. Oertling, "The History and Development of Ships' Bilge Pumps, 1500–1840," Master's thesis, Texas A&M University, 1984.
25. L. Mott, "Identification of the Words 'Singla' and 'Albaola' and Their Relation to Timbers Found on Fifteenth-Century Spanish Shipwrecks," *IJNA* 22, no. 3 (1993). The Basque word albaola was constructed from *albo* meaning "edge" (*alba-* when followed by a vowel) and *ola* meaning "plank." Thanks to M. Egaña Goya for this explanation.
26. Cf. M. G. L. Baillie, *Tree-Ring Dating and Archaeology* (London: Croom Helm, 1982), various articles in *Tree-Ring* Bulletin, and M. J. Aitkin, *Science-Based Dating in Archaeology* (London: Longman, 1990).
27. E. Jansma, "Wood Sampling and Dendrochronological Research of the Ship's Timbers," in *Amsterdam Project*, ed. J. Gawronski (Annual Report of the VOC-Ship "Amsterdam" Foundation 1985, Amsterdam: 1986), 67–72.
28. L. Turgeon, "Pour redécouvrir notre 16e siècle : les pêches à Terre-Neuve d'après les archives notariales de Bordeaux", in *Revue de l'Amérique française* 39, no. 4 (1986): 523–549, n. 47. Archaeological reconstruction of the Red Bay wreck event corresponds best with the documentary evidence of the *San Juan*.
29. F. Guibal, *Analyse dendrochronologique des épaves de Red Bay (Labrador), contrat : 1632/90-173* (Marseille: Laboratoire de botanique historique et palynologie URA 1152 CNRS, novembre 1995). This analysis succeeded in dating several cask staves from the wreck site to the period 1529–1563 by referring to a Breton chronology.
30. M. Barkham, op. cit. (1985).
31. B. Loewen and M. Delhaye, op. cit; analysis carried out by F. Guibal, Marseille.
32. M. Bridge and C. Dobbs, "Tree-Ring Studies on the Tudor Warship *Mary Rose*," paper read to the ISBSA 8, Gdansk, September 1997.
33. This research was conducted under the direction of M. Delhaye. Cf. B. Loewen and M. Delhaye, op. cit. (1997).
34. L. Clayton, "Ships and Empire: The Case of Spain," *Mariner's Mirror* 62, no. 3 (1976): 235–248.

La Base de données d'information sur les navires

The Ship Information Database



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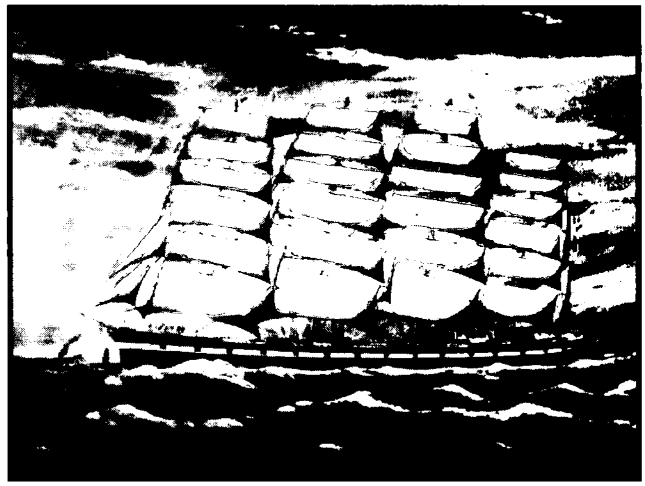

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Bureau fédéral d' archéologie, Lieux
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