THE PEPPER WRECK: A PORTUGUESE INDIAMAN

AT THE MOUTH OF THE TAGUS RIVER

A Dissertation

by

LUIS FILIPE MONTEIRO VIEIRA DE CASTRO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2001

Major Subject: Anthropology
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Approved as to style and content by:

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August 2001

Major Subject: Anthropology
ABSTRACT

The Pepper Wreck: A Portuguese Indiaman
at the Mouth of the Tagus River. (August 2001)

Luis Filipe M. V. Castro, B.S., Universidade Técnica de Lisboa;
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Chair of Advisory Committee: Dr. Kevin Crisman

In 1993, during a survey promoted by the Museu Nacional de Arqueologia and the non-profit association Arqueonáutica Centro de Estudos, under the direction of Dr. Francisco Alves, the remains of a ship were found in the mouth of the Tagus River, off the rocks of the fortress São Julião da Barra. These remains have been tentatively identified as the Portuguese Indiaman Nossa Senhora dos Mártires, lost at this location on its return voyage from Cochin, in India, on September 14, 1606, with a cargo of pepper and other goods.

The archaeological excavation disclosed an interesting collection of artifacts from the late 16th and the early 17th centuries and, most importantly, allowed for the study of the hull structure, making Nossa Senhora dos Mártires the first Portuguese nau ever to be studied by archaeologists.

An analysis of the dimensions and construction marks engraved on the frames by her shipwrights suggested that the ship was a standard Portuguese Indiaman of the late 16th century, as described by Fernando Oliveira in his treatise O Livro da Fábrica das Naus, written around 1580. The Nossa Senhora dos Mártires is presumed to have been a ship with a keel of around 27.7 m and an overall length of nearly 40 m.
DEDICATION

To my wife Siazza.
ACKNOWLEDGMENTS

I would like to start by mentioning the Instituto Português de Arqueologia who sponsored my Ph.D. through a three year grant, the Nautical Archaeology Program at Texas A&M University who granted me the assistantships that made it possible for me to live in Texas during this time, and the Institute of Nautical Archaeology who granted me the Marion Cook Fellowship and helped to finance my field work in Portugal during the summers of 1999 and 2000. Then, I must thank the Centro Nacional de Arqueologia Náutica e Subaquática for housing and feeding the 1999 and 2000 field season teams, and for supplying most of the equipment utilized. Finally, I must mention the Portuguese Navy, the Clube Naval de Paço d’Arcos, and the company Marascais for supplying free facilities for our equipment during the long working seasons of 1999 and 2000.

It is difficult to mention all the people whose influence and support were determinant for the making of the present dissertation. I feel that I should start with Siaska, who brought home the National Geographic issue with the 1987 Uluburun article in the early 1990s and who, after waking up an old passion of mine, was so absolutely supportive during the difficult period of change in my professional life, from the world of civil engineering to the one of nautical archaeology. Then, I should mention Carlos Martins and Augusto Salgado – and their wives Sofia and Elsa – whose solid friendship has been one of the major factors in the success of this project. Joined by the São Julião da Barra project since 1993, we soon became an indestructible team, not only when it was time to dive, survey, measure, photograph, study, and enquire, but also when we had to fight the difficult war with the political establishment that issued the Portuguese treasure hunting legislation of 1993, froze it in 1995, and replaced it in 1997.

Then I must thank Francisco Alves, who invited me for lunch out of the blue when I called the Museu Nacional de Arqueologia to ask where I could find information
about his non-profit association Arqueonáutica. Eduardo Prado Coelho mentioned my name to Simonetta Luz Afonso, who invited me to join the EXPO'98 project, changing my career forever. Again I must thank Francisco Alves, who pushed me to come to Texas A&M University, and Dr. João Zilhão and Eng.ª Monge Soares, who promptly proposed the possibility of a grant from the Portuguese Instituto Português de Arqueologia.

I should also mention the great team of the Centro Nacional de Arqueologia Náutica e Subaquática for their permanent support, the help with Portuguese books, and photocopies. I thank Paulo Jorge Rodrigues for his great sense of humor when too much work made it difficult to enjoy this job.

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After I was entrusted with the study of the hull found in SJB2, I was helped by
the wonderful teams of the 1999 and 2000 excavation seasons, who excelled in hard work and dedication. From Centro Nacional de Arqueologia Náutica e Subaquática I was lucky to be able to count on the always calm, firm, and wise hand of Miguel Aleluia, the center's rock of Gibraltar, and on Carla Almeida, Pedro Caleja, Tiago Fraga, Paulo Jorge Rodrigues, and Armando Sousa. From outside of Portugal I have gathered two great teams: in the summer of 1999, Michaeelle Amaral (USA), Tania Andujar (Spain), Paulo Camargo (Brazil), Erika Laanela (Canada), Suzana Martínez (Spain) and Mikkel Thomsen (Denmark); in the 2000 season, again Erika Laanela (Canada), Brian Jordan (USA), Sara Brigadier (USA), Anthony Randolph (USA), and Mason Miller (USA).

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One last and very important word of gratitude to the faculty of the Nautical Archaeology Program at Texas A & M University and most especially to Kevin and Ginny Crisman, who supported us from the first day in College Station, and made our stay in Texas such a pleasant time. Without their strong and permanent support this project would never have been possible.

And finally I am very grateful to Karen Sullivan, Erika Laanela, and Sara Brigadier for the painstaking work of editing this dissertation.
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CHAPTER I
INTRODUCTION

*Nossa Senhora dos Mártires* and the Pepper Wreck

After a six-month voyage from Cochin, India, and a three-month layover in the Azores, the Portuguese East Indiaman *Nossa Senhora dos Mártires* arrived in sight of Lisbon on 14 September 1606. A heavy storm forced her captain Manuel Barreto Rolim to drop anchor off Cascais, a small village a few miles from Lisbon. Here the nau *Salvação*, another returning Indiaman from the 1605 fleet, was already struggling with a southerly gale. Dangerously dragging her anchors in the direction of the beach, *Salvação* was too heavy to be towed against the wind by the galley that was sent from Lisbon to help her. The next day, after watching *Salvação* run aground on the Cascais beach, Rolim decided to head for the mouth of the Tagus River, hoping to escape the tempest in the calmer waters of the estuary.

However, getting past the sandbars was not easy. Two large sandbanks narrowed the entrance to the river, making the waters run dangerously fast in both the northern and the southern channels. Rolim headed for the northern passage, which by the early seventeenth century was already considered too narrow and shallow to drop anchor in. and too crooked for any galley to tow a large vessel. In the middle of the passage, the nau *Mártires* lost her headway and was dragged onto a submerged rock. She sank in front of the São Julião da Barra fortress in a matter of hours: soon afterwards *Mártires* was broken up into such small pieces that witnesses commented that it looked as if she had sunk long ago.

Her main cargo of pepper, stored loose in small compartments in the hold, spilled out upon wrecking and formed a black tide that extended for leagues along the coast and in the Tagus estuary. A large amount of this pepper was saved and dried by the king's

This dissertation follows the style and format of *The American Neptune*. 
officers. The population also salvaged a notable quantity, as it was impossible for the soldiers to stop the locals who, despite the dreadful weather conditions, went to the sea every night in small craft to salvage what they could. During the subsequent summers, the officers of King Philip III of Spain – who was also King Philip II of Portugal – may have salvaged a great part of the cargo from the shallow waters where the ship came to rest, and certainly rescued many cables, anchors and guns.

Like many other shipwrecks that occurred in this dangerous channel, *Nossa Senhora dos Mártires* was soon forgotten. The tidal wave that followed the earthquake of 1755 probably rolled heavy rocks over her remains, and in 1966 a codfish trawler wrecked near the site, covering a large area with other debris.

Stories of treasure troves in the vicinity of the fortress of São Julião da Barra were told by generations of local fishermen, and the growth of scuba diving from the early 1950s only heightened interest in the area. In the late 1970s a few archaeological surveys were carried out by avocational archaeologists, but no governmental action was taken to protect the site. As a result, it was heavily looted by sport divers during the 1980s.

In 1993 the Museu Nacional de Arqueologia sponsored a survey of the site under the guidance of its director, Francisco Alves, and identified two main areas of archaeological interest. The first one was designated as São Julião da Barra 1 (SJB1) and encompassed a large area littered with iron guns. The second area – designated as São Julião da Barra 2 (SJB2) – consisted of the remains of a wooden hull with shards of Ming porcelain and Chinese earthenware dating from the late 16th or early 17th centuries. Based on the information from the Museu Nacional de Arqueologia’s shipwreck archives, *Nossa Senhora dos Mártires* was identified as the most likely name for this shipwreck. The timbers tell us as well that the India nau that once sank at this place was almost certainly *Nossa Senhora dos Mártires*, which had a keel approximately 18 rumos (27.72 m) long and a displacement of around 1,200 tons by today’s standard.

In 1996 and 1997 excavations were conducted on the SJB2 site under the
direction of Francisco Alves and myself. The wooden hull was recorded and an area of approximately 100 square meters was excavated. Many artifacts were recovered from directly below an ubiquitous layer of peppercorns. These included three nautical astrolabes and two pairs of dividers, several sounding leads, as well as porcelain, stoneware, earthenware, and objects of brass, copper, pewter, silver and objects. Among the organic materials many peach pits were recovered along with rope, fabric, leather and straw, the latter being found between seven stacked porcelain dishes. Several of these artifacts were exhibited in the Portuguese Pavilion at EXPO’98, the World Exposition held in Lisbon during the summer of 1998.

An historical investigation led by the team of the Portuguese pavilion at EXPO’98 brought to light information about the lives of some of Mártires’ crew and passengers. Among them was Aires de Saldanha, the seventeenth vice-king of India (1600-1605), who died just before reaching the Azores on his return trip to Portugal; the ship’s captain, Manuel Barreto Rolim, who was trying to make his fortune in the India trade after being disinherited by his father due to an unapproved marriage; and one of the ship’s boys, Cristóvão de Abreu, who survived this shipwreck and the wrecks of another three India naus, only to die at sea in 1645, while returning from India as the boatswain of the nau S. Lourenço. No less interesting are the stories of Father Francisco Rodrigues, a Jesuit priest who lost his life in this wreck en route from Japan to see the Pope on matters concerning the future of the whole Japanese Jesuit mission; and a Japanese Catholic accompanying Father Rodrigues, named Miguel, who survived and eventually returned to Asia, dying in Japan many years later.11

In the summers of 1999 and 2000 the Instituto Português de Arqueologia, through its Centro Nacional de Arqueologia Náutica e Subaquática and the Institute of Nautical Archaeology, sponsored two excavation seasons on the SJB2 site, aiming for what is perhaps the most exciting part of this wreck - the hull remains. A portion of the bottom immediately forward of the midship frames was preserved, including a section of the keel, 11 frames, and some planking. Construction marks carved on the surfaces of
the floor timbers allows us to not only understand the method used by the shipwright to conceive the hull shape, but also to reconstruct some of the hull dimensions with a fair degree of certainty.

Several types of vessels sailed to and from India during the period of Portuguese maritime expansion, but the India nau was the true workhorse of the Portuguese overseas fleet. Although the word "nau" means literally "vessel" and seems to designate several types of ships during several different periods of Portuguese history, we know that the India naus were large vessels specially built for this trade, with forward and after castles well integrated into the hull, and three or four masts, of which the mizzen and bonaventure bore lateen sails.

India naus evolved during the 16th and 17th centuries, changing their shape, size, and rigging. In spite of their size and special characteristics, which attracted the attention of many people, these vessels were never recorded in detail in their time. Several descriptions and images of India naus are known, both from Portuguese and foreign authors, primarily from the middle of the 16th century, and several important texts pertaining to their construction have been published from the late 19th and into the 20th centuries. Nevertheless, these ships remain largely unknown. Although the sites of several Portuguese India Route wrecks have been identified, and the remains of a few have actually been found, the Pepper Wreck remains the only Portuguese nau of this period to have been excavated and documented by archaeologists. All of the other known remains either have been salvaged by treasure hunters or looted by fishermen and sport divers.

**Objective of this work**

The objective of this study is to reconstruct the hull found on the SJB2 site — hereafter mentioned as the SJB2 wreck or the Pepper Wreck — using the data retrieved from the archaeological site, as interpreted by a set of texts on Portuguese shipbuilding of this period. However, the study of a ship makes little sense in isolation with no
relation to its social and historical context. I will attempt to relate this ship to what is known about the people who built and sailed her, their understanding of the world, their objectives, and the technology available at the time of her construction.

The procedure adopted was to interpret the archaeological data in light of the texts on shipbuilding from the period around the time of her wrecking. After making a strong case for the identification of this wreck based on the dating of the extensive collection of artifacts in it, we have concluded that it is the wreck of a Portuguese Indiaman, and very probably that of Nossa Senhora dos Mártires, lost in 1606 at this location, as mentioned above. Once the ship was identified, the next step was to analyze the types of timbers utilized in her construction, and the scantlings of the preserved structure. Both reinforced the idea that this was a Portuguese Indiaman built in the late 16th or early 17th centuries. Then the geometric characteristics of the timbers preserved were analyzed in light of the data extracted from the available texts on shipbuilding from this period. I have concluded that there is a close match between the shape of the timbers preserved on this wreck site and the model prescribed in one of the shipbuilding texts studied, the Liuro da Fabrica das Naus, first written in Latin by Father Fernando Oliveira around 1570.

This work opens with a short introduction on the Portuguese historical background in Chapter II, beginning with the formation of the nation and the development of the country's relationship with the sea that led to its eventual expansion overseas in the 15th century. Then there is a brief discussion of the subsequent golden age of commerce in the 16th century, the goods traded and the dynamics of this trade, the voyages to India and life aboard the India naus. Following an account of the decline of Portuguese power in Asia and the rise of Dutch influence, there is an overview of the voyages of the India Route and a short description of the shipwrecks whose whereabouts have been identified.

Chapter III includes the origins of the India naus in the context of the Iberian shipbuilding tradition and explains the construction sequence, emphasizing the
techniques used at the Portuguese shipyards and their peculiarities. This chapter also includes important texts pertaining to the construction of ships in the early 17th century, in Italy, France, England, and Spain, detailing the sources in existence for Portugal. The final section of the chapter discusses the problems related to the evaluation of the size of a vessel based on its tonnage data from written sources, and addresses the units of measure in use in Portugal, in the late 16th and early 17th centuries.

Chapter IV describes the voyage to India in the early 17th century, in particular the context in which Nossa Senhora dos Mártires departed for India in 1605. It includes a quick description of the life aboard these vessels, the devotions, the gambling, the distribution of the space, the cargos, the crews, and the food. The few names that have been related to this nau and her last voyage are mentioned as well.

Chapter V delineates what is known about the site's formation process. Following a description of the Tagus sandbar and its characteristics is an account of a well documented process of silting that occurred in that locale for a short period in the late 16th and early 17th centuries. Even without knowing how near to the wreck this silting may have occurred, it certainly influenced the site formation process. The second part of this chapter refers to the human influence on the site, from the first documented attempts to salvage guns from the wreck, to the avocational archaeologists who exploited the site in the 1970s, and the intense looting that occurred during the 1980s.

Chapter VI includes the archaeological circumstances in which the Pepper Wreck was found, starting with the survey that led to the location of the site. A description of the site and the methodology adopted in its excavation follows. Finally, the chapter focuses on the question of identifying the wreck, detailing the clues from both the historical and the archaeological record. A list of the wrecks registered around the fortress of São Julião da Barra is given, and compared with a second, much larger list of the known wrecks in the mouth of the Tagus River.

Chapter VII includes a detailed description of the hull remains, focusing on the hull and the size of the scantlings, and describing each component as accurately and as
thoroughly as possible. Although this chapter is intended as an unbiased description of the wreck, a few specific details critical for understanding a vessel like the Pepper Wreck are highlighted. First is a description of the keel, with emphasis on the fact that it was assembled out of very small sections. Next is a description of the apron, the only longitudinal structural piece found other than the keel. The frames are detailed as much as possible since these are perhaps the most interesting aspect of the wreck. They present a collection of construction marks that express some of the hull conception theories followed by her shipwrights, namely the number of pre-designed frames utilized and the way in which the bottom timbers — floors and first futtocks — were cut and assembled. Following the framing information is a discussion of the planking and its dimensions. The planking yielded less information than expected, not allowing any particular insight on what is generally referred to by naval archaeologists as longitudinal control of the shape of the hull. After the planking is a discussion of the fastening methods used on this ship and the interesting caulking solution found in it. The last section of this chapter is dedicated to the puzzling question of the nonexistent ballast pile, or its possible mixture with the local rocks.

Chapter VIII deals with the interpretation of the data presented in the seven previous chapters, and with a proposed reconstruction of the vessel. The data are discussed in the order in which the wreck was described in Chapter VII. This chapter begins with a critical discussion of the size of these vessels from the contemporary written descriptions, and moves into the interpretation of the timbers described in the previous chapter. The probable design of the floors and futtocks is presented, as well as the narrowing and rising of the bottom, a technique in use in the Portuguese shipyards that is explained in Chapter IV. Finally, there is a proposed reconstruction of the hull volume and a lines drawing depicting the proposed hull shape. My goal is to demonstrate how the archaeological evidence relates to the model proposed in the learned literature of its time, namely the work of Father Fernando Oliveira.

Chapter IX, the final chapter, contains a summary of the assumptions and
conclusions of this work, and a critique of the methodology adopted, stressing its most important strengths and weaknesses.

This study will contribute to our understanding of these great vessels, of which so much has been said and yet so little is still known. Since the proposed reconstruction is based on perhaps no more than ten percent of the lower hull, it should be looked upon as an educated guess and a working hypothesis rather than a scientific reconstruction, even where the data seem to fit so perfectly the theoretical predictions.
CHAPTER II
PORTUGAL, INDIA AND THE INDIA ROUTE

Historical background

Portugal is a small and beautiful country that stretches along the western coast of the Iberian Peninsula, gently sloping towards the sea. Its territory is a long rectangle that borders Spain to the north and east, and meets the sea to the south and west. The frontier with Spain was fixed in the 13th century; mainly running along natural barriers such as rivers and mountains, it encompasses an area of about 92,000 Km². The coastline is over 800 km long, and offers a number of good natural harbors, river estuaries and inner bays. It was natural that the Portuguese economy developed strong connections with the sea from the earliest times of the country's creation in the late Medieval era (FIG. II.1).

![Diagram of the Iberian Peninsula](image.png)

FIG. II.1 - Iberian Peninsula c. 1300. Drawing: Filipe Castro.
Part of the Iberian cultural and demographic universe, the Portuguese nation began as a feudal county given in the 11th century by Alfonso VI of Leon to a certain Henry, the fourth son of Henry of Burgundy, as a reward for his deeds in the wars against the Muslims or Moors known as the Spanish Reconquista. Henry married a daughter of Alfonso VI and was made lord of the region of Coimbra in 1095, and of Braga in 1096. When Henry's father-in-law died in 1109, he declared himself Count of Portugal. His son Afonso Henriques (1108-1185) became the first king of Portugal in 1143, after Alfonso VII of Leon recognized the independence of this small kingdom. This recognition was not acknowledged by the Holy See until 1179.

In spite of the ongoing Reconquista, Spain always kept commercial and cultural relationships with the Muslim world and the north of Africa. Africa yielded gold, and its waters were rich in fish, both in short supply in Europe, the former arriving regularly in caravans from the sub-Saharan regions where it was mined. The pace of the Reconquista was dictated more by demographics than by military power as it was more difficult to populate than to conquer, and vast regions between the Christian and the Muslim worlds of the Iberian Peninsula were treated as a no man's land. Because they could not be farmed due to the danger of raids from either side, these lands hosted large flocks of sheep that fueled a growing wool industry. By the late 13th century the peninsula had important commercial ties with several Mediterranean ports, and merchants from Genoa, Majorca, and Andalusia raided the Canary Islands regularly to harvest its people, known as Guanches, to sell as slaves in Spain. Meanwhile, Catalan and Aragonese merchants were trading on the south coast of the Mediterranean and in the Levant; and Catalan vessels sailed along the Atlantic coast of Morocco, presumably as far south as the coast of today's Senegal.

During the 12th and 13th centuries Portugal expanded towards the south, the only direction available for the small country squeezed between the kingdom of Leon and Castile and the sea. In 1249 the conquest of the last fortified Moorish cities on the south Atlantic coast of the peninsula, the Algarve, marked the end of the Portuguese Reconquista. On the Spanish side, the efforts to expel the Arabs from the peninsula
went on until the fall of Granada, in 1492, thus keeping the spirit of the Crusades alive. Also preserved was the medieval practice of preying on enemy land and the barbaric noble class that this feudalism generated. For cultural and demographic reasons, the Iberian Peninsula would not see the development of an urban middle class of merchants and craftsmen as early as the highly populated areas of northern Italy, eastern France, western Germany, and the Netherlands.

In the late 13th century a few rich Italian cities opened commercial trade with the north Atlantic centers of England and Flanders. Seville and Lisbon were located at strategic points on their route and soon became important maritime centers. Dutch vessels came regularly to the old port of Setúbal, immediately to the south of Lisbon, to load salt for their fishing industries. In Spain the wool from the large flocks of sheep that grazed on the high planes of Leon and Castille was sold in Seville for the Dutch textile industry, which was developing as rapidly as the European population was growing.

During the 14th century the Iberian peninsula also underwent a population growth, albeit more slowly than the rest of Europe. In spite of a short period of cold weather in the early 1300s, and the spread of the black death in 1347, the population of Leon and Castille grew from three to six million during the 14th century, and the population of Aragon rose from 500,000 to one million in the same period. Around 1400 Portugal also may have had about one million people.

**The Portuguese expansion overseas**

The conquest of the north African city of Ceuta by King John I (1385-1433) in 1415 is the generally accepted date for the beginning of the Portuguese expansion overseas which eventually led to the establishment of the India Route. During the 15th century the Portuguese mariners and merchants sailed south down the western coast of Africa, engaging in trade with the local populations, frequently backed by bankers and merchants from Genoa and other Italian cities. In exchange for wheat, cloth, and manufactured goods, the Portuguese bought red peppers, gold, and slaves. The Atlantic
islands were explored and colonized, during the 1420s and 30s the Islands of Madeira and Porto Santo, followed in the 1440s by the Azorean archipelago, and in the 1460s the Cape Verde Islands. The Canary Islands were lost to Spain in 1436, after a series of conquest attempts by the Portuguese crown. From the 1450s on, the production of sugar in Madeira added large profits to the growing African trade. In 1482 Portugal established a trading factory and outpost at São Jorge da Mina, in the Gulf of Guinea, to support the rich trade of gold and slaves. Finally in 1487, a small Portuguese fleet under the command of Bartolomeu Dias reached the southern tip of Africa. A decade later, in 1498, Vasco da Gama arrived at Calicut, in the Indian peninsula, opening a fast and comparatively cheap maritime route to the Far-East to carry a trade in spices, silks, fine cottons, and drugs, a designation that encompassed a large number of products, from dye woods to chewing pawn leaves, a delicacy much appreciated in the Arabian Peninsula, or from medicinal roots to perfumes.

By 1500 Lisbon was a rich and rather cosmopolitan city with a small population of around fifty thousand. It was praised for its newly built "Rua Nova dos Mercadores," literally "new street of the merchants," which offered all sorts of exotic products to other Europeans from its exquisite shops, and for its rich royal palace – the famous Paço da Ribeira – with its beautiful Renaissance portico leading to the river, from which the commercial activity of the harbor could be enjoyed. Sophisticated and expensive, the court of King Manuel I (1495-1521) organized lavish events for its local and foreign visitors, such as parades of his elephants and wild beasts, or the celebrated fight between an elephant and a rhinoceros that was staged to amuse the queen in one of the palace’s yards in 1515.\textsuperscript{11,2}

**Golden age**

The India Route, as the round voyage from Lisbon to Goa and Cochin is known, developed quickly during the first half of the 16\textsuperscript{th} century and soon the Portuguese held a large share of the Far-East trade with Europe. This lasted until the 1560s, when the Venetian Republic managed to reclaim a fair share of this trade through the re-
establishment of the Red Sea and the Levant routes through Mecca, Alexandria, and the Syrian ports, which had been the traditional European supply routes of oriental products.

A small nation of around 1.2 million people, Portugal built an extensive sphere of interests, possessing fortresses, factories, and cities throughout four continents. By the late 16th century, the Portuguese were established in Macao, and their ships were sailing to Japan. Portuguese men were found throughout Asia and married local women, living in the Moluccas, Timor, Bengal and Pegu. Other Portuguese adventurers served under the Great Mogul (the Mogul Empire then extended from the Indian Peninsula to Persia). Sugar factories populated the Brazilian coast, and parties of explorers called *bandeiras* explored the South American jungle as far as Potosí and up the Amazon River. In Africa the envoys of the king of Portugal visited Mali and Gao, the capitals of gold; other *bandeiras* walked along the Zambezi River, reaching Great Zimbabwe and exploring the interior of the African continent from the Angolan coast to the east in search of a mythic Silver Mountain. There were Portuguese convents in Basra and in Persia, and Portuguese men accompanied the Venetian and Armenian merchants in the caravans that went from Basra to Tripoli and Aleppo. Portuguese merchants and sailors traveled aboard the Spanish ships that carried silk and porcelain on the long and dangerous trips from Manila to Acapulco, and silver ingots and coins return from Acapulco to Manila. Every year Portuguese ships dropped their fishing nets on the codfish banks of Newfoundland, in the New World, and visited the Biscayne and French fishing stations there. Portuguese merchants carried sugar to Venice and fish to Chios and Constantinople. Finally, Portuguese ships transported African slaves from Guinea and Angola to Brazil and, profiting from the unification of the crowns of Portugal and Spain, also to the Antilles and other Spanish ports in the New World, returning home with gold and silver.11,3

In the Far-East, Portugal managed to become a useful intermediary in the commerce between China and Japan, forbidden long before the arrival of the Portuguese, as a consequence of the heavy losses inflicted by Japanese pirates on the Chinese fleets. Established in Macao since the 1550s and in Nagasaki since 1571 – the year of the
foundation of the Spanish city of Manila, in the Philippines – Portuguese merchants were participating actively in the newly established trade route between Asia, the New World, and Europe.\textsuperscript{1,4}

Portuguese interests were extensive and varied, both in the Asia trade and in the India Route. The private trade of the India Route brought an average annual profit of five million cruzados around the end of the 16\textsuperscript{th} century, roughly 90 percent of the total traffic. The king’s share may have been slightly less than half a million cruzados. To give a comparative idea, the Venetian Levantine trade amounted to three million cruzados at its peak in 1600. This volume of business was only surpassed by Spain’s New World silver fleets, whose total value ranged annually between seven and ten million cruzados, the equivalent of six to nine million ducats.\textsuperscript{1,5}

Nevertheless, however hectic and rich this trade may have been, the public expenditure necessary to maintain these routes and protect these merchants probably were much larger than the returns. It appears that the India Route was a ruinous business to the crown from its very first days. It certainly brought more cash into the Portuguese treasury, more ideas into Portuguese minds, and more vessels into Portuguese harbors; but the profits were largely absorbed by a powerful and well connected merchant class which included the mighty German and Italian Fugger, Welser, and Affaitati families, as well as a large number of Portuguese families of merchants. These families operated globally and had transferred their spice-procuring operations from Venice to Lisbon as soon as the news of the new maritime route to the east reached Italy. Attracted by the good business opportunities offered in Lisbon by the Portuguese crown these merchants and bankers immediately started to reap a substantial share of the profits, both through high interest loans granted to the Portuguese treasury, and by control of the distribution of spices in northern European ports.\textsuperscript{1,6}

The king’s expenses included the building, maintenance, and operation of an ever-growing number of fortresses and factories on the west and east coasts of Africa, the Persian Gulf, the Indian Peninsula, Malacca, the Moluccas Islands, China, and Japan. Numbering over 50 in the 1570s, these strongholds certainly consumed more capital than
they yielded. To these costs, the crown had to add the building, maintenance, and
operation of several fleets which had to be kept at sea to maintain, or try to maintain, the
trade monopoly of the Portuguese crown. Furthermore the king had only a tenuous
control over part of this activity, which was divided into two almost independent worlds:
the India Route, and the Asia trade, or Estado da Índia as the latter was designated. The
first encompassed the trading relations between Asia and Europe, and the second the
intense European trade in Asia, too far away to be controlled from Lisbon.

The India Route traffic was always seen as a royal monopoly, both in the India
Route and the Asian trade. In the first decades after the establishment of the India Route
the king owned all vessels engaged in the voyage, or occasionally chartered them from
private contractors. All cargos of spices, pearls, and elephants loaded in Asia were
purchased with money borrowed from private investors, and they belonged to the king.
Once in Europe these products were sold through the Portuguese factory at Antwerp, and
the loans re-paid with the proceeds. Sometimes the king would sell the merchandise to
private investors at predetermined prices, and later, in the reign of King Sebastian (1568-
1578), the whole trade monopoly was leased to private investors. In the Estado da Índia
it was difficult to control all the private dealing, from Ormuz to China, Japan, and the
Philippines. The vice-kings limited their role to issuing permits and charging custom
fees.

In the Portuguese kingdom the unsophisticated financial organization could not
guarantee effective expenditure. Profits made by the Portuguese crown were
immediately spent on a sumptuous lifestyle and dissipated in fruitless ventures. During
King Manuel's time (1495-1521), money was spent in futile campaigns in the north of
Africa, and afterwards, during King John III's reign (1521-1557), on lavish dowries for
the marriages of his sister Isabel to emperor Charles V (1519-1556) in 1526, and of his
daughter Maria to King Philip II of Spain (1556-1598) in 1543. Royal expenditures
were huge. Distribution of Eastern goods was controlled by the Casa da Índia, an
immense bureaucratic organization where all merchandise was received, appraised,
stored, and sold under the control of a large army of public workers. The Casa also
supervised the loading and unloading of the ships, paid the crews, and inspected all vessels in a futile attempt to prevent, or at least reduce, the inevitable contraband, although it was never given the effective political authority to repress this activity.\textsuperscript{11.7}

In addition to the Casa da Índia, the crown maintained and managed a large shipyard in Lisbon. This shipyard – the Ribeira das Naus, or Ribeira de Lisboa – included the naval yards as well as a series of warehouses, a foundry, and a powder factory.\textsuperscript{11.8} The king's vessels were built, rigged, and equipped in the shipyards, by a large number of employees organized according to their different tasks, and supervised by a team of officials and masters of each of the trades involved. In the warehouses were stored and maintained in good order all the necessary fittings for the ships, such as cables, sails, masts, and spars. Guns were stored in the foundry, situated on the east side of the royal palace. The Ribeira das Naus was one of the largest institutions of commerce in 16\textsuperscript{th} century Europe, employing at one time fifteen hundred men.\textsuperscript{11.9} Similar yards were built in Asia: Goa, Cochin, Bassein and Daman, the Goa shipyard being as large as the one in Lisbon.

In the 16\textsuperscript{th} century the India Route opened in a climate of general optimism and euphoria; the busy traffic provided a varied array of precious and exotic products in great demand throughout a developing Europe. Each vessel arriving from the Far East brought new curiosities from overseas that enlarged the private collections of oddities and exotica that were so fashionable among the wealthy. As for the cargoes, they typically sold for high prices, provoking a circulation of capital never before seen in the kingdom.

\textbf{Commerce}

To keep account of the goods, the cargo was divided for custom duties into four major categories: \textit{drogas}, \textit{fazendas}, \textit{miudezas}, and \textit{pedraria}. Under the designation of \textit{drogas} (drugs) were listed all the spices – pepper, cinnamon, ginger, cloves, nutmeg, and mace – along with indigo, lacquers, resins, borax, camphor, china wood, sandalwood, incense, ebony, and ivory. The item \textit{fazenda} (cloth) included bales of cotton cloth, silk,
and thread, as well as slaves. Miudezas (odds and ends) was a vast designation that comprised most miscellaneous products, from chests and writing desks to musk oil. Finally pedaria (gems) referred to all semi-precious and precious stones, such as diamonds, pearls, and rubies.\textsuperscript{11,10}

We know a great deal about the spices and drugs produced and traded in India in the 16\textsuperscript{th} century. Western inquisitiveness produced several excellent descriptions of the trade very soon after the arrival of the Portuguese. Naturalists like Duarte Barbosa and Tomé Pires in 1515, and Garcia de Orta in 1564, wrote impressive treatises on the exotic products found in the East and their many uses and qualities.\textsuperscript{11,11} Slightly later Francisco da Costa, a humble scribe of the Portuguese factory in Cochin between 1582 and 1612, started a book that was completed by his brother Luis da Costa after his death, and that still stands as a valuable contribution to the understanding of the structure of the Portuguese pepper trade.\textsuperscript{11,12}

Peppercorn (the fruit of the \textit{Piper nigrum} Lineus, in Portuguese \textit{pimenta}) was undoubtedly the most important trade good in the East when the Portuguese arrived. Marco Polo estimated that only one percent of the total production was traded in Alexandria, the traditional last outpost of the long trade route overland from whence almost all merchandise was distributed into Europe.\textsuperscript{11,13} China probably absorbed the most important share of the whole production, buying in Sumatra (\textit{Sumatra}), Burma (\textit{Pegu} and \textit{Bremá}), Indonesia (\textit{Sunda} and \textit{Java}), Thailand (\textit{Sião}), Malaysia (\textit{Malaca}) and the Malabar Coast.\textsuperscript{11,14} Although it was used to season food, its primary use was to conserve food, and its economic importance was extraordinary. Peppercorn could be prepared through two different processes, either drying the whole fruit before full maturation and obtaining black pepper, or drying only the mature core of the fruit, and obtaining white pepper.\textsuperscript{11,15} For the voyage to Portugal peppercorn was stored in wooden boxes built in the hold of the ships, which were carefully closed and caulked.\textsuperscript{11,16} This practice is corroborated by a letter written by D. Luis de Bravo de Acuña to the king of Spain and Portugal in September 1606, after the wreck of the nau \textit{Nossa Senhora dos Mártires}, in which he states that not a grain was saved from soaking after the wreck,
since the peppercorn was stored in specially built boxes in the hold.\textsuperscript{11,17}

Other spices were also traded in the East. Ginger (the root of the \textit{Zinziber officinale} Roscoe (\textit{Amomum zingiber} Lineus)), \textit{gengibre} in Portuguese, was cheaper than pepper but not as largely traded. Much appreciated as a seasoning for salad, it could also be used in fish, minced meat, and in preserve with sugar. The most prized ginger was produced on the Malabar Coast, but its production extended along the western base of the mountain chain that runs along the west coast of the Indian peninsula. To prevent the attack of worms and insects, it was sometimes sealed in red clay before storage. Because of this, it was called red ginger, different from the fresh white ginger, and cheaper. To make sweet conserves it was abundantly pierced, so that the water and sugar would penetrate more quickly. Garcia de Orta warned the consumers that this pierced ginger should not be mistaken for rotten ginger, with holes from insect attacks.\textsuperscript{11,18}

Cinnamon, as well as clove and mace, were expensive spices, traded in small quantities with large profit margins. These three spices had similar prices in the Cairo markets. Cinnamon (the bark of the \textit{Cinnamomum cassia} Blume, \textit{canela} in Portuguese) was a much appreciated condiment that, although not mentioned by Marco Polo, was referred to by Ibn Batutah in the 14\textsuperscript{th} century, and Pero da Covilhã noticed it in the 15\textsuperscript{th} century, during his mission to India on behalf of King John II.\textsuperscript{11,19} It was not cultivated, but gathered in the wild, and although it was traded on the west coast of the Indian peninsula, it was produced abroad, the best and most abundant coming from in Sri-Lanka (\textit{Ceilão}). A smaller variety of the plant grew on the Malabar coast and produced a bark of lesser quality (\textit{Cinnamomum iners} Reinw). A highly odoriferous oil was extracted from the fruit of this tree and used as an unguent, or a “very gentle mixture for the stomach, and to alleviate the colic” and to “remove the bad smell of the mouth.”\textsuperscript{11,20}

Mace is the outer part of the nutmeg fruit (\textit{Myristica fragans} Houttuyn, \textit{maça} and \textit{nós moscada} in Portuguese) and was produced in the Banda Islands (\textit{Bandam} or \textit{Banda}), in today’s Indonesia. It was sold preserved in vinegar or in sugar as a much appreciated delicacy, good for the brain and certain nervous diseases. Its oil was prescribed for
sexual impotence. Each volume of mace was sold together with seven volumes of the nuts – nutmeg – whose price was one seventh of the price of mace in the Banda Islands, but only one third in Lisbon and one half of the cost of mace in Cairo.\textsuperscript{11,21}

Clove was produced on five little islands in the Moluccas (\textit{Ilhas de Maluco} or \textit{Malucas}), of which Ternate, Tidore, and Makian were the most important. Also a fruit from a small wild tree (\textit{Eugenia caryophyllata} Thunberg, \textit{Caryophyllus aromaticus} Lineus), \textit{cravo} in Portuguese, it was dried in the sun after being lightly moistened with sea water. It was then sold as a rare and expensive condiment.

Under the designation of \textit{drogas} some thirty other products, mineral, vegetable and animal, were traded as perfumes, unguents, dyes, medicines, and drugs. These included the chewable leaves of pawn (\textit{bétele} in Portuguese), opium, sperm whale ambergris, camphor from Borneo, musk (\textit{almiscar} in Portuguese) from the Tibetan goats, rhubarb (\textit{Rheum officinale} Baillon, \textit{rubardo} in Portuguese) – a root imported from Tibet that was indicated to treat liver malfunctions - and \textit{pau da China}, a root from a climbing plant (\textit{Smilax china} Lineus) utilized both as a powerful aphrodisiac and, probably afterwards, as a treatment for venereal diseases.\textsuperscript{11,22}

Besides these spices, many other products were traded in the east, such as precious and exotic woods like the Timor sandal, as well as silk, cotton, Chinese porcelains and first quality glazed earthenware, Burman brown stoneware (from the \textit{Martaban} kingdom), pearls, precious stones, jewels, and exotic animals. Under the designation of \textit{fazenda} were traded silks from Persia, China and India, cottons and silks with special prints, and bales of cotton cloth from the Indian peninsula. This profitable commerce was always an important one, and in the period from 1600 to 1610 it accounted for 60 to 70 percent of the total of the declared private trade. The cotton cloth trade sustained a well-known traffic: cotton was traded for slaves in Northern Africa, the slaves then traded for sugar in Brasil, and the sugar traded for wheat, copper, iron, and silver in Northern Europe. Cotton cloth was also traded for gold and ivory in Northern Africa, or shipped to Turkey, where it was greatly valued. Although Portugal was a minor player in the overall trade in Asia, the demand for cotton cloth led to great
developments in textile manufacture in the Gujarat, Coromandel, and Bengal regions.\textsuperscript{11,23} Mitadezas was a vast category that comprised almost everything brought back from these exotic places. Asian furniture was treasured in the West. Chests made of precious woods, lacquered or inlaid with ivory, tortoise shell, or mother-of-pearl, were carried to Lisbon along with writing desks, screens, cabinets, chests of drawers, bed frames, and chairs. Curiosity made smaller objects highly desirable as well. Boxes, statuettes, fans, porcelain pieces, lapis lazuli, azurite, amber, gold, pearls, and jewelry were all top commodities for the Portuguese market.

Finally, pedraria included the presumably profitable traffic of diamonds from India and Borneo, as well as rubies and sapphires. This trade was always surrounded by a certain degree of secrecy and fully controlled by a small number of specialized dealers who held a near monopoly until the 1630s, diverting the flow of stones from Venice, the main lapidary center in the 16\textsuperscript{th} century, towards Antwerp. It is difficult to estimate its volume and economic importance since it was largely undeclared. However, we know that the diamonds salvaged from the wreck of Nossa Senhora da Luz, which ran aground in the Azores in 1615, were valued at over 1 million cruzados.\textsuperscript{11,24}

We will never know how profitable these voyages were in absolute value because the merchant lobby kept an important share of the merchandise out of sight of royal bookkeepers. Therefore, today we cannot truly know some of the motivations that led these people across three oceans on such expensive and dangerous voyages, which cost so many lives and trouble, so much grief and sorrow, disease and death.

Nevertheless, considering only the profits declared by the merchants there is no doubt that the most important source of revenues in Portugal during the whole 16\textsuperscript{th} century and the first decades of the 17\textsuperscript{th} century was the commerce with India. This in spite of the fact that during the first half of the 16\textsuperscript{th} century African gold and slaves were still arriving in Portugal in notable quantities, mainly from the Portuguese factory of São Jorge da Mina on the Gulf of Guinea but also on a smaller scale from the eastern coast of Africa. This slave trading included supplying African slaves to the Spanish New World, a highly profitable business that complemented the already profitable sugar production.
from the colonies of Madeira and Brazil.  

The voyage to India

Less than a decade after Vasco da Gama opened the maritime route to India in 1498, the Portuguese were the dominant power in the Indian Ocean, building fortresses, fighting those who threatened their interests, making alliances with the cooperative local powers and, perhaps most importantly, establishing the East India trade. Every year a fleet sailed from Lisbon to India, departing in March and returning sixteen to eighteen months later loaded with vast quantities of spices, drugs and other trade goods, among which pepper was by far the most important for the crown. The large private trade and the large volume of contraband that undoubtedly certainly came with it generated enormous revenues for the king's administration in duties, bribes – generally described as 'voluntary' donations – and taxes.

As mentioned above, this trade route was known as the India Route, or Carreira da India. It invariably started in Lisbon. The first leg of the outward voyage consisted of a long, straight line passing south-southwest through the Canary Islands and the Cape Verde archipelago, taking advantage of the prevailing Northeast Trade Winds. Crossing the calm and windless equatorial zone of the Atlantic to the proximity of the Brazilian coast, the route then continued to approximately 4º South, the latitude of Fernando de Noronha Island. There the vessels started a long arc, encircling the southernmost tip of Africa, the Cabo da Boa Esperança, near 38º South latitude. The ships left Lisbon in March or April and tried to round the cape in July, in the middle of the southern winter. Once the cape was rounded, the fleet’s pilots and captains had to decide whether they would sail east of the island of São Lourenço – today’s Madagascar – directly to Cochin following the "outside" route, or take the "inside" route to Mozambique, through the Mozambique Channel, and pray not to encounter the Bassas da India atoll during the night. Everybody with a word to say inside the ship hated the idea of spending the winter in Mozambique, both to avoid the extra costs incurred in food, housing and business delays, and to avoid the ‘corrupt airs’ of the African coast. However, for the
miserable passengers and sailors this stop often meant a chance of survival from disease – most frequently scurvy – and starvation that plagued the India Route for at least the first two centuries. If all went well and the Cape of Hope was rounded before the 25th of July, the ships took the "inside" route directly to India, sailing past Mozambique to the Comoro Islands, from there to the Queimados Islets, and then to Goa or Cochin, where they would arrive from the second half of August to the first half of September (FIG. II.2). If the cape was rounded too late, the "outside" route was advisable in order to avoid the monsoon, the prevalent NE wind that blew in the Northern Indian Ocean from October to April. The ships continued by following a northeast course to the islands of João Lisboa, Pedro Mascarenhas or Diogo Rodrigues, and from there across the 16th parallel to the Queimados Islets and Goa. The duration of these voyages was usually around six months.

Once they arrived in India, the ships were either repaired and sent on missions in several parts of Asia, or simply loaded in Cochin and sent back to Lisbon. Loading was a careful process, generally performed under the supervision of the king’s officers and the ship's master. The Dutch traveler Linschoten left us a detailed description of the loading process, as he saw it in December 1588. By then the king was leasing the pepper trade to merchants for periods of five years, and both the merchants' representatives and the king’s officials supervised the loading operations. The pepper was stored in the two lower decks, in small holds built over a wooden platform which rested immediately above the ballast. These holds occupied almost the entire area of the two lower decks with the exception of the clearance area underneath the main hatch. After being filled, closed, and their lids caulked, the holds were all numbered and the quantities loaded in each one carefully noted.

The clearance space underneath and around the main hatch was then used to store water, wine, timber, and small items necessary for maintaining the ship during the voyage. Then, all the other merchandise was brought aboard, carefully registered, and stored in areas specially assigned either to the king’s commerce or to private trade (FIG. II.3).
FIG 11.3: The distribution of the cargo in an India Route nau after Figueiredo Ferreira.
Since the king's pepper took up most of the space in the holds, many boxes, barrels, bales, and everything else was stored in every possible corner – in the holds, on the weather deck, and sometimes even hanging outside the hull supported by ropes. Manuel de Mesquita Perestrelo, a survivor of the 1554 wreck of the nau S. Bento on the coast of South Africa described, "(...) the lower decks were solid. On the main deck were about seventy-two boxes and so many bales and boxes stacked that they equaled the height of the castles." 11.27

After about three months in one of the Indian ports it was time for the homebound fleet to sail back to Portugal. The return trip, or torna-viagem as it was then called in Portugal, was generally much more dangerous. Ships were frequently overloaded with cargo, and rounding the Cape of Good Hope claimed many ships. Despite the additional dangers, overloading was inevitable since towards the end of the 16th century the crown frequently defaulted on the payment of salaries. To ensure that a minimum crew of able seamen would risk the trip, a large private trade was tolerated; otherwise it would have been too difficult to recruit skilled sailors to man the ships. It is important to note that the Spanish Flotas to the New World were much safer for mariners, and many Portuguese sailed Spanish ships for Central and South America every year. 11.28

The shortage of sailors was an endemic problem from the beginning. A small country, Portugal had to recruit sailors from all available sources, and resorted to the extensive use of slaves as sailors. The lack of skilled seamen was proverbial and it is said that in 1505 Captain João Homem had to nail a garlic braid on one side of the main yard, and one onion braid on the other, for soon after departure it became clear that no one knew the concepts of port and starboard side:

(...) And the weather improving the governor sailed from Belem on March, twenty-fifth of fifteen hundred and five, and the king went by sea to see his departure, watching the fleet unfurl after raising anchor in the midst of great shouting and artillery fire, from both the ships and the tower. And sailing this
fleed down river, ordering the pilots to the helmsmen so that they sailed to port, and to starboard, as they used when they are sailing in a river, the sailors were confused, because they did not know yet that vocabulary, specially the ones aboard the caravel of Joao Home, and when they had to maneuver to port which is the right hand, they sailed to starboard, which is the left hand; Joao Home seeing this ordered the pilot to speak to the sailors with words that they understood; and when he wanted them to sail to starboard to say garlic, and when to port to say onions, and to each side of the ship he had a bundle of onions and a bundle of garlic tied, and as the pilot said those words, the sailors were not confused anymore and they sailed straight and true.\textsuperscript{11,29}

Certainly an anecdote, this story is even more delightful since the chronicler Castanheda also confuses his left and right hand, and starboard and portside.

Ships left Goa or Cochin in December, sometimes in January, and either made it to Mozambique, where they were supposed to arrive approximately one month later, or to the Cape, following the "new" or "outside" route, which was used from 1527 onwards. If they took the "old" or "inside" route to Mozambique, they would take on fresh supplies of water. Without these supplies, the trip could be dangerous if they missed the island of Saint Helena in the South Atlantic after rounding the Cape of Good Hope. If they sailed according to the rules, they were to leave Mozambique in January and round the Cape before the end of February with good weather, before the southern autumn. If they took the "new" or "outside," as most vessels that sailed from Cochin did, they were to sail down the coast of the Indian Peninsula to Cape Comorin, and from there to the Maldives. Then they followed a southwest route with the southeast trade winds to the Island of Diogo Rodrigues, the shoals of the Garajaus, and the Cape of Good Hope. Even on the "outside" route, it was as important to try to pass the Cape before the peak of the winter as on the "inside" route, and a departure after Christmas day could mean disaster.

However, economic difficulties could delay the acquisition of pepper and other
goods, and departures as late as February were frequent. During the 17th century the presence of the Dutch and the English made it preferable to leave in the last days before the monsoon, or even in the first days of the contrary monsoon, in order to avoid encounters at sea. This is certainly one of the main reasons for the substantial increase of losses after 1590. In the period from 1590 to 1640, the number of voyages interrupted by a winter sojourn in Mozambique rose considerably, and so did the number of wrecks.

After rounding the Cape of Good Hope, the ships turned north to find the island of St. Helena or, from the beginning of the 17th century onwards, tried to avoid it because of the possible presence of Dutch and English enemies. In either case they would sail northwest, with the Southeast Trade Winds astern, in the direction of the Island of Fernando de Noronha near the coast of Brazil. From there the ships would sail north and try to catch the Northeast Trade Winds by starboard, and then head east, as soon as the prevailing Westerlies allowed, to the Azores and Lisbon.

The decline

In the late 16th century, the voyages back to Portugal became increasingly more hazardous. A growing lack of organization, corruption, and nepotism were already apparent in the India Route during the reign of King Sebastian (1568-1578). The Counter-Reformation and the influence of the clergy over this young king created conditions for the reinforcement of power of the nobility over the more dynamic middle class of merchants. King Sebastian made some wise political decisions, such as terminating the crown’s monopoly over the commerce with India, the extension of the occupation of Brazil, and the mandatory use of plans for the building of all ships above 100 tons. However, he left too much power in the hands of a frequently ignorant and greedy upper class, whose aspirations were actually in Spain, to where a stream of silver was flowing from America. In 1578 King Sebastian was killed together with a large number of nobles in the fields of Ksar-el-Kibir in the north of Africa, during another futile attempt to extend Christianity and Portuguese interests into the African continent. Soon afterwards a succession of political crises delivered the Portuguese crown into the
hands of King Philip II, the powerful Habsburg monarch who already held an extensive empire in Europe and overseas. Claiming the Portuguese crown by inheritance, bribes, and finally by conquest, Philip II of Spain became Philip I of Portugal (1580-1598), starting a period of decadence that eventually led to the loss of the Asian trade. Although he never really mixed the interests of his two crowns, Philip II dragged Portugal into the religious wars that plagued Europe during the late 16th century, and the trend would be continued by his successors in the 17th century.

The Portuguese network of interests could hardly withstand such an unstable environment without damage. The Portuguese were too few, spread over too great an area, and the economic structure of the country too weak. Predictably, the Portuguese dominion slowly collapsed in the early 17th century, mainly due to the pressure of Dutch merchants, but also due to English privateers and a resurgence of native trading along the old routes leading to the Mediterranean.

Long before Vasco da Gama arrived in India, intense commercial activity surrounded the trade of spices, drugs, cloth, and other exotic goods in Europe. Arab and Gujarati merchants had traded with the Mediterranean world for a long time, creating lasting relationships with Levantine, north African and European merchant ports. They shipped pepper and ginger from India, cloves, nutmeg and mace from the Moluccas, and a number of other precious and exotic products from different parts of Asia. These goods followed the ancient routes through the Red Sea and the Persian Gulf, and were sold either in Alexandria, Egypt, or in one of several Syrian ports in the Levant.

By the beginning of the 17th century, the Moguls, Muslims and well-informed enemies of the Portuguese, ruled in the eastern Indian Peninsula. The Indian Peninsula was divided between the Mogul empire in the north, under the rule of the powerful Emperor Akbar (1542-1605), and numerous weak states in the south that arose from the disintegration of the Vijayanagar empire and which were undergoing an unification effort by the Hindu principedom of Ikkeri.11,31

The Portuguese intentions upon arrival were not only to trade but also to prevent the other nations from trading, and the impact of their presence drastically changed the
situation, but for a relatively short period of time. A violent war was conducted against Muslim traders, and customs charges were laid upon the remaining local traders whenever and wherever possible. Allied native powers were given permits to trade, but even these were often ignored by a class of Portuguese noble traders that respected neither the king's officers nor his administrators. It is not difficult to imagine how the first Dutch to arrive in Asia met a large number of potential allies to fight the unpopular Portuguese presence.

As soon as Philip II died, the new king promptly ignored his scrupulously kept promises for Portugal's full independence. Philip III of Habsburg (Philip II of Portugal) was neither very intelligent, nor very energetic. He did not care to rule the two kingdoms separately and, soon after his rise, Portuguese and Spanish interests became closely intertwined. The Portuguese aristocracy was amenable, at least in the beginning, seeing a world of opportunities in the economics of the Spanish New World. Many were also Spanish allies in their aspirations to religious purity and their hatred for the powerful New-Christian merchant class.

The much envied and hated New-Christians were the descendents of the Jews who had been converted by force to the Catholic faith in 1496 by King Manuel I (1495-1521) as a condition for his marriage to Isabel, the daughter of the devoutly catholic King Ferdinand of Aragon and Isabel of Castille. In 1492 the already-large Jewish community in Portugal received some 60,000 Jewish refugees expelled from Spain. To save them from the church officials and the most zealous of courtiers, King Manuel I ordered the forced conversion of an estimated 200,000 Jews – almost 20 percent of the entire Portuguese population – to the Roman Catholic faith. Many left Portugal and immigrated to Northern Africa, Turkey, and Antwerp, establishing a network of contacts that shared a common faith, language (Ladino), and blood ties. This network lasted for many centuries and helped boost the Portuguese economy, eventually transforming Lisbon into a rich and cosmopolitan city. The New-Christians were largely tolerated until 1539 when Henry, brother of King John III (1521-1557), was appointed head of the Holy Inquisition. This organization had been established in Portugal since the late 14th
century, but it was the new Inquisitor who started the systematic persecutions that led to the first executions of Jews and New-Christians in 1540.

Despite the energetic efforts of the inquisitors the merchant class was too powerful and too rich to be entirely destroyed by religious zealots. The merchants were the ones who financed a large share of the crown’s expenses and eventually came to finance Spain’s war in the Netherlands in the late 16th century.

Although Philip III of Spain inherited a huge and well-organized empire, he did not enjoy the happy times of his father. From 1596 to 1602 a plague is estimated to have killed almost 700,000 people in Castille alone. A pronounced decrease in the rural population, combined with an exodus to the cities, produced a shortage in the production of grain, which then had to be imported. This was partly the result of an agricultural policy in which the production of grain had never been a priority. Spanish fields were largely occupied by wool-producing sheep, a less profitable commodity, but one that required much less effort from the old landed aristocracy. Unfortunately the textile industry was depressed in Europe in the 1590s. High interest on royal loans paralyzed the economy, and the flood of silver that usually poured from the New World was in short supply in the last years of the 16th century. To make matters worse, the traditionally profitable Basque shipbuilding market was also depressed.

To further damage the economy, in 1609 and 1610, Philip III resumed the ruinous religious policies of his ancestors and expelled almost 300,000 moriscos (as the converted Arabs were known in Spain), accusing them of conspiring against the kingdom with the North African Muslims. Jews and New-Christians were also persecuted with renewed violence, and their money was extorted with false promises of Papal pardon for their alleged Jewish practices.

This policy was disastrous for Portugal. The religious wars in the north directly damaged the Portuguese economy, as by this time Portugal depended heavily on the Dutch merchant fleet not only to sell its products, but also to fuel an old and important native salt trade. In exchange for these products, Dutch merchants brought grain, along with many materials employed in the shipbuilding industry: masts from Riga, canvas for
sails from France, lead from Flanders, iron nails from Biscay, pitch for caulking from the Basque country, and tar from Danzig.\textsuperscript{11,32}

All of these factors contributed to a steady decline in Portuguese presence and power overseas. One can only imagine how difficult it was to organize such a long and dangerous trip as the India Route in a political environment of decadence, economic depression, war at sea, and an immediate absence of authority, when the king of Portugal was in Madrid and spoke a different language. After the death of Philip II in 1598, the situation progressively declined, and Philip III's right arm, the Duke of Lerma, was certainly not loved and probably not respected in Portugal.

Although the situation of the New-Christians worsened with the Spanish-Portuguese unification, the Portuguese merchant class as a whole thrived. The 'old' Christians were closely connected to the New-Christian merchant community by four generations of inter-marriages and alliances, and took advantage of the void of power felt in Lisbon. These merchants used the incompetent, corrupt, and nepotistic administration of Philip III to engage in a highly profitable private commerce on a global scale, buying their freedom with a large annual participation in the funding of the war with the Netherlands. Contraband thrived, as did illicit trade with the New World, the North African cities, and Turkey.

In fact, in spite of the entry of the new and aggressive Dutch and English competitors in the Asia trade, in the first two decades of the 17th century the core of the business was still held by a powerful international merchant class established in Lisbon and well-connected with the remaining important trading centers of the world. From 1599 to 1610 Portuguese merchants invested more capital in the India Route than the Dutch and English merchants together.\textsuperscript{11,33}

However, the persistent inability of the Spanish king to defend Portuguese possessions overseas from its Dutch and English Protestant enemies led to a sharp erosion of the Portuguese empire. At the same time, Spain drained Portugal of a significant part of its merchants and sailors, engaging them in trade with the Spanish New World. This trade required smaller investments and was safer than the Far East
trade. With Lisbon closed to the Dutch merchants who had traditionally distributed Portuguese goods in northern Europe, and Portuguese vessels falling prey to English privateers and Dutch Sea Beggars (the fierce Protestant zealots who sailed the North Atlantic from the late 16th century on), the king's commerce in the Estado da Índia was threatened, at least from an official and institutional point of view. Its maintenance depended more and more on the will of an international class whose roots were by no means exclusively Portuguese, and that eventually moved to the north of Europe for good.

In 1622 a combined force of English and Persian troops took Ormuz, in the Persian Gulf. Two years later, in 1624, the Dutch drove the Portuguese from the coasts of Angola and Benguela, in West Africa. In 1628 they conquered the factory of São Jorge da Mina, and in the following year managed to provoke the Portuguese expulsion from Japan. By 1630 the Dutch had invaded the northeastern coast of Brazil, not to be expelled until 1654.

In 1640 revolution arose in Lisbon following the enactment of a Spanish tax on the nobility for the protection of Brazil. With England's help, Portugal regained its full independence that year, but this status was not recognized by Spain until 1667, when King Charles II of Spain acknowledged defeat and the loss of Portugal.

Portugal was by then economically exhausted, and had an archaic social and economic structure compared to that of England or the Netherlands. In 1640 there were 11 ships in Portugal, eight galleons of Portuguese construction – of which one was not fit for navigation – and three other ships, one galleon seized from the French and two hookers seized from the Dutch. However, the India Route was quickly re-established, and although the revenues from the Asia trade lost their importance when compared to the profits from Brazil and Africa, it survived until the last days of sail.

Dutch pressure

The Portuguese situation was nearly ruinous for Dutch merchants in the late 16th century. In reaction to the closing of Lisbon to their ships, the Dutch Republic sent
Cornelis Houtman with four ships to India in 1595. Guided by the notes of Jan Huygen van Linschoten, a Dutchman who had sailed to India in the service of a Portuguese clergyman, the Dutch expansion overseas had started. Before the end of the century, the Dutch were purchasing their spices in India, their salt in Cape Verde and Venezuela, starting a profitable trade in the New World, establishing contacts in Madagascar, and building forts in the Lower Amazon region. In the early 1600s the Dutch established posts in the Guiana; their huge merchant fleet consisted of around 1,200 Dutch ships in the Baltic Sea trade alone. To this trade of timber, grain, fish, beer, textiles, and salt, the bulk of the St. Lawrence fur trade was soon added, along with the slave trade to the New World.

In 1602 the Vereenigde Oostindische Compagnie (VOC) was formed to promote, sponsor, and regulate the Dutch republic's Asian trade. As there was no minimum amount required to take part in its ventures, this highly sophisticated business organization combined the efforts of large and small investors. The VOC developed rapidly by spreading the risks over many investors and lending well-developed financial tools to the Far-East trade. The policy of the small Asian trading companies prior to 1602 had been to avoid any conflict with the Portuguese vessels at sea; now, war with the Portuguese was expressly mentioned in the guiding the principles of the Company. Although in the early 17th century the Dutch Republic posed a serious threat to Portuguese power in Asia, this was not fully understood until 1605, when news of the blockade of Goa by the fleet of van der Hagen one year earlier reached Madrid. In India the Vice-King Aires de Saldanha immediately realized the vulnerability of the Estado da India to European attack.

The arrival of the Dutch in India forced the Portuguese to spend more money on the defense of their strongholds, and to change routes and practices. For instance Cochin, the main cargo port of the 16th century – where at least half of the pepper bought by the Portuguese in India was loaded every year – was superceded in the first decade of the 1600s by Goa because the former port could no longer assure the security of the loading ships. The move was made in spite of the fact that Malabar pepper bought in
Cochin was cheaper than pepper bought in Goa, and the cost of repairs to ships in Goa before their departure to Portugal was double the price in Cochin.\textsuperscript{11,38}

When a highly-desired peace treaty was finally signed between the English and the Spanish in London in 1604, the Portuguese could foresee a small decrease in the English privateers' pressure on their trade, especially during the last part of the voyage, between the Azores and Lisbon. At this time, however, the Dutch increased their activities in the Far-East, blockading Goa for 23 days in September and October of 1605.\textsuperscript{11,39} Leaving the Netherlands in December 1603, a powerful Dutch fleet of 13 vessels had sailed to Asia under the command of Steven van der Hagen. Its mission was to seize the Portuguese fleet of 1604 either off the coast of Mozambique or off the port of Goa. However, the 1604 Portuguese Armada did not arrive in Mozambique on time, nor did it appear in Goa that year. Of the five intended vessels, three were forced back into port due to bad weather, one was shipwrecked, and the fifth, carrying the new Vice-King Martim Afonso de Castro, arrived late into the Indian Ocean. Having to winter in Mozambique, waiting for the monsoon to sail to Goa, it finally arrived in 1605.\textsuperscript{11,40}

When the news of a Dutch war fleet in the Far East reached Madrid, a large fleet was confront to fight them. In March 1605 four galleons and six naus sailed from Lisbon to Goa.\textsuperscript{11,41} Of these ships, five were intended to reinforce the fleet defending the Portuguese positions. The other five were to load a large cargo of pepper and transport it to Portugal, a vital concern due to the failure of the fleet of 1604. One of the six naus of the 1605 fleet was the newly built \textit{Nossa Senhora dos Mártires}. It left under the command of Manuel Barreto Rolim, one of the three captains of the 1604 Armada who had not sailed due to the bad weather conditions.

Deploying an armada of ten vessels was a huge effort for Portugal in the early 17\textsuperscript{th} century. The last decade of Philip II's reign and the early years of Philip III's saw a constant drain of money and energy from Portugal for wars with England and the Netherlands. Disorganization, corruption, nepotism, and a general lack of resources had contributed additional dangers to an already risky venture, and, before long, the number of shipwrecks almost doubled.
The movements of the India Route

No complete study of the journey between Lisbon and India has yet been made. The available data are dispersed throughout several sources. Vitorino Magalhães Godinho, Leonor Freire Costa, and the collective work of Paulo Guinote, Eduardo Frutuoso, and Afonso Lopes provide, to my knowledge, the most complete and reliable studies.\textsuperscript{11,42} Of the large number of studies and articles, Luis de Albuquerque and Francisco Contente Domingues deserve special mention, both for the quality and the extent of their work.

As for the contemporary written sources, there are only a few lists of departures and arrivals – \textit{Relações de Armadas} – and these unfortunately do not match exactly. In 1755 the archives of the Casa da Índia were completely destroyed by the violent earthquake, followed by a series of tidal waves and a huge fire, that crushed Lisbon on the 1\textsuperscript{st} of November. Close to 30 of these \textit{Relações} survived the earthquake in private libraries, of which two are marvelously illustrated: the \textit{Livro de Lisuarte de Abreu}, which covers the period between 1497 and 1563, and the \textit{Memória das Armadas}, covering the period between 1497 and 1566. In the last two decades Comandante Encarnação Gomes has published eleven of these texts.\textsuperscript{11,43} It is not possible to assert with any certainty the exact compositions of the fleets of 1604 and 1605, but since there is not a single reference to the nau \textit{Nossa Senhora dos Mártires} before 1605, it can be presumed that she was a newly built vessel when she left for Cochin in March of 1605. This period is considered one of the darkest in the history of the India Route, and the number of losses at sea certainly suggests the existence of major problems in its organization. However, a closer look reveals that despite the disproportionate number of shipwrecks that plagued the \textit{Carreira} in the first decades of the 17\textsuperscript{th} century, the Asia trade brought more money to its private investors than any other period before and after in the long history of the India Route.

Many authors divide the history of the India Route into two main periods. The first period reflects better overall control by the crown and fewer losses at sea between 1498 and the late 16\textsuperscript{th} century, certainly before the 1588 Spanish Armada, which resulted
in the default of many payments to private contractors and generated both a cash shortage and a distrust of the crown officials. The second period lasted from the late 16th century until 1640 and was certainly less organized, crown officials controlled the fleets to a lesser extent, and the trade was threatened by many competitors. After 1598 King Philip III diverted a great share of the profits from the India Route to his war efforts in the Low Countries, and in spite of huge contributions from the merchants of Lisbon, the necessities of the Carreira da Índia were never satisfied.\textsuperscript{11,44} Furthermore, in 1603 the English brought their first shipment of pepper to London and the Dutch were already supplying the continental market.\textsuperscript{11,45} The losses to piracy increased dramatically during this period. Before 1580 only two vessels had been taken by privateers: the ship of Captain Job Queimado in 1509, and the nau \textit{Santa Catarina do Monte Sinai} in 1525. Then in 1587, Francis Drake seized the nau \textit{São Filipe} in the Azores, loaded with additional cargo from the nau \textit{S. Lourenço} left behind in Mozambique. The nau \textit{São Filipe} was the first of a small list of rich catches that included the mythical \textit{Madre de Deus} seized in 1592 and taken to London with its cargo. It is estimated that between 1586 and 1635 at least fifteen ships were lost due to Dutch, English, or Turkish attack. This number is roughly 20 percent of the Portuguese global losses and about 3 percent of the Portuguese total voyages.\textsuperscript{11,46} Unfortunately for the pirates and privateers, most of these captures were lost to the sea before any cargo could be salvaged.

The changes in routes and timing may have had a much more important effect on the performance of the Portuguese fleets and were eventually the cause of many more losses. Departures late in the season became almost the rule because this practice diminished the probability of an encounter with enemies, but greatly increased the chances of being caught in heavy storms.

India Route shipwrecks have been counted and estimated by several authors, according to different sources and criteria. A recent study places the number of shipwrecks at 219 for the period between 1498 and 1650.\textsuperscript{11,47} This number is substantially larger than those advanced previously by Magalhães Godinho, who estimated the losses between 154 and 159 from 1500 to 1635, Quirino da Fonseca, who
estimated the losses around 112 for the period 1550 and 1650, or James Duffy, who presented 130 losses for the same period. The Guinote study is close to the estimates of João Vidago, who placed the losses at 201 between 1497 and 1640.148

According to Guinote, Frutuoso and Lopes, when all the data is carefully considered, it appears that the loss of ships to the India Route was higher than has been acknowledged by previous authors. These authors place the losses at 20 percent of the overall trips, a number much higher than Luis de Albuquerque's 10 percent, or Magalhães Godinho's 10 percent on the voyages to India and 15 percent on the returns from India.149

Shipwrecks

Only a few India Route shipwreck sites have been found, and almost all were heavily looted before archaeologists arrived. Moreover, there are almost no written references to any hull remains, with the exception of a small portion of the hull of a late 16th century wreck believed to be the Santo Antonio, wrecked in 1589 on the Boudeuse Cay, one of the Amirante Isles in the Seychelles archipelago.150 However, several collections of artifacts from these wrecks have surfaced in the past, and a few have been partially donated or sold to museums, or analyzed by archaeologists and partially published. I have compiled references to 14 India Route wrecks, dating from the period 1498-1650 (Table II.1). Of these, the sites of the S. João (1552), S. Bento (1554), Santiago (1585), Santo Antão (1589), Nossa Senhora dos Mártires (1606), Nossa Senhora da Luz (1615), S. Gonçalo (1630), Santa Catarina de Ribamar (1636), Santíssimo Sacramento and Nossa Senhora da Atalaia do Pinheiro (1647), have been tentatively identified with different but fair degrees of certainty. The remaining shipwrecks have been suggested to be those of Santo Alberto (1593), Santo Espíritu (1608), S. João Baptista (1622), and Santa Maria Madre de Deus (1643).

With a registered weight of 900 tons, the 'great galleon' S. João was one of the largest India Route naus built in its time. The account of her loss is included in the 18th century anthology História Trágico-Marítima of Bernardo Gomes de Brito and stands as
one of the most popular stories of the period of Portuguese expansion overseas. She was
built in 1550 in Lisbon's shipyards and sunk in 1552 on her way back to Portugal before
concluding her first voyage to India.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Date</th>
<th>Place</th>
<th>Hull remains</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. João</td>
<td>1552</td>
<td>Natal Coast, South Africa</td>
<td>No</td>
</tr>
<tr>
<td>S. Bento</td>
<td>1554</td>
<td>Natal Coast, South Africa</td>
<td>No</td>
</tr>
<tr>
<td>Santiago</td>
<td>1585</td>
<td>Indian Ocean - Bassas da India atol - France</td>
<td>Not known</td>
</tr>
<tr>
<td>Seychelles wreck / Sª António</td>
<td>1589</td>
<td>Seychelles</td>
<td>Yes</td>
</tr>
<tr>
<td>Sto. Alberto</td>
<td>1593</td>
<td>Sunrise-on-Sea, South Africa</td>
<td>Not known</td>
</tr>
<tr>
<td>Nossa Senhora dos Mártires</td>
<td>1606</td>
<td>Tagus mouth – Portugal</td>
<td>Yes</td>
</tr>
<tr>
<td>Santo Espíritu</td>
<td>1608</td>
<td></td>
<td>Not known</td>
</tr>
<tr>
<td>Nossa Senhora da Luz</td>
<td>1615</td>
<td>Isle - Azores – Portugal</td>
<td>Not found</td>
</tr>
<tr>
<td>S. João Baptista</td>
<td>1622</td>
<td></td>
<td>Not known</td>
</tr>
<tr>
<td>S. Gonçalo</td>
<td>1630</td>
<td></td>
<td>Not found</td>
</tr>
<tr>
<td>Sta. Catarina de Ribamar</td>
<td>1636</td>
<td>Cape Roca – Portugal</td>
<td>Not known</td>
</tr>
<tr>
<td>Santa Maria Madre de Deus</td>
<td>1643</td>
<td></td>
<td>Not known</td>
</tr>
<tr>
<td>Santíssimo Sacramento</td>
<td>1647</td>
<td></td>
<td>Not found</td>
</tr>
<tr>
<td>N.ª S.ª da Atalaia do Pinheiro</td>
<td>1647</td>
<td></td>
<td>Not found</td>
</tr>
</tbody>
</table>

She left Cochin on 3 February 1552 under the command of Manuel de Sousa
Sepúlveda with a load of 12,000 quintais of pepper, a great quantity of Chinese
porcelain, and other merchandise. A heavy storm damaged her rigging and hurled her
against the coast, breaking her hull into three parts against the rocky bottom near today's
Port Edward in South Africa. In the wreck, 120 of her more than 600 passengers
perished. The survivors endured a grueling five and a half month march to the mouth of
the Maputo River, during which the majority died of starvation, disease, and attacks
from the indigenous populations. Out of almost 500 people that undertook the march,
only 25 arrived at the Maputo River. In 1980 a sport diver recovered part of a bronze
gun from the place believed to be her wreck site. The area was surveyed in 1983 by a
team of sport divers who recovered many artifacts in spite of poor visibility, a difficult
rocky bottom, and strong surf and current. No hull remains were found. Some of the artifacts recovered were then offered to the Natal Museum, in South Africa, including the fragment of the bronze gun, shards of Ming porcelain from the Jiajing period (1522-1566), coarse earthenware, and glass beads from Cambay, India.\textsuperscript{11,51}

\textit{S. Bento} was built in Lisbon in 1551 with a registered weight of 900 tons, and lost on her return to Portugal on her first voyage. Also known from Bernardo Gomes de Brito's \textit{História Trágico-Maritima}, \textit{S. Bento} was lost in 1554 during a violent storm off the coast of South Africa with a load of pepper and other precious merchandise. Once again, the more than 300 persons that managed to make it to shore after the wreck had to walk to the mouth of the Maputo River – only 62 people arrived two and a half months later. The written account gave precious clues to the sport divers who found her presumed wreck site in 1968, and recovered 18 bronze guns and many artifacts. Judging from the reports it seems that no hull remains were found. Part of the collection of artifacts is in the Natal Museum and another part is in the Durban History Museum.\textsuperscript{11,52}

The nau \textit{Santiago} hit the atoll of Bassas da India during the night at full speed, on its way to India in 1585. She lost her bottom against the coral reef, and parts of her upper works floated away, and came to rest over the coral reef on the southern part of the atoll. The account of this wreck was published also by Gomes de Brito. \textit{Santiago} was described as a 900-ton nau, with 33 m of keel length, and around 50 m of length overall. The wreck site was found in December 1977 and several artifacts were salvaged in the three following years. Among many items recovered were 12 bronze guns, one astrolabe, several kilos of silver coins, religious objects, and a few jewels. The bulk of this collection would later be sold by \textit{Santiago Marketing Ltd.}, a company created for the purpose, and bought by the Portuguese Museu de Marinha and the South African Natal Museum.\textsuperscript{11,53}

In the 1970s, a group of 30 bronze guns was retrieved by local fishermen from the wreck site of a Portuguese vessel in Boudeuse Cay, Almirante Isles, Seychelles, believed to be D. João da Cunha's \textit{Santo António}, lost in 1589 at that island. Surveyed in 1976 by Warren Blake and Jeremy Green, this wreck still contained a small portion of
its bottom planking and framing in place, occupying an area of about 50 by 10 m. The hull planking was 9 cm thick, and the frames 17 cm sided and 18 cm molded. The planking was nailed to the frames with square iron nails. The caulking method was similar to that found on Mártires, with lead straps 2.5-3 cm wide and lead strings 5-6 mm in diameter. The majority of the artifacts went into private collections, with a small part going to the Carnegie Museum in Victoria, Seychelles.\textsuperscript{11,54}

Lost en route to Portugal after springing a leak in mid-ocean, the nau Santo Alberto is thought to have run aground close to the mouth of the Umtata River, on the east coast of South Africa, in 1593. The account of her wrecking is also included in Gomes de Brito’s História Trágico-Marítima, and was originally written by João Baptista Lavanha, the author of the Livro Primeiro de Arquitectura Naval. Its site was tentatively identified after Ming Dynasty porcelain shards of the Wan-Li period were found near Sunrise-on-Sea, in South Africa.\textsuperscript{11,55}

The wreck site of the Espiritu Santo, an India Route ship lost off the eastern coast of South Africa in February 1609, may have been identified through the find of porcelain shards, between Double Mouth and Haga Haga. There is no mention of any wooden remains.\textsuperscript{11,56}

The large Nossa Senhora da Luz was lost on 7 November 1615 at Porto Pim, Faial, Azores, and her presumed wreck site was found in 1998 by a team from Centro Nacional de Arqueologia Náutica e Subaquática / Direcção Regional dos Assuntos Culturais da Região Autónoma dos Açores under the direction of Paulo Monteiro, and surveyed in the following summer. No remains of the hull have been preserved.\textsuperscript{11,57}

Less sure is the resting place of the nau S. João Baptista, lost against the east coast of South Africa, after enduring a battle with two Dutch vessels in 1622. Ship remains found near Cannon Rocks, in South Africa, have been tentatively associated with this vessel. As with many of the other sites, it has only been tentatively identified through the porcelain shards found on the beach.\textsuperscript{11,58}

The small nau S. Gonçalo was one of five vessels offered by the Portuguese and Spanish crown to a newly created Companhia da Índia, formed in 1628 after the image
of the successful Dutch VOC. Lost in 1630 on the south coast of South Africa, the
remains of *S. Gonçalo* are known to lie somewhere in the bottom of Plettenberg Bay,
but have never been found. However, the camp built by the shipwreck's survivors was
still visible in 1788, when the area was settled by Jan Jerling. After exposing part of the
site during the construction of a new house, Jan's descendent John Jerling supported
archaeological excavations in 1979 which were conducted by a team from Cape Town
University. The Jerling collection includes over 1000 porcelain shards and many other
artifacts.\textsuperscript{11,59}

Lost in November 1636 near the mouth of the Tagus River, Portugal, against the
small islets of Cape Roca, *Sta. Catarina de Ribamar*'s wreck site remained in the
memory of the local population for many generations. Many locals still know the story
of Dona Ricarda, an old woman who knew in the 18\textsuperscript{th} century where to find golden coins
at the nearby beach after storms. In 1966 a bronze gun was raised from this site, and
another two may have been salvaged by looters (they are said to have been melted soon
afterwards). In the summer of 2000, a team from CNANS conducted a survey at the site,
finding a large anchor but no sight of the several bronze guns reported by fisherman to
be lying on the site, deeply encased in the rocky bottom. No mention has been ever
made about any hull remains.\textsuperscript{11,60}

The naveta *Santa Maria Madre de Deus* was lost off the east coast of South
Africa in 1643. Her remains were tentatively identified after the discovery of porcelain
shards in the 1960s. Later, in 1993, a section of a wooden hull washed ashore after a
storm at Bonza Bay. However, the description of the portion of hull found on the beach
suggests a later date for its construction. It was 10 m long by 3 m wide, and
encompassed 18 thick frames planked on both sides. It was fastened with wooden
treenails and 'brass' nails, fasteners not typical of Portuguese shipyards in the 17\textsuperscript{th}
century.\textsuperscript{11,61}

*Sanissimo Sacramento* was a large vessel built in India for the India Route. She
left Goa on 20 February 1647 bound for Lisbon and wrecked off the coast of South
Africa, after being driven ashore by a storm. The account of her loss and the adventures
of the survivors gave good indications to the whereabouts of her wreck site. In 1778 the
captain of a Dutch garrison stationed nearby visited Algoa Bay and marked the wreck
site on a map, referencing the location of huts built by the survivors. In 1949 an article
referred to the existence of a gun and two anchors in the tidal area, and three years later a
researcher named Harraway raised an iron gun from the site. Finally, in 1977 David
Allen and Gerry van Niekerk located 21 bronze guns under water in front of the site of
Harraway’s gun. Soon after, this number rose to 61 when David Allen found another 40
guns – 21 of iron and 19 of bronze.\textsuperscript{11,62}

_**Nossa Senhora da Atalaia do Pinheiro**_ left Goa with _**Santissimo Sacramento**_ on
20 February 1647, and wrecked a week after the loss of _**Sacramento**_, a victim of the
same storm. The survivors of her wreck met those of _**Sacramento**_ and marched together
to today’s Maputo. _**Atalaia**’s_ wreck site was located in 1978 by Dr. Bell Cross, director
of the East London Museum. Eighteen guns were found on the underwater site (ten
bronze and eight iron guns), together with many porcelain shards, Martaban jars and
other pottery remains. The remains of a camp were found on the beach in front of the
wreck site, 25 m above the tidal zone. Both sites have produced abundant cultural
materials which are now housed in the East London Museum.\textsuperscript{11,63}

There are few doubts concerning the identification of this small group of wreck
sites as those of Portuguese Indiamen, and the collections of artifacts, combined with the
information contained in the accounts of the respective wrecks, make strong cases for
their identification. However, none of these sites has yielded much information about
the most important artifact - the ship. We have abundant information about the India
Route, its history, the historical period, and the politics involved. There are thousands of
titles pertaining to the Portuguese expansion, and yet almost nothing is known about its
main vehicle, the India Route nau.

We have few, unreliable images, a scarcity of contemporary descriptions of these
vessels, and only a handful of technical texts pertaining to their construction. This data
does not allow us to clearly answer all of the questions raised about _**Nossa Senhora dos
Mártires**_. How large was she? How was she built? How was she rigged? How strong
was her hull? How were her officers, crew and passengers lodged? Evidence suggests that the story began in Italy long before the shipwreck of Nossa Senhora dos Mártires. In the next chapter I will discuss what we do know about the India Route naus and their origin.
CHAPTER III
THE SHIPS

Origins

Information about Italian ships is important for the reconstruction of the *Nossa Senhora dos Mártires* because there is evidence of similar design and construction techniques in use in Portuguese shipyards of the 16th century. The model for Portuguese India Route naus evolved from the Mediterranean round ship, which developed originally in Italy, and *Nossa Senhora dos Mártires* was conceived and built using methods that mirrored the Italian ways.

Written sources suggest that in the 13th century Italian master shipwrights of Naples, Genoa, and Venice had full control over the various craftsmen involved in the construction of ships, from the woodcutters in the forests, to the sawyers, carpenters and caulkers in the shipyards. The definition of Italian hull dimensions was the result of a set of pre-determined and simple proportions between the measurements of the keel length, beam, dimensions of the stem and sternpost, and depth in hold. The width of the floor timber on the lower, flat portion of the midship frame and the breadth of the section at certain heights above the top of the keel (e.g., *trepie* – three feet, and *sepie* – six feet) were determined from the maximum beam.

Italian archives house a great number of documents pertaining to the size and shape of vessels, the dynamics of the shipping business, and the work of its greater shipwrights. Although iconography is scarce and generally poor where the 12th, 13th, and 14th centuries are concerned, a series of texts detailing the construction of vessels have provided an important array of information about Italian shipwrightry.

This evolution of Portuguese ships from Italian practices comes as no surprise when we consider the large resident community of Italians in Portugal, the involvement of Italian merchants in Portuguese commerce from at least the 14th century on, and contact with Italian shipwrights from at least the 12th century. The presumption of an Italian influence is further reinforced after examining the comparatively scarce sources
pertaining to the shipbuilding industry in Portugal. The same patterns appear in the relations between ship owners and ship builders, although these existed in other regions of the western Mediterranean. Later, from the 15th century on, the archaeological record confirms the similarities in the building techniques between the two worlds of Italy and southern Iberia.

Another source of influence may have been the Arab world. However, the relations between Portugal and the Arab world are largely unknown, and although we suspect that Arabs may have been quite important, there is no solid evidence for involvement of moçarabes, as the christianized Muslims were known in Portugal, in ship construction, as there is in other activities such as architecture. The presumption of Arab influence in the Portuguese shipping industry is a typical case in which the absence of proof does not make a case for the absence of activity. We know that Arabs, Jews, and Christians enjoyed close and peaceful relationships in Portugal during most of the period of Muslin domination (712-1249). Later there was intense trade throughout the entire late medieval period that lasted at least until the expulsion of the mouriscos from Spain by Philip III in 1609 and 1610. And, as we will see below, tail-frames, important ship structural elements, bear an Arab name in Portugal, almogamas, and this is certainly not for lack of Italian designations.

Little is known about Arab shipbuilding, but there is evidence suggesting the use of frame-based vessels in the Arab world since the 10th century. Three Saracen wrecks – Plane 3, Agay A, and Batéguier – found off the southern coast of France and dating from the 10th or 11th centuries, show evidence of having their planks nailed to the frames. Not yet fully published, these vessels may have been similar to the Serçe Limani shipwreck, having a flat floor, a hard chine and flush laid planking nailed to the frames. Furthermore, a frame-based type of construction may already be suggested in a 7th century manuscript, the Aphroditio papyri, which mentioned the purchase of large quantities of iron nails for the Cairo shipyards. It is regrettable that one of the best Portuguese sources on shipbuilding, Father Fernando Oliveira, did not give any details of his visits to Moroccan shipyards, in spite of finding them worth mentioning in his
memoirs. Father Oliveira considered that his visits to North African shipyards increased his expertise and experience, and he certainly did not express any criticism of them in spite of his well-known candor. We can only suppose that Arab shipbuilding was as good and sophisticated as any other of its time.iii.8

Besides Italians and Arabs, many other influences may have helped to shape the model of the India nau. These can be seen even today in the traditional and local small craft, and were certainly much more clear in the 16th century outside the state managed shipyards.iii.9 The Iberian Peninsula was and still is a heterogeneous region, comprised of many different communities. Although most of its territory is a large central plateau, rural and isolated from the sea, the Portuguese coast is occupied by many different populations, all closely related to the sea and traditionally subsisting on maritime activities such as fishing and the harvesting of algae or gathering of salt. All these people carry different traditions, devotions, and ethnographies. They speak at least five different languages (Basque, Galego, Portuguese, Castilian, and Catalonian), and build different water craft. However, it is difficult to trace all influences with certainty, as Father Oliveira noted in his book Liuro da Fábrica das Naus: "(...) and if our [craft] changes, and we forgot it from yesterday into today, what can I say of the Latin and Greek [craft] from so many years ago." iii.10

The truly interesting aspect of Nossa Senhora dos Mártires is its construction in the state-driven shipbuilding industry, based on the new Renaissance trends of erudition. From the early 15th century on, when the crown got involved in commerce with the African coast, ships grew larger and trips grew longer. This was a period of discovery, contact, and accumulation of wealth, three factors that certainly encouraged creativity and eased change. The voyages of the beginning of the 15th century were undertaken in square rigged barcas and barinéis, vessels that Oliveira held to be similar to the trincados da Galiza, literally 'clinkers of Galicia'.iii.11 Nonetheless, quite early, a lateen rigged ship known as caravela seems to have become the prototype for the efficient middle sized vehicle of the discoveries. These vessels were first mentioned in Portugal as fishing ships in 1255, in the charter of the coastal village of Gaia, but were already
mentioned as ship's boats in 1159, in a Latin manuscript from the Archivo di Stato di Genova.\textsuperscript{11,12}

Drawing little water, tacking easily and rapidly, and capable of transporting artillery and victuals for middle range trips, caravels were extensively used during the Portuguese expansion along the western coast of Africa. They were not discarded until the early 1500s, when they were found too small for trips beyond the Cape of Good Hope. Caravels are the icon of the Iberian shipbuilding tradition, but may not be closely related to the large naus of the India Route. Lateen rigged and presenting a fairly high length to beam ratio, the caravels evolved during the 16\textsuperscript{th} century into something close to a galleon, with four masts (of which three were lateen rigged), a pronounced beak, and low castles always present in the mid-16\textsuperscript{th} century illustrations.\textsuperscript{11,13}

Square rigged ships were also extensively used during the 15\textsuperscript{th} century expansion, in voyages of trade, piracy, and discovery; and from the early 16\textsuperscript{th} century on, fully rigged ships appear together with large lateen rigged ships in almost all the views of Lisbon.\textsuperscript{11,14}

However different these two types of ships may have been, they shared the same shipbuilding tradition, which consisted of frame-based round hulls with a characteristic flush-laid planking that is still known today as carvel planking. They were conceived and built in the same manner, with the hull thought of as a central portion and two ends. The shape of the central portion was defined by a master frame, the widest section of the hull and two tail frames, which marked the extremities of this central portion. The bottom of the master frame was narrowed and raised towards the extremities using a simple and old geometrical algorithm. The ends were shaped by bending a series of ribbands, whales, or planks at several levels over the pre-designed central portion, and fairing their runs onto the posts. This concept entailed some sort of transversal control since the frames were determining the shape of the hull, at least at its central portion, and this was a relatively new concept in shipbuilding. Hulls had always been designed longitudinally, the shape obtained by the smooth runs of the longitudinal strakes. Evidence suggests that this system of frame-based construction developed between the
5th and 10th centuries in the Mediterranean, replacing the prevailing shipbuilding tradition. It is called frame-based in opposition to the prior shell-based systems used in the Mediterranean and northern European waters.\textsuperscript{15}

The Mediterranean frame based shipbuilding tradition

Ships were built according to two major traditions during the Middle Ages. In the north of Europe, the outer hull was assembled with overlapping strakes and then reinforced with frames nailed to its internal surface. In the Mediterranean the strakes were edge joined, with tenons inserted in mortises cut into plank edges. These tenons were generally locked in place with pegs inserted perpendicularly to the planks' surface.

There were many variations within these two broad traditions of shell-based hulls and many more styles of hulls and craft; but they all shared in common the fact that the hull was thought of as a shell reinforced with frames, and that its shape was defined by certain longitudinal runs.\textsuperscript{16}

In late Medieval era, however, most vessels in the Mediterranean were built following a completely different philosophy, showing varying degrees of evolution towards what would become the frame-based – or skeleton-first – tradition. By the late 16th century this designation still referred to the erection of only a certain number of frames over the keel before the insertion of ribbands that would fair and define the whole shape of the hull. There was already a different understanding of the hull, as Oliveira explains so clearly:

\begin{quote}
(\ldots) Nature teaches this in the bodies of sentient animals, in which there are also two parts that seem to respond to what I say and give an obvious example of these two necessities of the naus: one is the bones, that represent the strengthening pieces, because they support, straighten and form the body of the animal, such as the support does in the hull of the nau: the other is the skin that covers the support (\ldots).\textsuperscript{17}
\end{quote}
Again, there were many variations of this method of hull construction. Many still persist along the shores of the Mediterranean in a system known today as whole-molding. All whole-molding methods share one feature: the shape of a number of frames is pre-designed. In other words, part of the hull shape is controlled transversely rather than longitudinally, since the shape of the hull is obtained from a number of pre-designed frames fixed over the keel beforehand. Many times the hull is not fully defined until afterwards with the help of ribbands. There are two different ways to control the shape of a hull through this method. The first one was generally used for long or oared ships and required the pre-design of a certain number of non-contiguous frames placed along the keel at pre-determined intervals (e.g. every fifth frame). The second one was used for round or merchant ships, such as Nossa Senhora dos Mártires, and required that the hull be divided into three sections along its length, with a number of contiguous, pre-designed frames placed in the central section. This was just a general rule and sometimes only part of the frames in this central portion were pre-designed.

Whole-molding was less labor intensive than the earlier mortise and tenon joinery technique and therefore cheaper, but it was also more complex since it required a good a priori knowledge of what the shape of the hull would be. However, the advantages of this method were obvious, firstly because it represented a good solution for control of hull symmetry, secondly because it enabled shipwrights to predict the size and capacity of a ship with a fair degree of accuracy, and thirdly because it allowed for the replication of good prototypes.

During the Middle Ages in Southern and Western Europe, this method evolved into a relatively simple non-graphic way to pre-design the frames of the central portion of a ship's hull. This simplified system for building ships was slowly adopted in northern Europe during the 16th century, and gradually replaced the more labor intensive and perhaps less sturdy clinker or lapstrake construction.

The 16th century was a time of great advances in science, and corresponded to a period in which India naus grew in size, encouraged by the desire for profit and the acquisition of new techniques and tools in several disciplines. By the late 16th century,
reason and observation of nature coexisted with traditional medieval scholastic ideology, and a newborn critical reasoning refuted traditionally-accepted “ancient” knowledge.

The decades before and after the wreck of Mártires saw many new religious, scientific and artistic developments. In 1598 Henry IV published the edict of Nantes, allowing freedom of religion in France. In Rome the war against science and diversity held firm, and in 1600 the Holy Inquisition burned Giordano Bruno in Rome for heresy. A year later, however, Tycho Brahe died and left all his data to Johannes Kepler, who published his Optics in 1604 and New Astronomy in 1609. In that same year Galileo built his own telescope, a device invented in 1608 by Dutch scientist Hans Lippershey. The following year, in 1610, Galileo discovered the four largest moons of Jupiter and published this discovery in his Siderus Nuncius. In the very year of the wreck of Nossa Senhora dos Mártires, Shakespeare published his Macbeth, following Hamlet (1602), Othello (1604), and King Lear (1605). In 1605 Cervantes published the first volume of Don Quixote, and in 1607 Claudio Monteverdi composed his first opera, L’Orfeo, in a new style that would influence European music forever.

In the midst of this intellectual context, new hull shapes were developed, built, and tested. The overall size of ships grew, bow and stern castles were lowered for better performance when sailing at closer angles with the wind, the structure was reinforced to sustain more artillery, and ordnance became the primary concern in naval war. As batteries became heavier, engagement at sea could be held further away from enemy ships and boarding avoided.

By then frame-based construction had spread throughout the Mediterranean world, and had been adopted by the 16th century in the French Atlantic coast, extending soon after to England, and in the early 17th century to the North Atlantic countries.

**Texts on shipbuilding**

We are lucky to have a few late 16th and early 17th century texts that discuss the design and construction of this type of ship, the most important of these which were transcribed and published during the 19th and 20th centuries. These constitute a major
source of information both on the ways in which vessels were built and how they were conceptualized in the minds of their shipbuilders. It has not been completely explained why the late 16th and the early 17th centuries saw the appearance of so many of these texts and treatises. Before the 1570s there was only a handful of them, and to my knowledge all originated in Venice.

The description and analysis of India naua presented in this study depends substantially on the information contained in many of these texts and treatises, and it is therefore necessary to explain beforehand what these writings are, who produced them, and what is contained in each one of them.

The oldest texts date from the early and middle 15th century and are known as the Fabrica di Galere and the Timbotta manuscript. These two manuscripts are extremely important for the understanding of the history of the shipbuilding industry in post-medieval Europe. They are particularly relevant to this study, because they both mention a non-graphic method to pre-design the central frames, a practice followed in the skeleton-first shipbuilding tradition used in Portuguese shipyards in the early 17th century, when Nossa Senhora dos Mártires was built. In this method, ships were considered to be formed longitudinally in three sections: a central section in which the shape of the frames was obtained through the use of molds and gauges, and the two ends of the vessel whose shapes were obtained through the runs of longitudinal ribbands or wales, positioned at given heights over the pre-designed central frames, and running from post to post.

When we examine the Fabrica di Galere or the Timbotta manuscript, or indeed any of the European shipbuilding texts of the 15th to 17th centuries, we have to ask ourselves the question: who wrote these texts and treatises, why, and with what kind of knowledge of their subjects? The majority should not, or cannot, be taken literally since they were written either by outsiders or theoreticians and contain inconsistencies; or they were written by experts, for experts, and may contain data that cannot be taken out of a precise context that is unknown to us.
These two earliest texts are the product of two different types of authors. The *Fabrica di Galere* is the writing of a professional, and the Timbotta manuscript consists of the notes of a cultured and well-informed dilettante. These two different sources of information must be considered separately, since they were written by people with two fundamentally different approaches to the design of vessels: a theoretical one, and a practical one. The *Fabrica di Galere* was copied from an original that may have been written by an admiral of the Venetian Arsenal, not a shipwright, but certainly a professional of the sea, and an expert on ships and shipbuilding. As to Zorzi Timbotta, creator of the Timbotta manuscript, it seems he was a cultured Renaissance man with many interests, and, therefore, an outsider who collected notes from some expert source.

The texts discussed in this chapter represent an important body of information on shipbuilding in 16th century Europe, and display important insights in the history of science. They often show which tools were available to the shipwright in terms of mathematical and geometrical knowledge, and reflect the organization of labor within the industry in a period that saw the development of the independent naval architect. This kind of theoretician was already accepted in Venice in the first half of the 16th century in the person of Vettor Fausto (a humanist and Greek teacher whose galleys were well appreciated) but seemingly did not exist in the rest of Europe until the late 16th century. Then, around the final quarter of the 16th century, the first of a large number of texts and treatises on shipbuilding made their appearance. Some were written by professionals such as the English shipwright Matthew Baker, but the majority were assembled by enlightened outsiders like the Portuguese priest Fernando Oliveira, the Portuguese kingdom's Engineer João Baptista Lavanha, or the Spanish merchant Diego García de Palacio. The latter published in Mexico, in 1587, the first treatise on shipbuilding ever printed.

Considering the relatively narrow scope of my research, I have focused on only a few of these works, namely the Portuguese ones, directly related with the construction of naus for the India Route. However, because it is important to look at the information contained in these Portuguese texts in the context of different contemporary approaches,
I will mention a total of 17 texts that I found relating to this shipbuilding tradition during the period under study.

Besides the *Fabrica di Galere* and the Timbotta manuscript, there are five other Italian texts whose relevance deserves mention. These are the anonymous *Ragioni Antique dell'arte del mare et fabbriche de vasselli* and the *Arte de far vasselli*, the *Instructione sul modo di fabricare galere* by Pre Teodoro de Nicolò, the letter known as *Visione del Drachio*, and Bartolomeo Crescenzo's treatise on galleys, *Nautica Mediterranea*.

Closely related to the Italian tradition of shipwrightry are a French text on the design and building of galleys called *La Stelomonie*, and four important English texts: a collection of notes by Matthew Baker known as *Fragments of Ancient English Shipwrighty*, a *Treatise on Shipbuilding & A Treatise on Rigging* attributed to John Wells, and two manuscripts with similar contents, dating from around 1600, and pertaining to the proportions of vessels, one known as the Scott manuscript (attributed to Phineas Pett), and the other surviving through a later copy by Isaac Newton.

Also important for this study are seven Spanish texts, of which three are true treatises: the *Ytinerario de Navegación de los mares y tierras occidentales* by Escalante de Mendoza; the *Instrucción nautica para el buen uso y regimiento de las naos, su traza y goyerno* by Diego García de Palacio; and the *Arte de construir naos*, by Tomé Cano. Three are royal decrees: the *Ordenanzas* of 1607, 1613, and 1618, and a seventh is a dialogue known as *Diálogos entre un viscaino y un montañez*.

**The Italian texts**

The *Fabrica di Galere* is a Venetian manuscript with 123 folios, dated by paleographical evidence to around 1410, now deposited in Florence, in the Biblioteca Nazionale Centrale, codex Magliabechiano, XIX.7. The writer is unknown, although the original is thought to have been written by an admiral of the Arsenal. Plentiful in comprehensive pen and ink drawings, it covers a galley of Flanders (folios 1-13), a galley of Romania with a digression on sail-making (14-25v), a light galley (26-32), a
lately rigged ship (33-36), and a square rigged ship (37-49). It presents a formula for calculating displacement – the oldest I know of – and a description of a whaler (ballanier) as built by those of the West (quelli de ponente). There follows a section on rigging and spars (51-64v), sail-making (65-72v), and again the galley of Flanders (73-75v), the galley of Romania (75v-folium number omitted in the publication available), and a light galley (folium numbers omitted). The next section is dedicated to smaller craft and contains a mention of the great Greek shipwright Theodoro Baxon, whose light galleys were praised as being among the best ever built in the Arsenal. In 1407 eight of Baxon's galleys were ordered by the Senate to be set aside to serve in emergencies and to be copied as models since Theodoro was not a young man anymore, and there was a fear that he may not have taught everything to his Italian fellow workers. The manuscript then presents the measurements for a falchioni to be made in the Arsenal (folium numbers omitted), followed by the prices of ironwork, timber, oars, and other equipment (folium number omitted -87v). The last folios are dedicated to the design of rigging for square rigged ships (88v-100v), sail-making (101-122v), and information on the tides (122v-123).

The Timbotta manuscript was written in a Venetian dialect and signed by a Zorzi Timbotta from Modon in 1444. It is now in the British Museum, Cottonian manuscripts, volume Titus A.26. Bound in a small volume with several other manuscripts, it covers several matters: music (folios 2-8), a table of contents (8v), the virtues of rosemary (9-11v), sails and rigging (12-16); astronomy (16v-19v), a letter to the pope (20-23), accounts (23v-25v and 26v), shipbuilding (27v-28v), engineering (29v-36), and again shipbuilding, sail-making and arithmetic (37-60v).

The Ragioni Antique dell'arte del mare et fabrique de vasselli is a manuscript dating from the late 15th century, bearing two different hand writings, of which not much is known. It is not available for study in any publication and it only deserves mention here because it has been quoted as containing the approach to the design of the central frames of a vessel as the two previous manuscripts, namely the use of molds and gauges
to allow the shipwright to vary the width and dead rise of the floor timbers in a smooth, but not graphically pre-determined manner.\textsuperscript{26}

The \textit{Instructione sul modo di fabricare galère} is also a Venetian text, signed by Pre Teodoro de Nicolò, and dated around 1550. The manuscript is in the Biblioteca Nazionale Marciana, ms. ital. IV.26 (=5131) and refers also to the system of conceiving and building a vessel's shape from a number of pre-determined frames.\textsuperscript{27}

The same subject is covered by the \textit{Arte de far vasselli}, a manuscript now in Vienna, in the Oesterreichische Nationalbibliothek, manuscript No. 6391, which is not available.

The sixth of the Italian texts is the \textit{Visione del Drachio}, a letter with 15 folios dating from the end of the 16\textsuperscript{th} century, in which a shipwright named Baldissera Quinto Drachio explains how to build a galley of 14 benches. It is now in Venice, in the Archivio di Stato, Archivio proprio Contarini, No.19.\textsuperscript{28}

The last Italian text is a book, \textit{Nautica Mediterranea} by Bartolomeo Crescenzi Romano, printed in Rome in 1607 by Bartolomeo Bonfadino. It is a treatise whose first chapter is dedicated to the construction of galleys and contains a clear description of the methods in use to pre-design the frames that were to be pre-erected over the keel, showing the narrowing and rising of the bottom marked on the turn of the bilge, in the Mediterranean tradition.\textsuperscript{29}

\textbf{The French text}

The French text \textit{Stolonomie}, sub-titled \textit{Tracté contenant la matière de dresser et fournir aequiper et entretenir en tout temps en bon ordre une armée de Mer et raisô des frais d'icelle}, is an anonymous manuscript dated from 1547 to 1550 and pertains to the design, building, handling and maintenance of galleys. Colbert purchased it in 1682 from the private library of Mr de Montmort, Henry-Louis Habert, whose grand father had exerted functions of Treasurer of the Galleys around 1580. The manuscript encompasses 91 folios still in the original binding, and starts with a dedication to King Henry II of France (1547-1553), which stresses the importance of having an organized
fleet of galleys in the Mediterranean (folios 1-2). Follows a short introduction (folios 3-4), and 20 chapters dedicated to several aspects of the building, manning, and maintaining a fleet of galleys (5-87). The last folios contain an index of the work (88-91). Only the first chapter deals with the question of building the vessels, containing a complete description of the different timbers necessary to build a galley of 24 banks. The original is presently in the Bibliothèque Nationale de Paris, under the reference français 2133 and has been published with a complete study by Ian Fennis.\textsuperscript{30}

The English texts

The *Fragments of Ancient English Shipwrightry* is a collection of miscellaneous notes and incomplete plans of ships started by an English shipwright named Matthew Baker (1530-1613) in the 1570s, and continued with notes from one of his apprentices, John Wells, with annotations on mathematics. Baker was born in 1530, the son of a shipwright of King Henry VIII of England. There is notice of him traveling to the Levant in January 1551, at the age of 21, probably as a ship's carpenter aboard an English merchantman. He may have visited Italian and Greek shipyards and collected Venetian and Greek designs of midship frames. A fairly cultured man with a good understanding of mathematics, he certainly had contacts and was influenced by the revered Italian shipwrights hired by Henry VIII in 1543. These Italians appear to have remained in the country for over forty years, earning wages thirty percent higher than their English counterparts.\textsuperscript{31} In 1572 Baker was appointed Master Shipwright of the kingdom. He worked with other men of knowledge, and his notes reflect the first steps of a trend to change English shipbuilding from the Medieval empirical method to the modern standard of paper plans and conceptual models that could be repeated, improved and enlarged. When he died in 1613, he seems to have left the manuscript to his neighbor and protégé John Wells. Baker's notes present a compilation of precious observations, abacus, tables, and drawings, comprising more than 30 geometrically defined midship sections, from the sections of 4 galleasses designed by his father, James Baker, in the second half of the 16\textsuperscript{th} century to the early 17\textsuperscript{th} century midship sections
that were in use when new methods to determine the rising and narrowing of the bottom of the vessels in the central portion were fully defined in England. The part added by John Wells is mostly occupied with calculations of spherical geometry, making extensive use of logarithms from 1617 on, only two years after they were re-discovered in England.\textsuperscript{32}

The Scott manuscript is an important and still unpublished document with the number 798 in library of the Royal Institution of Naval Architects, dated from 1590 to 1605 from the watermarks on the paper. Since it seems to have been written by a very well informed expert, it has been suggested that its author may have been the English shipwright Phineas Pett. Unfortunately it has not been published yet.\textsuperscript{33}

A similar document in content but by no means a direct copy of the former is in the Cambridge University Library, with the reference MSS. Add. 4005 Part 12, and is a copy of one or two late 16\textsuperscript{th} or early 17\textsuperscript{th} centuries manuscripts on shipbuilding by Isaac Newton's hand. It encompasses a section on shipbuilding, with proportions, dimensions and rules for the building of ships, and a section on the proportions of masts and spars. A reference to the Queen's ship Beare, rebuilt between 1598 and 1603, in the section with the proportions on masts and yards places this document around 1600.\textsuperscript{34}

The fourth English text, Treatise on Shipbuilding & A Treatise on Rigging, has been attributed to John Wells and dated to around 1620-25. It is not as important for this study as the previous ones, since it refers to an emancipated English shipbuilding tradition in full development, in a period of change during which there is little in common with the Portuguese tradition.\textsuperscript{35}

**The Spanish texts**

The first of the Spanish treatises considered here was written by Juan Escalante de Mendoza in 1575 under the title *Ytinerario de Navegación de los mares y tierras occidentales*. Born around 1530 in Valle de Riva de Deva in Santander, Mendoza served in the Spanish *Carrera de las Indias* from a young age, reaching the position of capitán general de la flota de la Nueva España in 1595, one year before his death in
1596, in the city of Nombre de Dios. His manuscript was much appreciated in the Consejo de las Indias, but never authorized for publication as it was found to contain too much information on the routes and secrets of New World navigation. It is composed of three books. The first book presents a description of navigation down the Guadalquivir river, from Seville to the oceanic port of Sanlúcar de Barrameda and its sandbar, followed by a treatise of naval architecture. The second describes the navigation from the mouth of the Guadalquivir to the Gulf of Vera Cruz, for the fleet of Nueva España, and the port of Nombre de Dios, for the fleet of Tierra Firme. It includes dialogues on nautical instruments, measurement of latitude and meteorology. The third describes the voyage back to Spain and includes several dialogues on diverse issues such as the compensation of the magnetic compass, the fires of San Telmo, seasickness, shipwrecks, privateers and other topics related to sea voyages.\textsuperscript{36}

Diego García de Palacio wrote the first treatise on shipbuilding ever published. His work was published in Mexico in 1587 by editor Pedro de Ocharte under the title Instrucción nautica para el buen uso y regimiento de las naos, su traza y gobierno. It is a general work on navigation that includes a treatise on shipbuilding. Diego García de Palacio was born in Santander, in the Basque country, from a family with a great tradition of involvement with the sea. After studying law at the University of Salamanca, he was sent to Guatemala and Mexico where he worked for the crown and wrote several works on China and the Philippines, eventually being appointed to the Consejo de Indias for his knowledge and experience. His Instrucción Nautica is written as a dialogue between two Basques, a Viscayan and a Montanes, and is divided into four books and a glossary. The first two are dedicated to navigation issues, the third to astrology, meteorology and cartography, and the fourth to shipbuilding - detailing a ship of 16 codas of beam (9.20 m). This fourth book provides sections on the design of hulls, masts and spars, rigging, sails, ship's boats, artillery, victuals, and crews, detailing the functions and obligations of the captains, masters, and pilots. It is available in Spanish and English.\textsuperscript{37}
Tomé Cano’s *Arte para fabricar, aparejar naos de guerra y mercante* was printed in Seville in 1611 and is the first monograph published on shipbuilding in Spain. Tomé Cano was born in Tenerife, in the Canary Islands, in 1545, and died in Seville in 1618. He wrote his treatise around 1608 in the form of a dialogue between three men—one of whom is the author himself—sailing down the Guadalquivir to their ships, which were undergoing some repairs at a place called los Pajares. Following a short introduction that he calls *dialogo primero*, Cano describes a nau of 12 *codos* of beam (6.90 m) in the *dialogo segundo*, with all the proportions required for a good performance. He follows the norms of 1607, but defends a practice that was strictly forbidden at that time, which consisted of adding a second deck to the vessel by connecting the stern and forecastles. In the third dialogue, he details a way to find the tonnage of his ship. The fourth and final dialogue pertains to the dimensions of the flat of the midship frame, and its narrowing and rising to the bow and the stern.\(^{39}\)

We learn from Cano’s *Arte para fabricar, aparejar naos de guerra y mercante* that a master shipwright from Rentería, in the Basque country, was developing a new way—“nueva fábrica”—to build ships, which was followed in Portugal since 1597, the date of the construction of the galleon *San Mateo* in Lisbon, following the “fábrica nueva de Rentería.”

The *Ordenanzas de fábricas de navios* from 1607, 1613, and 1618 are sets of specifications issued by the Spanish government for the building of ships that put this new style of hull on paper. I am not aware of any publication of the first set of laws, but the *Ordenanzas* of 1613 are an enlarged and corrected version of the 1607 ones, containing 106 articles. There the concept of official tonnage is established and detailed, and 15 standards carefully defined, divided into *pataches*, *navios*, and *galeones*. The *Ordenanzas* of 1618 are again a new version of the previous ones, establishing now only 14 standard sizes for vessels, all called galleons. This third set of laws has been fully reprinted in Spanish.\(^{39}\)

The *Dialogos entre un vizcaino y un montañez* is an undated manuscript in the library of the University of Salamanca. It has been attributed to Pedro Lopez de Soto.
and dated to 1631 or 1632. It generally follows the structure of Palacio’s *Instrucción Náutica* and is also written as a dialogue between a Vizcayan and a Montañes, but its ships are much different now. The vessel described in this text is much larger, with 22 *codos* of beam (12.65 m).\textsuperscript{40}

The Portuguese texts

The most important collection of texts for this study were written in Portuguese between the 1570s and the 1610s. These are the treatises of Father Fernando Oliveira, *Ars Nautica*, and *Liuro da Fabrica das Naos*, the ones of João Baptista Lavanha and Manoel Fernandez, respectively the *Livro Primeiro de Arquitectura Naval*, and the *Livro de Traças de Carpintaria*, and the two texts included in the manuscripts *Livro Náutico*, and *Coriosidades de Gonçalo de Souza*. To these texts we must add the two contracts for the construction of India naus by Sebastião Themudo and Gonçalo Roiz, Figueiredo Falcão's *O Livro de toda a Fazenda*, and a list of prices pertaining to the construction of two India naus in the 1620s from Harvard University library. Finally, we must consider the comments of the commission charged with analyzing the size of the India naus in that period.

The *Liuro da Fabrica das Naus* has been dated to 1580 and is a translation of Father Oliveira's previous work in Latin *Ars Nautica*, although it does not contain – at least in its surviving version – the general drawings of the first Latin one. Fernando Oliveira was born around 1507 at Aveiro, a coastal city with great mercantile traditions. He studied at the University of Évora where he became a Dominican priest at the age of 25. Soon after he left for Spain, for unknown reasons. In 1536 he was again in Lisbon where he published his first book, a Portuguese grammar, the first known. Around 1540 he left again to Spain, and from there he sailed to Genoa, where he visited the shipyards. When his ship was seized by a French galley he was made a prisoner but managed to be engaged as a pilot. In 1543 he returned to Portugal, although not for long, since in 1545 he engaged again on the French Mediterranean galleys as they stopped at Lisbon bound to England. He served as a pilot in the galley of baron Saint-Blancard from where he
probably witnessed the sinking of the Mary Rose at Portsmouth. In 1546 his galley was taken by the English and he was imprisoned. In England he visited the shipyards, and may have met James Baker, the father of Matthew Baker. His resources must have been many, for soon he was serving as a diplomat near the future King Edward VI, whose protestant inclinations did not seem to prevent from admire Father Oliveira, since he is known to have given him the unusual amount of £110, certainly not for counseling in shipbuilding industry, for it is known that James Baker's salary was not more than 12 pence per day, less than £20 per year, and that even Agustino Levello, one of the Italian shipwrights hired by Henry VIII in 1543, made only 16 pence per day.\textsuperscript{31,41} We do not know what services Oliveira rendered to the king, but in 1547 he was back in Portugal and was arrested by the Holy Inquisition. He refused to comment on King Henry VIII's religious views, in his own words because \textit{"he had been Henry's servant, and eaten his bread."} \textsuperscript{31,42} Freed in 1551, Oliveira engaged in the Portuguese expedition of 1552 against Algeria, where he was taken prisoner after the defeat of the Portuguese army. There, once again he visited the shipyards. Freed two years later in 1554, he was back in Portugal, where he published his \textit{A Arte da Guerra no Mar} and was arrested soon after, again by the Holy Inquisition, although we do not know exactly why. In 1557 he was freed again and probably left Portugal forever. He died after 1585, presumably in France, leaving a series of unpublished works, among which are the \textit{Ars Nautica}, now in the Library of the University of Leiden, and the \textit{Liuro da Fabrica das Naus} presently in the National Library of Lisbon, in the codex 3702.

The \textit{Liuro} is the theoretical work of a scholar and not the practical work of a shipwright. It is comprised of a clear text, with few illustrations, and is, unfortunately, incomplete. As it survived, it is divided into nine chapters. Father Oliveira defines the dimensions of the primary structural components of a ship – stem, stern post, midship and tail frames – as simple proportions of the length of the keel. He then describes the use of algorithms similar to the ones described by Timbotta – such as the mezzaluna or the incremental triangle – to calculate the narrowing and rising of the floor timbers in the central portion of the hull, between tail frames (almogamas), the first and the last of the
pre-designed frames of a vessel. As Father Oliveira described it, all the frames in the central portion of the hull were pre-designed. No indication is given of the conception of the frames before and after the tail frames, but the use of ribbands is suggested. The midship frame is quite simple: a flat floor and a single circular arc for the futtocks. The chapters on rigging are missing. The Livro is available in two editions which both contain a facsimile of the original, a transcription and a translation into English. The second edition contains a translation into Cantonese.\textsuperscript{11,43}

The Livro Primeiro de Arquitectura Naval has been dated between 1608 and 1615, and is generally considered to have been written around 1608 to 1610 by João Baptista Lavanha, the Chief Engineer and Chief Cosmographer of the kingdom of Portugal at that time. Lavanha was born in Lisbon around 1550, son of a court officer, and he enjoyed a successful career in spite of his Jewish origins. He served as Master of Mathematics for four kings – Sebastian (1568-1578), Philip I (1581-1598), Philip II (1598-1621) and Philip III (1621-1640). In 1586 he was appointed Engineer of Portugal and in 1591 Chief Cosmographer. In 1601 he visited Flanders. In 1607 and 1613 he sat on the commissions in charge of the standardization of the shipbuilding industry in Spain and Portugal, which issued the Ordenanzas of 1607 and 1613. Between 1610 and 1615 he worked on a map of Aragon, and in 1616 he worked on a system to supply water to Lisbon, a city constantly plagued by the scarcity of fresh water. In that same year he was appointed Chief Chronicler. A friend of Cervantes and Lope de Vega, Lavanha died in 1624 after publishing many volumes, among which are a Description del Universo, written in Spanish, a Regimento Náutico, a Tratado da Arte de Navegar, a Tratado do Astrolábio, written in Portuguese, as well as a narrative of the shipwreck of the nau S. Alberto which was later included in the História Trágico-Maritima by Bernardo Gomes de Brito. The Livro Primeiro de Arquitectura Naval is also the theoretical work of a scholar, and not a practical text of a shipwright. It deals only with one type of vessel: the four decked nau for the India Route. It is clearly more modern than Oliveira’s Livro da Fabrica das Naus, basing the construction of hulls on paper drawings. Nevertheless, Lavanha calls for the need to pre-design a central portion of the hull, although only for
five frames forward and abaft the midship section. The importance of this treatise lies in its accurate description of construction techniques, and in its detailed illustrations. It is incomplete, ending abruptly in the beginning of a description of the drawing of plans. A facsimile was published in 1996 with a transcription and a translation into English.\textsuperscript{44}

The naus of Gonçalo Roiz and Sebastião Themudo are two manuscripts copied by Lavanha and transcribed and published by João da Gama Pimentel Barata in his comments to Lavanha's Livro Primeiro. These two short descriptions of India naus contain only the measures and features considered by their authors fundamental in the definition of these ships and present precious information on the length of keel and posts, number of pre-designed frames, and other basic characteristics, such as the shape of the transom.\textsuperscript{45}

The Livro de Traças de Carpintaria is signed by a Manoel Fernandez, shipwright, and dated to 1616. We do not know with certainty who this shipwright named Fernandez was, although there are a few possible candidates, none of whom were ever entrusted with high ranking responsibilities either in Lisbon or in India.\textsuperscript{46} The Livro de Traças describes a variety of vessels, from caravels to India naus, and is divided into two main sections. The first section has lists of dimensions of the primary structural components of a ship such as stem, stern post, midship and tail frames. The second contains an impressive collection of drawings, mainly intended as descriptions of the structural components of the ships, and less concerned with the conceptual aspect of the shipbuilding process. When analysed together with the one of the Coriosidades de Gonçalo de Souza, it becomes clear that these two texts are copies of the same original. Manoel Fernandez's version contains a number of gaps and mistakes that reinforce our first impression of him as a practical man, as a shipwright should be, rather than a theoretical expert, as would be expected from a master shipwright or a naval architect.\textsuperscript{47} His work was published as a magnificent facsimile in the early 1989, followed by a transcription and translation into English in 1995.\textsuperscript{48}

The Livro Náutico is a collection of manuscripts from the late 16\textsuperscript{th} century, presently located in the Biblioteca Nacional in Lisbon. It contains much important data
pertaining to the organization of the part of the Spanish Armada of 1588 that was fitted in Lisbon, and several lists of all the timbers needed for the construction of vessels. Of these manuscripts, one pertains to the building of a 500 ton India nau. This list is available through a transcription published in the late 19th century by Henrique Lopes de Mendonça.iii.49

The Coriosidades de Gonçalvo de Sousa is a manuscript from the early 17th century, the original is in the Library of the Universidade de Coimbra. It also contains a list of timbers needed for the construction of an India nau. To my knowledge it has never been published; however, a copy of it is available in the Biblioteca Central de Marinha in Lisbon.iii.50

The Livro de toda a fazenda is a large book written by the king’s officer Luiz de Figueiredo Falcão containing all the rents and profits of the Portuguese crown in 1607. It contains an interesting schematic with the division of space within an India nau.iii.51

The "Harvard manuscript" is a list of prices referring to the construction of two vessels, the three decked naus São Bartolomeu and Santa Helena, ordered by King Philip III of Portugal and IV of Spain in 1624 for the armada of 1625, and kept in the library of Harvard University.iii.52 To my knowledge, this manuscript is still unpublished and is interesting as it refers to the naus visited by a committee formed by King Philip IV of Spain to analyze the famous letters of Admiral Corte Real on the size and performance of the India Route naus in the early 17th century. These letters were transcribed and published by Christiano Senna Barcelos in “Construções de Naus em Lisboa e Goa para a Carreira da India no Começo do Século XVII.” iii.53

Although an in-depth analysis of the collection of Portuguese shipbuilding texts has not yet been done, it seems already possible to foresee the existence of a standard for the India nau which underwent continuous transformation in time. All these texts present a more or less standardized idea of an India nau, with a capacity of around 500 or 600 tonéis, which roughly correspond today to a displacement of 1,000 to 1,200 tons for a draft of 4 m. The length of keel grew slightly during the period under analysis, but the rake of the sternpost, the spring of the stembpost, or the basic relations between
defining dimensions such as keel/breadth, breadth/transom, keel/depth in hold, or keel/length overall did not vary much. It was at the level of the upper works, namely the number and height of decks, size of the quarterdeck, height of the forecastle, and other features related to the ship's cargo capacity and defense possibilities that we can trace some evolution.

The construction sequence

Evidence shows that by the late 16\textsuperscript{th} century the sequence of tasks and operations in the building process in Portuguese state-owned shipyards was remarkably similar to the one described in the Venetian Arsenal at the same time.\textsuperscript{111,54} Once the size and type of the vessel was defined, a length of keel was selected, which in turn determined the length, shape, and rake of the stem and stern posts. Then the shape of the midship frame was selected from many available models, and its fundamental dimensions obtained through simple proportions from the dimensions of the keel and posts. For a specific type of vessel such as 
*Nossa Senhora dos Mártires*, intended for the India Route, the length of the keel was almost standard, subject to few variations. The midship section was probably chosen from a small number of possible types, as were the rake of the sternpost, and the height and spring of the stem. These vessels were fairly standardized by then, and keeping close to a known model was important to avoid unnecessary risks.

After defining the size of the vessel and its main structural elements, the master shipwright charged with the construction of *Nossa Senhora dos Mártires* had to define dimensions and create templates of the timbers required for its construction in order to shop around the shipyard for the appropriate logs and order the remaining timbers from the usual suppliers. By the early 17\textsuperscript{th} century wood was a precious material, always in short supply on the Iberian Peninsula and timber merchants had to fell their trees further and further away from Lisbon, adding the rising costs of transportation to the already high cost of timber.

To lay the keel, a place was chosen in the shipyard and a cradle built on sloping ground, perpendicular to the river. To avoid disasters, the structures were carefully
designed to sustain the weight of the complete hull and the stresses of the launching operation. Most iconography from the 16th century on shows that the Portuguese built their ships with the stern to the water, while other nations built theirs facing the water front. It is not known why the Portuguese shipwrights did this, but it is possible that they were aware of the advantages of this system, which reduced the sagging stresses imposed during the launching. The relatively even distribution of the load of a vessel over its cradle changed when the hull slid into the water and started rotating upwards as it floated. At the last stage of the launching, most of the support of the cradle was localized at the end still resting on it. If a ship was launched stern first its buoyancy was not felt as early as when the bow hit the water first, and therefore the localized stress imposed during the last stage of the operation represented a much smaller percentage of the total weight of the vessel.\textsuperscript{55}

A slight arc was given to the keel in order to counteract the anticipated hogging of the hull. Keels of large vessels such as Mártires were assembled from several smaller logs for two main reasons. Firstly, shipwrights preferred cork oak for keels, and cork oaks do not have the tall, straight trunks required for a keel almost 30 m long. Secondly, it seems that some shipwrights believed it to be dangerous to carve the entire keel from a single log because it could warp and twist in the process of drying, and eventually snap during the construction of the ship.\textsuperscript{56} The stem and sternpost were designed, cut, assembled and erected, connected to the keel through traditional timbers called couces, which were basically knees fastened to the extremities of the keel in order to make the transition between keel and posts. The sternpost was surmounted by a transom beam, generally measuring half of the maximum breadth projected, to which the fashion pieces were attached, traditionally covering two thirds of the sternpost's height.

With the keel and posts in place, it was time to erect the frames located in the central portion of the keel. The shape of the midship frame had to be drawn in full size, because this building process demanded a construction mold. There was a marked tendency – perhaps reflecting the fashionable Platonic influence on Renaissance thinking – for the use of simple proportions relating the different measurements for the different
parts of ships. Relative proportions were also used for the conception of masts, yards, rigging and sails.

In Italy midship frames were first shaped following a series of offsets, or horizontal lines determining the width at certain heights, generally every foot or half a foot (an Italian foot being 34.7 cm). These horizontal lines became more widely spaced over time, and by the 1550s only three or four offsets were defined for small craft: tre pie (three feet), sei pie (six feet), and bocha (beam).\textsuperscript{57} For larger craft the midship frames were drawn with a series of circular arcs, such as the ones reproduced in Matthew Baker's notes, making for fairly sophisticated and complex shapes with three or four arcs: a turn of the bilge arc, a futtock arc, a tumble-home arc, and an inverted, concave arc to straighten the top timbers.\textsuperscript{58} Although sections with four arcs do appear in Fernandez's book, evidence suggests that in Portugal and Spain the midship sections were generally drawn with one simple circular futtock arc, and the turn of the bilge and tumble home portions later faired during construction. It is not known if this taste for several arcs reflected simply an intellectual mannerism of the time or some other form of aesthetic option of the shipwrights, as it does not seem to translate into a better performance at sea, either in terms of speed or stability, when compared to the simpler shapes that are more characteristic of the Iberian midship frames (FIG. III.1).\textsuperscript{59}

Standard moulds may have been used both for large and small craft, although there is no solid evidence for this practice in Portugal.

The central portion of the hull was defined by the number of pre-designed frames before and abaft the midship frame. In Portuguese these pre-designed frames were called cavernas gabaritadas or graminhas, and in Spanish cuadernas de cuenta. The total narrowing and rising of the bottom was also pre-defined, the bottom being considered the portion of the frames limited by two points on each side of each floor, called turn of the bilge points. The total rising and total narrowing were marked on the last of the pre-designed frames, which were to be placed before and abaft the midship frame, defining the central portion of the hull that was pre-designed, pre-assembled, and erected over the keel before any planking began. These last pre-designed and pre-
erected frames, or tail frames, had particular designations in Italian: *chodera chorba* (Fabrica di Galere), *qudiera chorba* (Timbotta ms.), *chavo di sesto* (Instructione of Preteodoro) and *capo di sesto* (Dracchio's Vistone). However, as mentioned above, in Portuguese they go by the Arab word *almogamas*, possibly following an Arab shipbuilding tradition whose rules and techniques are long forgotten.

The next stage of the building process was to define where the midship frame sat on the keel, and this was generally before the middle point of the keel, where some texts advised that the mainmast step should be placed. Then, the position of the tail frames was obtained from the number of pre-designed frames required, generally a function of the keel length, and the value of the room-and-space.

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FIG. III.1 - A common Portuguese midship section after Fernando Oliveira, and a Greek one after Matthew Baker.
With the keel, posts, and master frame in place, and the tail frames' shape defined, the remaining pre-designed frames were cut and assembled on the ground through a very simple process that is today known as whole-molding. As these frames were being assembled, they were erected over the keel, forming the central portion of the hull where the main cargo capacity was located. As I have mentioned before, the master shipwright had by then defined the rising and narrowing of the bottom forward and aft of the master frame, as well as the total number of pre-designed frames required for the hull (FIG. III.2).

![Diagram of hull construction](image)

FIG. III.2 - Rising of the bottom of an India nau after Oliveira.

The design of each frame was then determined with the progressive raising and narrowing of the bottom distributed over the frames using a simple and ingenious algorithm. First, a series of increasing values was obtained through one of several geometrical methods, known as *mezzaluna* (half moon) in Italian and *meia lua* or *besta* (crossbow) in Portuguese. This method is referenced in the Timbotta manuscript (FIG. III.3). These values varied between zero and the value of the total rising or narrowing required for the bottom of each particular vessel in each of the tail frames. The number of intervals obtained was the number of frames over which the incremental values were
to be distributed, from the maximum breadth and minimum height on the midship frame to the minimum breadth and maximum height on the tail frames. Then a ruler was built for each sequence of incremental values. In Portugal both this ruler and the algorithm were called *graminhos*.

![Diagram of the *graminho* design process](image)

**FIG. III.3** - The *besta* method to design a *graminho* after Oliveira.

Each one of the pre-designed frames could now be drawn, the timbers cut and floor timbers and futtocks assembled to the required shape. The length of the flat part of each floor was obtained by subtracting the respective value of the *graminho*, and the measure of the rising of each floor's foot (pe) by adding the respective value of the *graminho*, as shown below (FIG. III.4).

Once all the pre-designed frames were in place over the keel, the shape of the remaining parts of the hull was obtained with the help of wooden ribbands, wales or planking strakes placed over these frames at given heights to determine the overall shape and to allow for the design of the remaining frames. A notched keelson was then fitted over all the frames, from stem to stern, and solidly bolted to the keel.
Carpenters would start planking the hull over the pre-erected structure while another team inside would finish the with the footwales and stringers needed to give the lower hull additional longitudinal strength, as there were no wales on the outside of the hull below the water line. When all the lower stringers were in place, the clamp to support the lower deck would be placed, and the deck beams solidly fastened, starting with two adjacent beams placed precisely above the mainmast step that determined the masts' rake aft. The construction would continue by repeated tasks, every deck preceded by a line of futtocks, wales, a clamp, and its beams and carlings. Clearly perceived as a much less important part of the vessel, the upper works were sometimes built by a different team of carpenters. When the hull was ready, it was launched into the water, and masts, spars, rigging and other fittings installed in place.

The rigging and appearance of India naus

There are no detailed, accurate illustrations of India naus, and we must reconstruct their images from the evidence available, which consists mainly of sketches illustrating accounts of voyages (Relações), itineraries (Roteiros), or maps, and
depictions in religious paintings, occasionally of very good quality, like the well-known Retábulo de Santa Auta, in Lisbon's Museu de Arte Antiga. The great majority of these illustrations is, however, very simple and unreliable since most painters were generally oblivious of the secrets of the seafaring world. Flags pointing in the opposite direction of the wind that fills the unfurled sails below, ships sailing in different directions under impossible wind conditions, or misplaced rigging cables, are common examples of the liberties taken by the artists who depicted these vessels. However, the study of iconography can be of great help for our understanding of these long gone vessels. A few scholarly representations remain, such as the illustrations of Manoel Fernandez' treatise, but again leaving many questions unanswered in what concerns, for example, the structural details and fastening solutions adopted in the construction of the decks and upper works.

The first and most striking feature of the India naus was the size of their mainsails. In most illustrations from the 16th century, we see a sturdy mainmast, a long main yard, and a huge main sail called papa-figos – literally figpecker – that exceeds all other sails shown on other vessels of the time. Exaggerated or not, this mainsail often bears a bonnet hanging outside, and sometimes even below the gunwales, kept in place by two sets of clew-lines. In the beginning of the 16th century, there are frequently four masts - fore, main, mizzen and bonaventure, but towards the time of Nossa Senhora dos Mártires the bonaventure was being phased out and it was more usual to find only three mast. Although both the fore and mainmast bear two square sails each, it is rare to see topgallant masts. Large and heavy round tops, with a bowl-like shape, were placed in between these two sails. The mizzen and bonaventure masts were always rigged with a lateen sail, and at the bow, a long bowsprit invariably carried a large square spritsail.

The hulls look dark and sturdy, showing no decorations, paintings, or carvings. Strong wales stood out, sometimes with a pronounced sheer that does not correspond to what we know from the written treatises, and some illustrations show fender cleats amidships. The forecastle was generally high and short, ending in a triangular shape that distinguished carracks of the 15th and early 16th centuries. The quarterdeck extended all
the way to the mainmast and hung generally 1/5 of its length abaft the transom. It was topped by a poop deck which covered more or less one half of the quarter-deck's length (FIG. III.5).

FIG. III.5 - A Portuguese nau in the middle 16th century, after Lisuarte de Abreu.

Below is a short glossary of the most important parts of the India naus, as they are shown above and as they are described in contemporary literature (Table III.1 through Table III.3). We must be aware of the fact that, as it often happens with the iconography of Portuguese vessels of the 16th and 17th centuries, the drawing above (FIG. III.5) was done by a passenger, not by an officer, a sailor or a shipwright.
### Table III.1
**Glossary - Hull elements**

<table>
<thead>
<tr>
<th>No.</th>
<th>Portuguese</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chapitêu</td>
<td>Poop deck</td>
</tr>
<tr>
<td>2</td>
<td>Tolda</td>
<td>Quarterdeck</td>
</tr>
<tr>
<td>3</td>
<td>Convés</td>
<td>Main or Weather deck</td>
</tr>
<tr>
<td>4</td>
<td>Castelo de proa</td>
<td>Forecastle</td>
</tr>
<tr>
<td>5</td>
<td>Primeira coberta</td>
<td>Gun deck</td>
</tr>
<tr>
<td>6</td>
<td>Porão</td>
<td>Hold</td>
</tr>
</tbody>
</table>

### Table III.2
**Glossary – Masts, spars and sails (see FIG. III.5)**

<table>
<thead>
<tr>
<th>Portuguese</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Mastro da cevadeira</td>
<td>Bowsprit</td>
</tr>
<tr>
<td>8 Verga da cevadeira</td>
<td>Spritsail yard</td>
</tr>
<tr>
<td>9 Vela da cevadeira</td>
<td>Spritsail</td>
</tr>
<tr>
<td>10 Mastro do traquete</td>
<td>Foremast</td>
</tr>
<tr>
<td>11 Verga da gávea do traquete</td>
<td>Fore topsail yard</td>
</tr>
<tr>
<td>12 Vela da gávea do traquete</td>
<td>Fore topsail</td>
</tr>
<tr>
<td>13 Verga do papa-fígos do traquete</td>
<td>Fore yard</td>
</tr>
<tr>
<td>14 Papa-fígos do traquete</td>
<td>Fore sail</td>
</tr>
<tr>
<td>15 Mastro grande</td>
<td>Mainmast</td>
</tr>
<tr>
<td>16 Verga da gávea grande</td>
<td>Main topmast</td>
</tr>
<tr>
<td>17 Vela da gávea grande</td>
<td>Main topsail</td>
</tr>
<tr>
<td>18 Verga do papa-fígos grande</td>
<td>Main yard</td>
</tr>
<tr>
<td>19 Papa-fígos grande</td>
<td>Main sail</td>
</tr>
<tr>
<td>20 Mastro da mezena</td>
<td>Mizzenmast</td>
</tr>
<tr>
<td>21 Verga da mezena</td>
<td>Mizzen yard</td>
</tr>
<tr>
<td>22 Vela da mezena</td>
<td>Mizzen sail</td>
</tr>
<tr>
<td>23 Botaló</td>
<td>Outrigger</td>
</tr>
<tr>
<td>Mastro da contra-mezena (^{(A)})</td>
<td>Bonaventure mast</td>
</tr>
</tbody>
</table>

\(^{(A)}\) Not showing in the drawing of FIG. III.5.
Table III.3
Glossary - Standing and running rigging

<table>
<thead>
<tr>
<th>Portuguese</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Enxárcea</td>
<td>Shrouds</td>
</tr>
<tr>
<td>25 Estai do traquete</td>
<td>Fore stay</td>
</tr>
<tr>
<td>26 Estai da gávea do traquete</td>
<td>Fore topmast stay</td>
</tr>
<tr>
<td>27 Estai do mastro grande</td>
<td>Main stay</td>
</tr>
<tr>
<td>28 Estai da gávea do mastro grande</td>
<td>Main topmast stay</td>
</tr>
<tr>
<td>29 Braços</td>
<td>Braces</td>
</tr>
<tr>
<td>30 Escotas</td>
<td>Tacks</td>
</tr>
<tr>
<td>31 Escotias</td>
<td>Sheets</td>
</tr>
<tr>
<td>32 Guardim</td>
<td>Vang</td>
</tr>
<tr>
<td>33 Carregueiras</td>
<td>Leech lines</td>
</tr>
</tbody>
</table>

That is probably why the braces (29) of the foresail fall almost vertically, in a position impossible to handle. Note the existence of bonnets in both the fore and main sails.

As often happens, some of these parts have several different names, and sometime even nick-names as for instance the main sail, which is sometimes called *vela grande*, literally large sail, and other times *papa-figos grande*, literally large figpecker.

As mentioned above, these vessels may have been quite standardized in view of the regularity of the voyages and the structure of the trade. It is nevertheless difficult to make an educated guess as to how *Nossa Senhora dos Mártires* looked, was built, rigged, and sailed, in spite of the details of the upper works, spars, sails, and standing and running rigging we may obtain from the iconography.

The development of the model of the India naus

During the 16th and 17th centuries, a small fleet would leave Lisbon for India almost every year, making the India Route one of the longest regular routes of its time. The ships were designed and built specifically to sustain a six-month journey. They had to provide enough space for the crew and passengers, together with their water and victuals, and leave enough free space for the large amounts of merchandise brought back.
on the return trip. The main cargo – peppercorns – was a light commodity to store in the holds, especially if these vessels were to carry heavy artillery on the upper decks. A large amount of stone ballast was therefore added, reducing the space available in the holds. All things considered, it seems incredible that the average late 16th century India Route nau had a keel length of less than 30 m (100 ft).

Driven by the demand for large and reliable vessels for this long trip, Lisbon’s shipyard developed from a modest medieval structure into a large and complex organization, employing thousands of workers. Records from the 16th and 17th centuries show clearly that ships for the India Route were different from all other vessels built and sailed in Portugal, and that there was no possible interchange between the ships of this trade and the ones of other more traditional routes. The most obvious difference was in capacity. India naus may averaged around 500 or 600 toneladas (around 1,000 tons displacement) in the 16th century. The smaller trade ships that sailed the routes of northern Europe, the Mediterranean, the western coast of Africa, and Brazil, generally had capacities between 40 and 100 toneladas by the mid 16th century. The volume of the trade did not allow for larger vessels without increasing the risks of the business for a number of reasons. Larger vessels meant a more costly initial investment, higher maintenance and operating costs, bigger crews, slower trips, less maneuverability, longer stops at harbors, and were prized by pirates and privateers. These risks meant that larger ships had to carry artillery, an expensive feature that every shipper wanted to avoid because of the extra weight, extra people, higher costs, and heavier maintenance - all for dubious results in actions with professional plunderers. Nor was there a guaranty of full capacity freights year around for big ships. Everything weighed against the building of larger ships. Nevertheless, since at least 1470, the state issued a continuous stream of incentives to construct ships over 100 toneladas.

These incentives did not enhance the shipbuilding industry, and they were soon extended to the import of ships above this capacity. The state had an obvious interest in enlarging the fleet, however, both in number and in capacity, and restrictions were imposed on the sale of ships to foreigners as well as on the freights of ships owned
by foreigners. The volume of Portuguese trade did not seem to justify the purchase of ships bigger than 100 toneladas, and legislation issued in 1567, imposing the obligation of carrying artillery on all ships with capacities above that tonnage, met with the resistance of many ship owners who complained that this measure was going to increase the costs to an unbearable point for the freighters, and could kill their activity.

From the beginning of the 16th century, the state tried to impose standards for stronger, more durable naval construction, extending the rules and designs in use in its Lisbon shipyards to all the shipwrights in the country. The systems of weights and measures were also on the way to being unified, as were the taxes and benefits related to the trade and the shipbuilding industry. In this context, the India Route vessels' standard was probably a good political instrument to implement new rules and increase the general quality of shipbuilding in the Portuguese shipyards. Until this point, the great majority of shipyards were family businesses operating under old rules, traditions, and techniques transmitted orally through generations, and producing ships that could not respond to the demand for strength imposed by the use of artillery.

The arduous journeys of India naus required much more than the technology and materials of Portuguese shipbuilding could offer. These ships had to sail to India, where they were laden with pepper, spices and other exotic merchandises, and then sailed back to Portugal. The voyages could easily last from six to eight months each way, sometimes more. The most prized feature now was space. Besides huge cargoes of spices and merchandise, the ships had to carry supplies for the large crews, passengers and soldiers, spare sails, cables, anchors, masts, spars and other timbers, tools, artillery, and smaller weapons.

It is easy to understand why a tendency towards increased size in the ships developed since the beginning of the India Route, when Bartolomeu Dias's caravels were dismissed as too small to withstand such a long trip around the Cape of Good Hope. It seems that there was no consensus around the advantages of the size of these ships, which grew perhaps too large too soon, and legislation was issued in 1571 fixing the capacity of the ships built for the India Route between 300 and 450 tons. The
organization of the Lisbon shipyards was such that its workers, contractors, and suppliers tended to increase their profits if the ships were bigger, but the first really large India vessels did not prove advantageous. In spite of being much praised, the three great galleons built in the 1550s wrecked one after the other on the east coast of Africa. First S. João of 900 tons and built in 1550, was wrecked in 1552, then S. Bento, also of 900 tons and built in 1551, was wrecked in 1554. Finally Graça, rated at 1,000 tons and built in 1556, was and lost in 1559.  

The 1550s was not a good decade for super naus. Moreover, these large ships represented a smaller investment but greater risk in view of the value of the cargo that they could carry. Later, when the nau Madre de Deus, said to have a capacity of 1,600 tons, was captured by the British in 1592, the Portuguese crown endured another loss of a huge fortune in the disaster of just one vessel.  

However, the reasons mentioned by King Sebastian in 1570 supporting the prohibition on constructing India Route naus constructed with capacities above 450 tons were fundamentally financial: smaller ships were easier and cheaper to build and outfit for the voyage, easier to load, required smaller crews, and if they had to winter in Mozambique they incurred fewer expenses. There was no mention of the unseaworthiness of the larger ships of 900 to 1,000 tons. However, this omission does not exclude the possibility that the size of these ships may have elicited negative reactions among pilots and officers; they were probably more difficult to handle than the average 400 ton ship, and therefore more risky. The disadvantages of large vessels were later expressed by João Pereira Côrte Real, in the early 17th century, when shipbuilders again showed a tendency towards increased ship sizes, and specifically, to add a fourth deck to the already very high hulls.  

No matter how strong the efforts of the young King Sebastian to establish a standard for the India Route ship, it is doubtful that he managed to implement his ideas. It was not an easy task for royal officials engaged in this regulation to establish a priori the final tonnage of a ship, especially against the will of its builders — workers, officials, contractors, and suppliers, of its owners, and of the master shipwright in charge of its
construction. Whether Sebastian succeeded or not is impossible to say, because the available data pertaining to the tonnage of ships leaving Lisbon bound for India during the period 1487 and 1604 cover less than 10 percent of the vessels. It does show that less than one percent was smaller than 100 tons, 34 percent were between 100 and 300 tons, roughly 26 percent of the vessels had estimated capacities between 300 and 450 tons, and 40 percent above 450 tons.\textsuperscript{III.68} By the late 16\textsuperscript{th} century it seems that royal officials and shipbuilders were reaching a consensus about the size of India naus, at least from the perspective of the written texts and treatises on shipbuilding.
CHAPTER IV
THE VOYAGE OF THE NOSSA SENHORA DOS MÁRTIRES

The voyage

The East India Route was already over one century old one when Nossa Senhora dos Mártires set sail to India at the beginning of the 17th century. The mortality rates sustained in the first voyages diminished on later passages as experience grew. Vasco da Gama lost almost half of his men on his first trip in 1498-99 (Cornelis Houtman, leading the first Dutch expedition to the Far East nearly a century later, in 1595, lost 153 of his 240 men). Unfortunately, other problems faced by Portuguese crews were far from improved. Experience alone could not solve many of the difficulties and the seamen, soldiers, politicians, and merchants involved in the India Route endured dreadful living conditions for periods of six months and more, no matter how skillful they were. Ships always were too crowded, and living space was minimal. Sanitary conditions were bad, even by 17th century standards. As late as 1687 Father Fernão de Queiroz complained about the lack of sanitary conditions, which he identified as the primary cause of disease at sea.\textsuperscript{1} Food and water were almost always scarce, and its quality degraded rapidly in the tropical warmth. Vitamin deprivation generated terrible diseases such as scurvy and many lives were lost.

Crews

To date, no adequate scholarly study of life aboard the 15th and 16th centuries' India Route vessels has been made that focuses on the ages, social status, social mobility, and economic status of crews, passengers and soldiers – as has been done with the Spanish Carrera de las Indias to the New World.\textsuperscript{2} It is obvious that the destruction of the Casa da Índia's archives in the earthquake of 1755 makes this task far more difficult, but a number of accounts of voyages have survived in the form of chronicles, narratives, and letters, and these texts contain volumes of information about life aboard the India Route naus. The twelve best known, and perhaps most important,
of these narratives were gathered and published in the 18th century by Bernardo Gomes de Brito, under the title *História Trágico-Marítima*, and to which a new apocryphal volume was added (also in the 18th century) with another six accounts of voyages. Another collection of stories of voyages and shipwrecks was published by historian António Sérgio in the 1950s, and yet another by João Palma Ferreira in the 1970s. There is one other compilation containing six accounts published in *Biblos*, a history magazine, in 1916.

Foreign accounts of voyages to the East are another source of information. Around the time of the wreck of *Nossa Senhora dos Mártires* there are three main authors: Jan Linschoten, François Pyrard de Lavall and Jean Mocquet.

Especially important for this study are the accounts of three men who embarked on the nau *Betancor* in the last days of December of 1605, bound for Lisbon, as *Nossa Senhora dos Mártires* was a few days later. These three authors are Frei Gaspar de S. Bernardino, Nicolau Orta Rebelo, and Antão de Mesquita. Although *Nossa Senhora de Betancor* wrecked in Mozambique, these accounts of the first part of the trip offer a good insight into life aboard an India nau in the early 1600s. After the wreck, Frei Gaspar de S. Bernardino took the land route to the Mediterranean and sailed to Marseilles, from where he took another overland route to Lisbon. Antão de Mesquita sailed back to Goa and embarked in the nau *Nossa Senhora da Conceição* to Lisbon in the following year, in December 1606. As for Nicolau Orta Rebelo, he sailed to Mombassa and also took the land route to the Mediterranean, Marseilles, and Lisbon.

Perhaps the most interesting and disappointing fact is that there was a narrative of the loss of *Nossa Senhora dos Mártires*, written by a certain D. João Soares de Alarcão (1580-1618). The historian Patrick Lizé mentioned to me that it is referred to by Diogo Barbosa Machado in his *Bibliotheca Lusitana*, an 18th-Century catalogue of all the Portuguese literature existing at the time. We have both tried to contact the family and see if there is an archive where this account might be preserved, since there was no trace of it in the public libraries. Unfortunately, this manuscript is almost certainly lost, since by the second half of the 19th century, when Innocência Francisco da
Silva published his *Diccionário Bibliographico Portuguez*, an equivalent to Machado's *Bibliotheca Lusitana*, this text is no longer mentioned among the works of D. João Soares de Alarcão.\textsuperscript{IV.10}

Another important source of information for the understanding of life aboard the India Route nais are the numerous itineraries, in Portuguese *Roteiros*.\textsuperscript{IV.11} These generally dry and focused texts mainly describe the sailing conditions and decisions made by the captain and the pilots, the latitudes taken every day or so, the currents, winds, storms, islands and coasts sighted, the fauna seen around the ship, encounters with other vessels, and occasional accidents and happenings. These latter generally included deaths, births, and special religious ceremonies, and may occasionally prove a rich source of details. For instance, in Lisuarte de Abreu's narrative of the trip of the nau *Rainha* from Lisbon to Mozambique in 1558, a fast and calm trip of three and a half months – from April 7 to July 22, we learn of an encounter with a ship coming from India – the nau *São Gião* – on April 30, and the exchanges of food between them: chicken, sweets and wine from the *Rainha* for rice and coconuts from the *São Gião*. On the very night of the encounter between these two vessels, a sailor fell in the sea from the bow but managed to grab a cable hanging from the stern and was hauled aboard by the crew. Further on, Lisuarte de Abreu mentions how the only passenger to die on that trip, on May 11\textsuperscript{th}, was buried at sea the next morning with a cannon ball tied to his feet. His wife was aboard with three daughters, the eldest being 11 years old, and a boy of 8. As for the crew, Lisuarte tells us that a boy fell in the sea on the night of May 15 and could not be rescued because of the darkness, and that a fight on the 23\textsuperscript{rd} of the same month between two cabin boys, 14 and 8 years old, caused them to fall into the sea, one was retrieved but had already died from hitting his head on the anchor as he fell in the water. He was buried at sea by the chaplain, wrapped in a cloth, an hour later. A fourth cabin boy died on June 14 of a disease that made his feet swell. He was also buried in the sea, inside a big basket. After rounding Cape Agulhas on June 30, the wife of a cooper gave birth to a girl, on July the 10\textsuperscript{th}. About religious events, Lisuarte mentions a series of processions, on the 5\textsuperscript{th}, 13\textsuperscript{th}, 20\textsuperscript{th}, and 25\textsuperscript{th} of June, and on July 19, in which the
faithful crowd walked around the deck with candles singing and reciting prayers. The death of sailors and cabin boys was inevitable, since their work was risky, and their lives certainly violent. These vessels could carry large crews of 150 to 200 persons, of which approximately 60 were sailors, and 70 were cabin boys. The former were generally assigned tasks that required more practice and experience, such as steering, handling the sails, or fixing the rigging, and the latter carried out the tasks that required agility and strength, such as those that involved climbing masts and hanging from spars. The youngest cabin boys, like the 8 year old boy who died on the nau Rainha in 1558, were generally protected by older kin or friends, and received jobs like cleaning and scraping, cooking, and fetching things. It is likely that these boys also took the largest share of smacks, slaps, kicks and punches distributed aboard.

There is fair amount of data about the composition of the crews of Indiamen in the 16th and 17th centuries. Every crew included a captain (capitão), with ultimate authority over crew and passengers, a clerk (escrivão), charged with the cargo and its whereabouts, a chaplain (capelão) responsible for the care of the souls aboard, two pilots (piloto and sota-piloto) fully responsible for all matters related to navigation, and the seamen and ship's boys with their internal hierarchies. The sailors reported to the master (mestre) and the pilot through the boatswain (contramestre), and the boatswain's mate (guardião). The former was responsible for the crew at the stern and the latter at the bow. Then there were the auxiliary people, such as the carpenters (carpinteiro e carpinteiro sobressalente), caulkers (calafate and calafate sobressalente) and the cooper (tanoeiro), ready to fix everything that was broken. Also aboard were the purser (despenseiro), in charge of food stores and stocks, the bailiff (meirinho) who filled the role of justice officer, the barber (barbeiro), charged with hair care and the blood-letting of the sick, and the constable (condestável) with his gunners (bombardeiros) and soldiers (soldados). Some officers would be assisted by cabin boys or pages (pagens), generally charged with scrubbing and cleaning the ship, distributing meals and cleaning up afterwards. Their numbers varied from vessel to vessel. Contente Domingues cites the galleon S. Bartolomeu in 1589, which left for India with a crew of 150, and 250
soldiers. Figueiredo Falcão mentions a crew of 124 people in 1607, and described their wages and benefits. The jobs and numbers of people performing each role also varied, as did the designations of the functions, but only slightly, as shown on Table IV.1.

To the ship's crew were added the passengers, generally businessmen, nobles, and priests, and frequently a number of soldiers. This crowd was packed on the main deck, castles, and weather deck, sharing their space with a number of animals brought by the rich for consumption during the trip, and that usually included cows, sheep, and pigs, together with the ubiquitous chickens, ducks, and rabbits.

<table>
<thead>
<tr>
<th>Galleon S. Bartolomeu, 1589</th>
<th>India nau, 1607</th>
<th>English equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Capitão</td>
<td>1 Capitão (^{(1)})</td>
<td>Captain</td>
</tr>
<tr>
<td>1 Escrivão</td>
<td>1 Escrivão (^{(1)})</td>
<td>Clerk</td>
</tr>
<tr>
<td>1 Capelão</td>
<td>1 Capelão (^{(1)})</td>
<td>Chaplain</td>
</tr>
<tr>
<td>1 Mestre</td>
<td>1 Mestre</td>
<td>Master</td>
</tr>
<tr>
<td>1 Piloto</td>
<td>1 Piloto</td>
<td>Pilot</td>
</tr>
<tr>
<td>1 Contramestre</td>
<td>1 Contramestre</td>
<td>Boatswain</td>
</tr>
<tr>
<td>1 Guardião</td>
<td>1 Guardião</td>
<td>Boatswain's mate</td>
</tr>
<tr>
<td>1 Sota-Piloto</td>
<td>1 Sota-Piloto</td>
<td>Second Pilot</td>
</tr>
<tr>
<td>2 Estrinqueiros</td>
<td>2 Estrinqueiros</td>
<td>Sailors (^{(2)})</td>
</tr>
<tr>
<td>2 Carpinteiros</td>
<td>2 Carpinteiros</td>
<td>Carpenters</td>
</tr>
<tr>
<td>2 Calafates</td>
<td>2 Calafates</td>
<td>Caulkers</td>
</tr>
<tr>
<td>1 Tanoeiro</td>
<td>1 Tanoeiro</td>
<td>Cooper</td>
</tr>
<tr>
<td>1 Despenseiro</td>
<td>1 Despenseiro</td>
<td>Purser</td>
</tr>
<tr>
<td>1 Meirinho</td>
<td>1 Meirinho</td>
<td>Bailiff</td>
</tr>
<tr>
<td>1 Barbeiro</td>
<td>-</td>
<td>Barber</td>
</tr>
<tr>
<td>50 Marinheiros</td>
<td>45 Marinheiros</td>
<td>Seamen</td>
</tr>
<tr>
<td>50 Grumetes</td>
<td>48 Grumetes</td>
<td>Ship's boys</td>
</tr>
<tr>
<td>4 Pagens</td>
<td>4 Pagens</td>
<td>Pages</td>
</tr>
<tr>
<td>1 Condestável</td>
<td>1 Condestável</td>
<td>Constable</td>
</tr>
<tr>
<td>29 Bombardeiros</td>
<td>11 Bombardeiros</td>
<td>Gunners</td>
</tr>
<tr>
<td>250 Soldados</td>
<td>-</td>
<td>Soldiers</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Not mentioned by Figueiredo Falcão, but obviously always part of the crew.

\(^{(2)}\) Sailors in charge of the windlass that operated the main sail and the foresail in the naus. There were no estrinqueiros aboard the galleons, since the sails were operated from the capstans.
There was a certain social mobility, which is suggested in a 1654 letter from the widow of Cristovão de Abreu, in which she asks the king for a pension. In this letter we learn that Cristóvão de Abreu had survived the wreck of Nossa Senhora dos Mártires in 1606, at the end of his first round trip to India. He completed another nine round trips and died on his 11th one in 1645, on the way to Lisbon, presumably of disease. His adventurous life deserves a description here. He was a ship's boy until 1610, having made three rounds trips to India in this capacity, in 1605-1606 on Nossa Senhora dos Mártires, in 1607-1608 aboard the nau S. Francisco, and in 1609-1610 aboard the galleon Santiago e S. Filipe. In 1610 he survived another shipwreck in the mouth of the Tagus, working as a seaman, when the nau Nossa Senhora da Oliveira was lost against the rocks of S. Lourenço da Cabeça Seca. The following year he again left Lisbon for India, aboard the nau S. Filipe, and did not return until 1616, on the galleon Nossa Senhora de Jesus. After one last trip as a seaman aboard the nau S. Carlos in 1619-1620, he embarked as a boatswain on the galleon Bom Jesus, part of the fleet that the king maintained to defend the coast. In 1622 he was boatswain's mate on the galleon Sto. António, capitânia of this fleet. In 1624 he departed to India on the galleon S. Pedro, this time as master.

In India he served in the armada that fought the Anglo-Dutch fleet in Ormuz and was appointed "captain of all people of the sea" in Goa, one year later. After serving as master on the galleon S. Jerónimo in India, he set sail to Lisbon as boatswain on the naveta Madre de Deus and served in the coastal fleet again, in 1629, aboard the urca S. João. In 1631-1632 he again journeyed to India, on the nau Nossa Senhora do Rosário, and again in 1633-1635, on the nau Nossa Senhora de Belém. This last vessel wrecked on the Natal coast, and Abreu survived both the wreck and the following death march through the deserted and perilous east African coast to the Portuguese base of Mozambique. Another survivor of this wreck, captain Joseph de Cabreira, wrote an account of these events but never mentioned Abreu's name, although he did write that "the boatswain was always punctual with his sailors." In 1639 Cristóvão de Abreu was master of the Lisbon shipyards – the famous Ribeira das Naus – and departed again
to India as master on the ship *Nossa Senhora do Rosário*, keeping his position in the shipyard. In 1642 he suffered another shipwreck on the way to India, as master of the galleon *S. Bento*, but he was back in Lisbon by 1644, when he departed again to India. According to his wife's letter – where she calls him captain – he died as master on the galleon *S. Lourenço* in 1645, on return from India. If he was 8 years old when he embarked in 1605 on his first voyage to India, he would have been 53 when he died, and far from an old man.\textsuperscript{14,16}

**Space**

The rich and powerful shared the after castle, namely the lodgings on the quarterdeck (*tolda*) and the small poop deck above it (*chapitêu*), and the after area of the main deck (*primeira coberta*), under the quarterdeck. The boxes and bales of their personal trade that would not fit in these areas were stored near the main mast, and their livestock was stored abaft the main mast, birds and rabbits in cages carefully piled and tied. The remaining area on the main deck was supposed to be cleared, including the forward area, under the forecastle, where the ship's boys would bundle to sleep. Underneath the main deck on the lower deck (*segunda coberta*), were the lodgings of the crew and soldiers, and the storage areas of their private merchandise. To starboard and abaft the main hatch were the lodgings and storage areas of the captain, master, pilot, second pilot, clerk, and purser. The corresponding area to the port side and a portion of the deck situated before these two areas were used for storage. Towards the bow, to starboard were the lodgings of the boatswain and boatswain's mate, and to port those of the carpenters, caulkers, and cooper. At the bow, under the foremast step, slept sailors and more ship's boys. The hold was used solely for drugs and spices of which pepper was the main cargo, stored in smaller magazines built for that purpose (FIG. II.3).

In the 1620s Admiral João Pereira Corte Real proposed a series of reforms to King Philip IV of Spain (1621-1665) – and III of Portugal (1621-1640) – which were primarily concerned with the size of the India Route naus, but which included a few
changes. His letters prove that by then there were several lodgings on the main deck, toward the bow, under the forecastle. IV.17

The lower decks were almost entirely occupied with cargo. On the return trip from India, holds were built on the lower deck, atop the ballast, which were carefully caulked and closed after being filled with the precious peppercorns. Most of the boxes and bales were stored above, on the second deck. Although the weather deck was supposed to carry livestock, and otherwise be clear for proper maneuvering of the ship, food preparation, religious activities, and defense of the vessel against enemy attack, it was frequently laden with merchandise on the return trips from India. These were mainly foodstuffs in the first weeks of navigation, but did include all sorts of boxes and bales piled around and above the ship's boat, the bits, capstan, and hatches. IV.18 For example, in 1554 the nau S. Bento was not only packed solid with merchandise under the main deck, but "brought seventy-two boxes and five barrels piled on the weather deck, and had such an amount of boxes and bales here that its height equaled the castles and poop deck." IV.19 Sometimes the cargo would also hang outside, over the channels, and even cabins were occasionally built hanging on the outside of the hull. Referring to the galleon Santiago in 1602, Melchior Estácio do Amaral wrote:

and in the body of the ship and under the bridge, and above it, and on the quarterdeck, and on the poop deck, over the ship's boat, and around the capstan, and on deck, there were so many boxes and bales stacked that one could not fit a person in. And even outside the hull, on the bulwarks and channels, hanged bales and cabins, as it is usage on these vessels, in such a way that one could not operate the sails, and nobody could use the capstan for eighteen days. IV.20

Life aboard

The lack of living space combined with abject boredom generated frequent quarrels, fights, and threats of revenge at the port of arrival. There was not much social life aboard except for the regularity of meals, and there are no references to reading
books as this activity was documented aboard the 16th century Spanish ships bound to the New World.\textsuperscript{IV.21} Gambling seems to have been a major occupation in spite of the efforts of the clergy. Father António Vieira claimed that gambling was considered bad and dangerous since the time of King Manuel, and advised that instead of gambling, the idle should learn how to operate the different weapons aboard, train in the arts of music, learn how to read the clouds, the sea, and the compass, how to operate the whipstaff, the pumps, or learn what cares were needed to handle the oven.\textsuperscript{IV.22}

In the "Relação do naufrágio da nau Santiago no ano de 1585, e itinerário da gente que dele se salvou, escrita por Manuel Godinho Cardoso, e agora novamente acrescentada com mais algumas notícias" the author explains that priests incapable of stopping such a vicious practice as gambling, allowed it, if the proceeds of every first hand of every gambling table were taken to help the poor and the sick.\textsuperscript{IV.23}

The Carreira da India cannot be discussed without mentioning the ubiquitous sea sickness, a nuisance that plagued almost everybody at least in the beginning of voyages. Manuel Godinho Cardoso mentioned an encounter with two Portuguese ships in the Atlantic, early during the trip to India of the nau Santiago in 1585. The ships were first thought to be French and orders were immediately given to prepare to fight, but not much was achieved, because the majority of the men in arms were sick.\textsuperscript{IV.24}

Religious life aboard ship was taken seriously, prayers were said every day, mass held every Sunday and holy day, and processions and other religious ceremonies, sometimes plays, were carried on for the entertainment of all. Aboard the nau Santiago, mass was not only said every Saturday, Sunday and holy day, but also on so many other days by pure devotion "that sailors that had been in the Carreira for fifteen and twenty years never had seen such solemn and divine performances."\textsuperscript{IV.25}

Together with the schedule of the prayers the schedule of the meals must have dictated the rhythm of the whole day.
Food

Apart from the time spent on devotions, gambling and small talk were the main occupations aboard, filling the long slow days. To eat was a source of great pleasure for the 'haves,' and much time, effort, and energy were spent on it. Slaves and servants would prepare several meals a day, from which sweets were seldom absent. For the 'have-nots' things were much simpler, but even they generally ate at least once a day, a perk that was not granted to a substantial part of the European population in the 16th and 17th centuries.

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<table>
<thead>
<tr>
<th>Quantities on the list</th>
<th>Totals in metric units</th>
<th>Rations (av. 362 people x 180 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.074 quintais of hardtack</td>
<td>64.44 tons</td>
<td>989 grams / person per day</td>
</tr>
<tr>
<td>115 pipas of wine</td>
<td>37.674 m³</td>
<td>0.578 l / person per day</td>
</tr>
<tr>
<td>1.086 arrobas of meat</td>
<td>16.29 tons</td>
<td>250 g / person per day</td>
</tr>
<tr>
<td>150 dozens of hakes</td>
<td>1800 units</td>
<td>5 fishes / person for the whole trip</td>
</tr>
<tr>
<td>315 quartilhos of azeite</td>
<td>157.5 liters</td>
<td>0.435 l / person for the whole trip</td>
</tr>
<tr>
<td>13 pipas of vinagre</td>
<td>4.259 m³</td>
<td>0.458 l / person per week</td>
</tr>
<tr>
<td>313 pipas of water</td>
<td>102.539 m³</td>
<td>1.764 l / person per day</td>
</tr>
<tr>
<td>25 moios of salt</td>
<td>19.5 m³</td>
<td>0.31 l / person per day</td>
</tr>
<tr>
<td>130 arrobas of sardines</td>
<td>1.950 tons</td>
<td>5.387 kg / person for the whole trip</td>
</tr>
<tr>
<td>14 alqueires of chick-peas</td>
<td>182 liters</td>
<td>0.5 l / person for the whole trip</td>
</tr>
<tr>
<td>10 alqueires of almonds</td>
<td>130 liters</td>
<td>0.36 l / person for the whole trip</td>
</tr>
<tr>
<td>10 alqueires of plums</td>
<td>130 liters</td>
<td>0.36 l / person for the whole trip</td>
</tr>
<tr>
<td>10 alqueires de lentilhas</td>
<td>130 liters</td>
<td>0.36 l / person for the whole trip</td>
</tr>
<tr>
<td>2 alqueires of mustard</td>
<td>26 liters</td>
<td>0.07 l / person for the whole trip</td>
</tr>
<tr>
<td>724 cabos of garlces</td>
<td>a cabo is a braid</td>
<td>2 braids / person for the whole trip</td>
</tr>
<tr>
<td>724 cabos of onions</td>
<td>-</td>
<td>2 braids / person for the whole trip</td>
</tr>
<tr>
<td>8 arrobas of sugar</td>
<td>117.52 Kg</td>
<td>325 g / person for the whole trip</td>
</tr>
<tr>
<td>8 arrobas of honey</td>
<td>117.52 Kg</td>
<td>325 g / person for the whole trip</td>
</tr>
</tbody>
</table>

(1) Source: Falcão, Luiz de Figueiredo, Livro em que se contêm toda a fazenda e real patrimônio dos reinos de Portugal, India, e ilhas adjacentes e outras particularidades, ordenado por Luiz de Figueiredo Falcão, secretario de el rei Filipes II,... Lisboa, Imprensa nacional, 1859, p. 200.
(2) Merely indicative, since we know that the soldiers' portions of hardtack, wine, olive oil, vinegar, salt, sardines, chick-peas, plums, lentils, mustard, sugar, and honey, were generally about 1/3 smaller than the ones of the crew.
A common sailor aboard a Portuguese Indiaman in the early 17th century would be supplied daily with a diet of hardtack – a hard bread, cooked two or three times – soaked in a mixture of wine and water, some salted meat, and beans, rice, or lentils. Fishing and personal supplies supplemented this diet.

The personal supplies frequently consisted of some fresh water, smoked ham, sausages, pickled vegetables, onions, garlic, and a small portion of fruits and sweets, which were generally finished long before the trip was over.  

A 1607 book gives a list of supplies for a nau of 550 tons, carrying a crew of 112 people and 250 soldiers and is presented below, in Table IV.2.

For the upper classes, there are extensive records of all the delicacies brought aboard to soften the boredom of their six-month trip. Gambling may have been the major preoccupation on the mind of the clergymen charged with the salvation of each ship's souls, but it appears that their personal zeal was directed towards gluttony. One would think that obsession with food would be considered a deadly sin in their day, but it was widely practiced among the rich, and the clergy itself gave no image of frugality when it came to this earthly occupation.

There are several accounts of the goods brought by Jesuit priests on their trips to India. One list of recommendations issued by the Order in 1602 included a long inventory of delicacies, of which the fresh pork, smoked ham, sausages, dried dog-fish, and sweets were not stored in the holds, but in an accessible locker, because they had to be eaten soon before they rotted in the warmth of the equatorial dead calm periods.

Wine, olive oil, vinegar, and hardtack were loaded, as always, in such abundance that their sale in India was expected to bring some revenue at the arrival, along with the pottery, pewter and copper wares, and empty barrels. The priest's daily diet was registered in detail with other recommendations which included advice for a calm trip, like an order to always side with the powerful and upper hierarchies during dissensions and quarrels, regardless of the reason for the argument. The meals consisted of a 'stove breakfast' taken early in the morning, between 8:30 and 9:30 AM, a substantial dinner around 2:00 PM, and a frugal supper, consisting of fresh fruits, dried grapes or figs,
cheese, olives and almonds, which could be followed by cold meats from dinner (some ham, sausages, or pork). Considering the possibilities allowed by this light supper, one wonders what quantities of food were consumed at the substantial dinner. Moreover, to those accustomed to eating immediately after waking up, a glass of wine to soak a slice of hardtack was advised before breakfast. Chicken was saved for Sundays, and so were the most substantial sweets. These were generally jams of sour cherries, peaches, pears, apples, melons, or plums, boiled in sugar syrup, as well as quince jam, and several other jams and jellies.\textsuperscript{IV.27} There is a list of the victuals that another Jesuit priest, Father Alexandre Valignano, returning to Portugal in 1576, brought aboard. He later returned to Asia and became a colleague and friend to one of the passengers of the nau \textit{Mártires}, Father Francisco Rodrigues, with whom he worked in Macao in 1603 and 1604.\textsuperscript{IV.28} Father Valignano's personal food list consisted of around 75 liters of wine, 4 barrels of water, 4 barrels of hardtack, 1 smoked pig, 30 kg of salted beef, 100 chicken, 50 pork sides (spare-ribs), 60 sausages, 20 hakes, 100 dried dog-fish, 15 pumpkins, 10 bales of rice, 1 barrel of vermicelli, 3 baskets of onions. Also included was a long list of different types of peas and beans, sweets, dried fruits, spices and condiments, all in small quantities, that included chick-peas, beans, lentils, sugar, quince jam, dried raisins, plums, and dates, mustard, garlic, pickled roots (achar), saffron, coriander, "one pound of each spice," olive oil, vinegar, and butter.\textsuperscript{IV.29} As to the officers' needs, we know that in 1631 a Captain António de Saldanha embarked on his trip from Lisbon to Goa with the impressive quantity of 275 kg of sweets, consisting of the above mentioned jams and jellies, sweet yellow paste – a mousse made of egg yolks and sugar syrup – and several sorts of sugars and honeys.

Besides the already-mentioned smoked ham and multiple varieties of sausages, there were much appreciated delicacies, such as pork feet or cow tongues, kept in barrels with salt. The beef and deer were packed fresh in barrels with vinegar, salt, mustard, and oregano. Partridges were first roasted in the oven, and once cooled quickly fried in boiling olive oil and stored in layers, with olive oil, vinegar, and spices. Rabbits, headless, were prepared in the same way.
Livestock was considered indispensable and included chickens, turkeys, geese, rabbits, and lambs and cow calves. Captain Saldanha also brought 600 chickens aboard for the six month trip. Each Jesuit priest was entitled to 100 chickens, which gives an impressive rate of consumption if one considers that they were to be consumed on Sundays, and that there were about 26 Sundays in the average six month duration of the voyage.

Fish was considered quite healthy, and in addition to the dried dogfish already mentioned it was common to bring smoked herring or salmon, as well as dried and salted fish. Much appreciated were the escabeches, several species of fish and mollusks (mostly cuttle-fish, sole, eels, mussels and oysters) fried in olive oil and garlic, and stored with fried onion rings and spices.

All these meats were eaten with several kinds of beans, lentils, rice, or bread. Wheat and other types of flour were used to bake bread and many types of cakes, which supplemented the hardtack. Butter was preferred to pork fat because it lasted longer. Eggs were stored in large quantities, in glass containers filled with olive oil, as well as large amounts of cheeses of different qualities. Olives were stored in salt; pickled capers and other vegetables were used to strengthen one's appetite, and chestnuts were roasted with sugar and later used in the stews.

Fruits and vegetables were also part of the fresh diet, consisting of oranges, lemons, watermelons, and apples which were eaten at the beginning of the voyages. Vegetables such as cabbage were preserved in salt, or fried in olive oil and stored with pepper, onions, vinegar, mustard, and olive oil. Onions were either pickled in vinegar or stored fresh, hanging in plaits, as was the garlic.

Even considering that no food could sustain a six-month trip under those conditions without some sort of chemical and bacteriological decay, the same limitations applied to the diet of those on land, and fresh meat and vegetables were by no means an abundant commodity in 17th century Europe.

Regarding the filthy conditions of the vessels, often times mentioned in the literature, we know for a fact how tolerant the 17th century population was to foul smells.
As an example of this, we can imagine what sort of odors would emanate on breezeless, hot afternoons from the narrow alley in late 17th century Port Royal, Jamaica – the second most important city in the French and English New World – where the local butcher dumped the bones, guts, and other waste from his shop.\textsuperscript{IV.30} Mired in stench, these relatively small and highly crowded naus sailed down the Atlantic Ocean during the spring, across the torrid equator during a perpetual summer, and around the tip of Africa in the peak of the southern winter, in order to reach the Indian Ocean and finally lay anchor in the tropical wet climate of the Indian peninsula. If the trips lasted the average of six months, chances of surviving were actually quite high. Disease, commonly scurvy, would plague many, but by the early 17th century captains rarely lost more than a few people to fevers and scurvy. Some well fed, others starving, all badly lodged, the majority suffering from thirst and lack of vitamins, and all permanently shaken by the sea, the majority would arrive safely in India, with hopes of fortune, glory, or just a better life.

**The East India voyage in the late 16th and early 17th centuries**

During the Habsburg period, fate for many was rather different. Statistics show that the number of shipwrecks increased greatly, and many must have perished in these accidents. Many authors have addressed this wave of losses of Portuguese vessels at sea, and have assigned several probable causes to it, building a picture of catastrophic decline that may not actually be true.\textsuperscript{IV.31} It seems that from 1582 to 1602, 38 ships wrecked on the India Route. Of these, a small percentage was taken or burnt by English or Dutch privateers and the overwhelming majority sank due to bad weather conditions.\textsuperscript{IV.32} Some scholars contest this catastrophic view, arguing that a number of these lost vessels did not sink, but were beached in Africa and Brasil instead, and therefore the cargoes were not lost.\textsuperscript{IV.33} In fact, there are records pertaining to transshipment of the cargoes from stranded vessels, and arrivals of merchandise one year after the loss of a ship, as well as strong evidence for the sales of cargoes from lost ships in Brazil.
To give an idea of the sums involved in this trade, the building and fitting of an India nau, in the first decade of the 17th century, would cost 60 to 75 thousand cruzados (24 to 30,000$000 reis), twice the amount needed to build and fit a galleon of 550 toneladas. If two vessels of a fleet of four completed the round trip, as happened almost always, the king generally received 350,000 cruzados in pepper, plus another 150,000 in custom taxes. The merchants could make around ten times that amount, excluding the undeclared goods. This meant that the 250,000 cruzados spent building four vessels represented less than five percent of total gross returns.\textsuperscript{IV.34}

Possibly for this reason, not many of these profits were invested in the India Route – building new vessels, improving their performance, or studying the enemy's vessels. Upon examining the history of this period, it seems that there was a general lassitude among those politically responsible, partly because the king was in Spain, and a foreigner anyway, and partly because the investors were not yet challenged by the competition of the Dutch and English East India companies.

In 1601 three galleons arrived safely at Lisbon – S\textsuperscript{ão} Francisco, Concei\c{c}\~{a}o, and a third galleon whose name is not referenced – and brought 9,914 quintais of pepper (roughly 595 tons) that sold at 52 cruzados per quintal, producing 515,529 cruzados of revenue, to which the king added an unknown amount in customs duties, and 250,000 cruzados extorted from the New-Christian merchants in 'voluntary' loans. Half of the proceedings of 1601 were spent on the India Route, fitting new ships and crews, and the other half wasted on the war with Flanders.

In 1602, only two of the three vessels which left Goa arrived in July, bringing 7,598 quintais of pepper. In that year the nau S. Tiago Maior, under the command of António de Mello de Castro, fell into Dutch hands in St. Helena.\textsuperscript{IV.35} The king received close to 350,000 cruzados from the sale of the pepper, and another 150,000 from tax customs on private trade. Almost everything was spent on the war with Flanders, and the merchants and municipal corporations of Lisbon and Porto were forced to cover the costs of fitting the 1603 Armada.
In 1603 four vessels arrived with 21,349 quintais of pepper, but since the Dutch and English also shipped some pepper that summer the prices dropped drastically, and the Portuguese merchants were forced to buy the entire cargo from the king at an inflated price. King Filipe III of Spain was given 800,000 cruzados from the pepper and another 350,000 from customs on private trade, which he spent on the war with Flanders.

In 1604 six vessels arrived safely in Lisbon with a large cargo of pepper and other goods. The custom fees alone yielded the king 385,000 cruzados. Once again, almost all was spent on the war in Flanders, provoking another shortage of funds in Lisbon that dangerously delayed the departure of the 1604 fleet. As a result, of the five vessels that left Lisbon that summer, only one managed to pass the Cape of Good Hope and make it to India. Nossa Senhora da Palma, Nossa Senhora das Mercês, and São Nicolau came back in October, failing to round the Cape. The nau São Filipe was lost at sea. Only the nau S. Jacinto with the new Vice-King Martim Afonso de Castro arrived in Goa.

As mentioned in Chapter II, in 1604 a Dutch fleet of 13 sails, under the command of Steven van der Hagen, laid a blockade on Goa for 23 days in September and October, waiting for the Portuguese fleet. They only missed the ship of the vice-king because she spent the winter in Mozambique waiting for the monsoon, and did not arrive in India until 1605.\textsuperscript{36} By late 1604 or early 1605, the news that a Dutch war fleet had blockaded Goa and was remaining in Asia forced the crown into action, and 10 ships were fit to sail to India in 1605.\textsuperscript{37}

The voyage of Nossa Senhora dos Mártires

The voyage of Nossa Senhora dos Mártires to India in 1605 was said to have been a swift one, lasting exactly six months, and no one in the entire fleet died.\textsuperscript{38} In that year two fleets left for India. The first was commanded by Brás Telles de Meneses, and composed of six naus and a galleon (or seven naus), Nossa Senhora de Betancor. Captain Brás Telles de Meneses himself, Nossa Senhora da Oliveira, Captain Dom Francisco de Almeida, Nossa Senhora da Conceição, Captain Pero da Silva, Salvação,

The first fleet was supposed to load with merchandise and sail back to Lisbon in December. The second was to remain in Asia, to chase and give fight to the Dutch enemies, whose aggressive actions were bringing much concern to the Spanish authorities and the Portuguese merchant community.

The second fleet left the Tagus first, on March 9, with the vessels *Palma* and *Salvador*. The first weighed anchor two weeks later, on the 21st, now composed of five naus: *Nossa Senhora de Betancor*, *Nossa Senhora da Oliveira*, *Nossa Senhora da Conceição*, *Salvação*, and *Nossa Senhora dos Mártires*. IV.40

*Nossa Senhora dos Mártires* arrived safely on the Goa sandbar on September 28, six months and one week after leaving Lisbon. Preparations started almost immediately to load the merchandise and leave for Lisbon no later than December, as was standard. The nau *Mártires* and another three vessels departed almost immediately for Cochin to load with pepper, to be purchased for the sum of 180,000 cruzados. The nau *Betancor* stayed in Goa with the nau *S. Jacinto*, from the 1604 fleet, and underwent repairs. IV.41

On the voyage back to Lisbon, the former Vice-King Aires de Saldanha chose to travel aboard the nau *Mártires*, probably because it was in better shape, and invited Father Francisco Rodrigues to this vessel together with his young company, a Japanese Catholic named Miguel. Father Francisco Rodrigues was a Jesuit traveling to Rome to see the pope on an important mission pertaining to sustaining the Portuguese presence in Japan which had been threatened by a cut of Papal payments since 1597. IV.42

*Nossa Senhora dos Mártires* departed from Cochin with the nau *Salvação* on January 16, 1606, two weeks later than the rest of the fleet, which departed from Goa on December 30, 1605. IV.43 The outcome of these voyages was tragic. The nau *Nossa Senhora de Betancor* was stranded and abandoned in Mozambique, the majority of its
crew sailing back to Goa with part of the cargo. The nau *Nossa Senhora da Oliveira* lost its rudder opposite of Sofala, Mozambique, and sailed back to Goa with an improvised side rudder made of a large oar. The nau *Conceição* ran aground in Madagascar, also damaging its rudder. It limped to Mozambique, where it spent the winter, and sailed back to Lisbon in 1607, arriving safely. The naus *Mártires* and *Salvação* apparently sailed without major incident to the Azores, where we know *Mártires* arrived safely in late June. There they seem to have delayed their departure to Lisbon for several months. The Vice-King Aires de Saldanha died aboard *Nossa Senhora dos Mártires* on June 18, a few days before arriving at Terceira, and he was buried in the Cathedral of Angra do Heroísmo. His body was later transferred to the continent, to his hometown in Santarém, although nobody seems to know in which of the over 50 churches existing in the city at the time he was buried.\textsuperscript{14,44}

It is almost certain that the naus *Mártires* and *Salvação* sailed together from Angra do Heroísmo, in the Azores, to Lisbon. *Salvação* was in sight of Cascais on September 12, 1606, during a violent storm with strong southerly winds that made it impossible for the galley *Santiago*, of Dom Diego Brochero, to tow *Salvação* into the harbor of Lisbon. *Salvação* lay at anchor over the night, but the next day she broke her mooring cables and beached on the sandy bottom of the Bay of Cascais, allowing for the safe rescue of the crew, soldiers and passengers, as well as almost all of the cargo. *Nossa Senhora dos Mártires* arrived in sight of Cascais on September 13 and, unable to make it to the mouth of the Tagus against the strong southerly winds, dropped anchors to wait for improved weather. From her mooring place, Captain Manuel Barreto Rolim helplessly witnessed the loss of the nau *Salvação*. Two days later Mártires also lost her cables, the tide being low, and Captain Rolim tried to make it to the Tagus mouth. The Tagus bar was a difficult obstacle, however, since two large sandbanks narrowed the entrances, making the waters run dangerously fast in both the northern and southern channels. Rolim headed for the northern canal, which by the early 17\textsuperscript{th} century was already considered too narrow and shallow to lay anchor in, and too crooked for towing large by.\textsuperscript{14,45}
The construction of the São Julião da Barra fortress in the late 16th century obstructed the channels between the small islets upon which the bastion of S. Filipe had been built, and had allegedly triggered a process of silting in the channel. In the middle of the passage, the nau Mártyres lost her headway and was dragged onto a submerged rock. The nau sank in front of the São Julião da Barra fortress and was broken against the rocks in a matter of hours. The beaches from Lisbon to Cascais were soon filled with debris, and witnesses said that it looked more like the wreckage of an entire fleet than that of a single ship. On 19 September, about 200 bodies had already washed ashore, together with boxes, barrels, bales, and a black tide of peppercorns that extended several kilometers up and down the coast, pushed by the tidal currents. The officers of the crown recovered much of the cargo in the days that followed the tragedy, although nothing could be done to stop the populace from salvaging whatever washed ashore away from the soldiers.

A few names associated with Nossa Senhora dos Mártyres' last voyage

A historical investigation led by the team of the Portuguese Pavilion at EXPO'98 brought to light information about the lives of some of Mártyres' crew and passengers. These were Aires de Saldanha, 17th Vice-King of India (1600-1605), who died just before reaching the Azores on his return trip to the kingdom, and Captain Manuel Barreto Rolim, who survived the wrecking and continued trying to make a fortune on the India Route after being disinherited by his father due to an undesirable marriage. Rolim died in 1609 of disease near the Cape of Good Hope. Another two men aboard Mártyres were Pedro Álvares, a seaman who served 15 years in the India Route, who survived this wreck and retired from his seaman's life as boatswain's mate in 1611; and the ship's boy Cristóvão de Abreu, whose long career was described above. Of the clergy and passengers there was Jesuit Father Francisco Rodrigues, who lost his life after he refused a place on the ship's boat with the captain, and stayed behind to help and absolve those who asked for confession in face of death, and Miguel, the young Japanese Catholic convert who was traveling with Father Rodrigues and survived the wreck.
Miguel is known to have returned to Asia later, and is believed to have died in Macao around 1609 without ever returning to Japan.

This handful of people is an interesting sample of the people that traveled aboard the India naus: a vice-king, a captain, a sailor, a ship's boy, an experienced missionary, and a young Japanese Catholic. It is interesting that among the artifacts found on this wreck was the tsuba of a Japanese sabre (FIG. VII.5) from the Momoyama period (1573-1603). Of these six names only Father Rodrigues lost his life in *Nossa Senhora dos Mártires*’ shipwreck, but it is known that more than 200 people perished in this awful accident.
CHAPTER V
SITE FORMATION: WRECK, SALVAGE, AND LOOTING

The Tagus sandbar

It is not known whether the Nossa Senhora dos Mártires tried to enter the Tagus estuary through the southern or the northern channel. The letter from Don Luis Bravo de Acuña indicates the northern channel. The wreck occurred during a southern storm and at ebb tide, however, and it seems almost inconceivable that anyone would have attempted to navigate such a difficult passage. Rolin was an experienced sailor and must have known the risk he was taking.

FIG V.1 - The mouth of the Tagus River in the early 17th century showing the alignments utilized to enter the sandbar after Leonardo Torriano's Discurso.
In any case, navigating the sandbars at the mouth of the Tagus was never easy. Two large banks known as the Cachopos narrowed the channels and made the waters run dangerously fast in all three possible entrances (FIG. V.1). In addition to the northern and southern routes, a third, less important channel, known as the Torrão, was squeezed between the southern Cachopo, and the beach of Trafaria. By the early 17th century the latter channel was almost totally silted.

It seems probable that Rolim headed for the northern channel, which in the early 17th century was still the main entrance for vessels coming from the north. At that time, it was much larger and deeper than it is today, in spite of an ongoing process of intense silting that started in the early 1590s after the construction of the bastions of São Filipe and São Pedro extended the fortress of São Julião da Barra over the narrow channels separating the rocky promontory from the islets around it. The construction of the fortress of São Lourenço da Cabeça Seca, better known as Bugio fortress, also increased sedimentation rates.

São Julião da Barra was originally built according to the plans of the architect Miguel de Arruda, dated 1553. The extension of the fortress to the east, through the addition of the two bastions, followed the design of the Italian friar Giácomo Palearo, dated 1582 (FIG. V.2). The fortress of Bugio was ordered by the Duke of Alba before his death in 1582 and designed by another Italian, Tibúrcio Spannoch, Chief Engineer of Spain. Its construction was started in 1590 as part of a system designed to defend the mouth of the Tagus using three strategically-placed fortresses: São Julião da Barra, São Lourenço da Cabeça Seca, and Santo António do Estoril. The latter was also built in the 1590s, a project of yet another Italian friar, Giovanni Vicenzo Casale.\textsuperscript{V,3}

The construction of the fortress of São Lourenço da Cabeça Seca involved dumping tons of rocks over the shallows on the northern part of the southern Cachopo, and soon after the construction started an intense silting process arose at the sandbar. The deposited sand started to narrow the channels to dangerous widths and depths, making the entrance very difficult for vessels entering the Tagus. This threatened to destroy Philip II's plans to use Lisbon as the main port of his empire, as he had already
linked it to the inner plateau of Spain by expensive engineering work that allowed the Tagus to be navigated as far as the village of Aranjuez in Spain.

FIG. V.2 - The fortress extension over the islets to the east, as designed by Giácomo Palearo in 1582 and finished in 1590 or 1591, after Torriano's *Discurso*.

For the vessels of the India Route, this was one last difficulty to add to an already long and dangerous voyage. Although most pilots remained optimistic during the last years of the 16th century, by the early 17th century Italian engineer Leonardo Torriano was very apprehensive. Torriano was a strong-minded, straightforward personality that the Habsburg king had promoted to engineer of the kingdom of Portugal. After many examinations and observations, the intensity of the silting process was documented by several tests that showed increasingly shallow soundings in the three channels. In spite
of general animosity of the pilots towards Torriano, even some of them even agreed that
the sandbar was getting dangerous (FIG. V.3).

Gaspar Martinz, a pilot of the India Route, stated that "he would not dare to put
into the Northern Channel, because it was shallow, and not deep enough, and because it
was narrow and therefore it was impossible to lay anchor in it, and also because it was
crooked, making it impossible for the galleys to tow any nau out of there." V.4

The nau Mártrres is said to have lost her headway in the middle of the northern
passage and been dragged toward a submerged rock by the current. She sank in front of
the fortress of São Julião da Barra in a matter of hours, and soon afterwards she was
broken up into such small pieces that witnesses commented that it looked as if she had sunk long ago. V.5

FIG. V.3 - The mouth of the Tagus River in 1590 and 1595, before and after the beginning of the
construction of the fortress of São Julião da Barra after Torriano's *Discurso.*
Her main cargo of pepper had been stored loose in small holds and spilled out upon wrecking, forming a black tide that extended for leagues along the coast and the estuary of the Tagus. A large amount of pepper was saved and put to dry by the king’s officers. The local population also salvaged a notable quantity, as it was impossible for the soldiers to stop those who went to sea every night in small craft to salvage what they could despite the dreadful weather conditions. Fifty bodies washed ashore immediately after the wreck, and that total number rose to two hundred in the two or three subsequent days, a number that shows the scale of this terrible tragedy.

Salvage and looting

During the subsequent summers, the officers of King Philip III of Spain (who was also King Philip II of Portugal) may have salvaged a great part of the cargo from the shallow waters, and also recovered cables, anchors and guns. In spite of its dangers for navigation, the area around the fortress is frequently calm during the summer, and it is possible to work there during periods of low current, at high and low slack tides. Furthermore, near the fortress there is a zone that has almost no current during the whole ebb tide period. Historian Patrick Lizé found a letter in the Arquivo Histórico Ultramarino in Lisbon, dated from 2 July 1618, in which three divers asked permission to raise bronze guns from this site:

The Marquis Vice-King sent to this council a petition from Domingos Pirez, Jorge Pirez and Luís Galvão, divers, in order that it be analysed, and whatever issues that may seem relevant in it clarified, in which petition it is said that they (the divers) want to salvage the bronze guns that are in São Julião da Barra, for 30.000 reis each, on account of his majesty’s treasury. After consultation by this council, the Provedor dos Almazens was of the opinion that this offer should be accepted at that price, in view of the value of the guns, and so that His Majesty should order the said divers to retrieve the guns and pay them 30.000 for each
one, and pay any other remaining costs of the operation as well, in view of the
great need for guns in the king's fleets. V.6

In view of the opinions expressed in this document it seems certain that this
proposal was approved and that an unknown number of guns was retrieved from the area
around the fortress. These guns may have belonged to the Nossa Senhora dos Mártires,
the Spanish nau San Juan Baptista, lost nearby in 1587 while leaving Lisbon, or to an
elusive Portuguese galleon also believed to have been lost near the fortress in 1594, but
about which there is almost no information.

Many other bronze cannons have since been found on the site, and at least two
remain in situ, one deeply buried in the sand on the west side of the fortress, and another
covered by the wreckage of the trawler Santa Mafalda, lost in 1966. Another bronze
gun was found very close to the wreck during the 1994 excavation season. It was saved
from disappearing into a private collection by a group of dedicated sport divers during
the winter of 1994, following the introduction of treasure hunting legislation. With their
illegal, but very wise, initiative to raise this gun, these three divers saved a very
important clue for the dating of the wreck designated SJB2. Unfortunately, they also ran
into trouble with the authorities, who were at the time devoted to the legalization of
treasure hunting in the country, and suspicious of anyone who claimed not to be
interested in the monetary value of underwater cultural heritage. As expected, they were
soon acquitted of all charges, and we were left with a magnificent gun cast by the
famous Flemish founder Remigy the Halut (FIG. V.4).

FIG. V.4 - The bronze gun recovered by sport divers in 1994 after conservation.
Photo: José Pessoa, CNANS. Printed with permission of CNANS.
During inquiries conducted in the summers of 1999 and 2000, the existence of another three bronze guns was discovered. The first was found in 1972 by José Garcia, a sport diver, and sold to the Museu do Mar de Cascais soon afterwards. It is badly eroded due to lack of proper conservation treatment and has not been formally studied (FIG. V.5).

![Diagram of a site with a bronze gun and surrounding structures.]

FIG. V.5 - The bronze gun retrieved by José Garcia in 1972. Map and Photo: João Pedro Cardoso. Printed with permission of CNANS.

The second was recovered by a group of young divers and sold to an unidentified collector. However, two pictures are available and show a fairly small gun, probably dating from the 18th century and almost surely not related to the SJB2 wreck. Although I could not get copies of the pictures, one of the divers showed me the spot were it was found (See Appendix A, site SJB21). The third gun was very large and was found close
to the wooden hull structure. It was probably one of the Martires' guns, but unfortunately it was broken up in situ and sold for scrap in the 1980s. A picture of it was found in a private collection (FIG. V.6).

![Image](https://via.placeholder.com/150)

FIG V.6 - The bronze gun sold for scrap in the 1980s. Photo: CNANS archive. Printed with permission of CNANS.

As with many other wrecks that occurred in this dangerous channel, the Nossa Senhora dos Mártires was probably forgotten soon after its demise. By the 1620s the silting process stopped and the sandbars slowly began to erode. There is no apparent explanation for this reversal, although the older fishermen and the riverside population had blamed the horrible earthquake of 1531 for changes upriver that were at the turn of the 16th century still associated with increased sedimentation. Time rolled over the wreck as annual often dreadful winter storms slowly destroyed the remains of its heavy structure. In 1755 an earthquake again shook Lisbon. The tsunami that followed this
violent earthquake rolled heavy rocks over the hull remains of the *Mártires*. During excavation in 1996 stones weighing over one ton were found on top of the planking in the southern area, and over a layer of debris to the north.

Other wrecks came to rest around the fortress, spreading their artifacts over the site, and the violent dynamics of the sea mixed them with the material from the *Mártires*. Finally, in 1966, a codfish trawler wrecked near the site. It covered a large area, and protected many artifacts from the curiosity of spear fishers and sport divers who discovered the site in the early 1970s.

Stories of treasure troves around the fortress of São Julião da Barra were certainly transmitted through generations, and the spread of scuba diving beginning in the early 1950s heightened interest in the area. In the late 1970s, archaeological surveys were carried out by avocational archaeologists, but no governmental action was taken to protect the site (FIG V.7). As a result it was heavily looted by sport divers during the 1980s.

FIG V.7 - First map of the SJB1 area, drawn in 1976 by Mário J. Almeida. Map: CNANS archive. Printed with permission of CNANS.
Other maps of the area were drawn during the early 1980s by a group of avocational divers (FIG. V.8).

FIG V.8 - Second map of the SJB1 area, by Guilherme Cardoso. Map: CNANS Archive. Printed with permission of CNANS.

Many artifacts were retrieved from the area, the great majority ending up in private collections, or simply degrading away for lack of conservation. However, three collections of artifacts were eventually donated to the Museu Nacional de Arqueologia in Lisbon. The first was gathered in the 1970s and early 1980s by Francisco Reiner Garcia, an avocational archaeologist who organized a group of divers to survey the site and tried to open a small museum in the nearby village of Cascais. The museum proposal was thwarted by the bureaucratic labyrinths of the municipality, but the
majority of his collection was eventually donated to the Museu Nacional de Arqueologia. The second collection consists of a small number of artifacts mapped and retrieved by João Pedro Cardoso in the 1980s. The third collection encompasses 2008 artifacts and was donated in 1993 by Carlos Martins and Sofia Marques, two sport divers who lived near São Julião da Barra during their youth, and knew the area like the palm of their hand. When they joined the association Arqueonáutica they brought with them an intimate knowledge of the site that eventually lead to the discovery of the wooden hull structure. Furthermore, their precious collection of artifacts, gathered during more than a decade, was very well conserved.

Due to its extent and accessibility, the site situated immediately to the south of the fortress, designated as SJB1, is the one that has yielded – to my knowledge – the largest and perhaps most interesting collection of artifacts. The site was partially covered in the early 20th century by the construction of a swimming pool, and the shoreline is covered with debris from the countless portions of wall destroyed by the sea during the winter storms. Divers who used to spearfish in that area report a pile of lead ingots that once lay near the swimming pool and extended underneath it. A small number of these ingots were recovered in the 1970s, but none has yet been dated (FIG. V.9).

The officers in the fortress of São Julião da Barra have a bronze gun said to have been found in the area now occupied by the pool. The children who used to swim around the shoreline tell of countless silver coins once concreted to the rocks, that were recovered, melted and sold in Lisbon.

In addition to these stories of troves of coins and jewels, a large number of artifacts is known to have been found, dating from three distinct periods. The first group, consisting mostly of porcelain shards, dates to around 1600, and is clearly associated with the wreck of Nossa Senhora dos Mártires. Moreover, several pairs of dividers, similar to the ones found at SJB2 are said to have been found here, together with three interesting mortars. These artifacts are presently in private collections, making some of them inaccessible for study (FIG. V.10).
The second group of artifacts dates to the second half of the 17th century. Several coins bearing the date of 1655 were found within a large concretion containing more
than 500 *realles de a ocho* (pieces of eight), evidence of a still unidentified wreck that occurred after that date. Several sets of bronze nested weights also date from the second half of the 17th century. The existence of at least 19 sets as well as 22 isolated pieces has been reported. Thus far the whereabouts of 14 sets have been confirmed: six sets and 22 isolated pieces are in the collections of CNANS, one set is in the Museum of Quinta das Cruzes, in Funchal, Madeira Island, and seven sets are in known private collections (FIG. V.11). Two other sets were sold by an antique shop in Cascais to unknown private collectors, and three other sets could not be traced.

![Image of nested weights](image)

FIG. V.11 - Sets of nested weights from SJB1 in the collection of CNANS.
Photo: CNANS Archive. Printed with permission of CNANS.

The third group of artifacts is far less interesting from an archaeological point of view and pertains to the loss of the fishing boat *Santa Mafalda* in 1966. Most artifacts retrieved from São Julião da Barra dating to the 20th century are in private collections.
The majority consists of brass scuttles, although a few nautical instruments were recovered.

During the summers of 1999 and 2000, I conducted an inquiry on the whereabouts of all artifacts from São Julião da Barra whose possible existence had been reported. Sport divers known to have frequented the area were interviewed and the information they provided was later verified during dives at the site. As a result, a total of 28 sites can be identified that yielded artifacts dating from a period that starts in the late 16th century and ends in the late 20th century (FIG. V.12 and Table V.1).

![Map of Sao Julião da Barra and sites yielding artifacts.](image)

FIG. V.12 - The area around the fortress of São Julião da Barra and the sites that have yielded artifacts. Drawing: Filipe Castro.

Of these 28 sites, only a few can be securely related to the SJB2 wreck, presumed to be *Nossa Senhora dos Mártires*. These sites are SJB1, SJB2, SJB3, SJB6, SJB27 and
SJB28, as shown in FIG. V.12. Furthermore, the sites designated as SJB10 and SJB17 may be related to the wreck. The former site consists of a series of depressions in the rocky bottom from which several artifacts were retrieved, while a concretion containing fruit pits was found at the latter location. Only further study will be able to tell us whether these impressions of fruits are related to the SJB2 wreck site.

Table V.1
The artifact clusters and wreck sites around São Julião da Barra

<table>
<thead>
<tr>
<th>No.</th>
<th>Description of the site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anchors, iron guns and many artifacts including silver coins dating from the 1650s</td>
</tr>
<tr>
<td>2</td>
<td>Wreck site presumed to be the <em>Nossa Senhora dos Mártires</em>, 1606</td>
</tr>
<tr>
<td>3</td>
<td>Three iron guns and Wan-Li porcelain from the late 16th and early 17th centuries</td>
</tr>
<tr>
<td>4</td>
<td>Two large anchors, lead ingots and a pewter plate</td>
</tr>
<tr>
<td>5</td>
<td>Muskets and pottery shards dated to the 18th century</td>
</tr>
<tr>
<td>6</td>
<td>Large standing anchor with fluke stuck under the rocks and shank bent in the direction of the wreck</td>
</tr>
<tr>
<td>7</td>
<td>Iron hull of a steamship</td>
</tr>
<tr>
<td>8</td>
<td>Bronze object, presumably part of a bell</td>
</tr>
<tr>
<td>9</td>
<td>Wooden barrels</td>
</tr>
<tr>
<td>10</td>
<td>Pair of earrings dated to the late 16th and early 17th centuries</td>
</tr>
<tr>
<td>11</td>
<td>Artifacts from a 20th century wreck</td>
</tr>
<tr>
<td>12</td>
<td>Copper bolts and copper alloy pan handle</td>
</tr>
<tr>
<td>13</td>
<td>Small admiralty anchor</td>
</tr>
<tr>
<td>14</td>
<td>Section of the trawler <em>Santa Mafalda</em>, 1966</td>
</tr>
<tr>
<td>15</td>
<td>Pile of lead ingots</td>
</tr>
<tr>
<td>16</td>
<td>Large modern anchor, possibly from the trawler <em>Santa Mafalda</em>, 1966</td>
</tr>
<tr>
<td>17</td>
<td>Concretion with fruit pits</td>
</tr>
<tr>
<td>18</td>
<td>Bronze gun found during the construction of the swimming pool</td>
</tr>
<tr>
<td>19</td>
<td>Bronze gun trapped under the wreckage of the <em>Santa Mafalda</em></td>
</tr>
<tr>
<td>20</td>
<td>Gold and silver coins found during the construction of the swimming pool</td>
</tr>
<tr>
<td>21</td>
<td>Small bronze gun retrieved by sport divers in the late 1970s and lost</td>
</tr>
<tr>
<td>22</td>
<td>Recent iron gun</td>
</tr>
<tr>
<td>23</td>
<td>Small bronze gun retrieved by sport divers in the late 1970s</td>
</tr>
<tr>
<td>24</td>
<td>Iron guns</td>
</tr>
<tr>
<td>25</td>
<td>Iron gun</td>
</tr>
<tr>
<td>26</td>
<td>Bronze gun buried in the sand</td>
</tr>
<tr>
<td>27</td>
<td>Large bronze gun retrieved by sport divers in the early 1980s and sold for scrap</td>
</tr>
<tr>
<td>28</td>
<td>Hull timbers and peppercorns</td>
</tr>
</tbody>
</table>
A study of the artifacts related to the presumed wreck of Nossa Senhora dos Mártires is currently the subject of a Master's Thesis at Texas A&M University.\textsuperscript{7} However, a complete catalogue of the materials from the vicinity of São Julião da Barra sorted by sites and probable dates has not yet been undertaken.
CHAPTER VI
SURVEY AND EXCAVATION

The discovery

During the fall of 1993 and the spring of 1994, the Museu Nacional de Arqueologia and Arqueonáutica, conducted a survey of the area below the fortress of São Julião da Barra under the direction of Dr. Francisco Alves. Two main areas of archaeological interest were identified. The first area – designated SJB1 – consisted of a large concentration of anchors and iron guns, next to which many silver coins had been found during a previous survey, conducted by amateur archaeologists in the late 1970s (FIG. VI.1).

The second area – designated SJB2 – consisted of the remains of a wooden hull and associated shards of Ming porcelain and Chinese earthenware dating from the late 16th or early 17th centuries (FIG. VI.2). Based on information from the Museu Nacional de Arqueologia’s shipwreck archives, Nossa Senhora dos Mártires was identified as the most likely name for this wreck.

In 1993, the Portuguese government passed a law that allowed treasure hunting in Portuguese waters. Despite the scandal that arose almost immediately following the law's ratification - after the press made public a professional relationship between at least one advisor of the committee for the promotion of this decree and a known American treasure hunter - this law was not reversed until 1995, and was not repealed until 1997. All underwater archaeology projects were suspended during this period.

During these two years both the Museu Nacional de Arqueologia and Arqueonáutica spent all their time and energy promoting the cause of archaeology – mainly through courses offered around the country to sports divers, using the British Nautical Archaeology Society model – and attacking the treasure hunting legislation through an information campaign in the press. As a result, this legislation was finally halted in 1995 before any permit was ever issued to the many treasure hunting companies that proposed to work in Portugal. The government decided to create an agency to deal with the problems of the underwater cultural heritage and the project of São Julião da Barra was selected as the anchor project for the creation of this agency organism. Profiting from an excellent opportunity created by the preparations for the world exposition EXPO '98 held in Lisbon in the summer of 1998, this project became the main subject of the Portuguese pavilion at the exhibition, making a clear statement from the Portuguese government against treasure hunting.

In 1996 and 1997 excavations were therefore conducted on the SJB2 site, under the direction of Dr. Francisco Alves and myself, although I was hired only as a manager and an advisor to assist both the creation of the state agency for nautical archaeology mentioned above and to manage the logistics. The need for a manager was seen as necessary since this project was launched on a very tight schedule and in an environment of heavy bureaucracy and traditionally slow processing of information and documents.

The wooden hull was recorded, and an area of approximately 100 square meters was excavated. Many artifacts were recovered from within an ubiquitous layer of peppercorns. These included three nautical astrolabes and two dividers, several sounding leads, as well as porcelain, stoneware, earthenware, brass, copper, pewter,
silver and gold objects. Among the organic materials many peach pits were recovered along with ropes, fabrics, leather and straw, the latter found between seven stacked porcelain dishes. Several of these artifacts were exhibited in the Portuguese pavilion at EXPO '98, the World Exposition, held in Lisbon during the summer of 1998.

**Description of the site**

This archaeological site encompassed a large area strewn with lead straps and pottery shards over a layer of small pebbles and peppercorns. It was composed of the remains of a vessel – SJB2 or Pepper Wreck – located approximately 200m from the fortress of São Julião da Barra, at 9 meters of depth measured at high tide (FIG. VI.3).

The wooden structure was enclosed in a natural depression of the rocky bottom, sheltered by a small crest of rocks which extends north and west. A slight slope towards the south was filled by sediment. The hull remains rested on a layer of small pebbles with diameters between 8 and 15 cm and was embedded in a thick mire of peppercorns and pebbles with very few artifacts. The planking was separated from the frames and rested on the bottom, molded to its shape rather than to the shape of the lower face of the frames, as we were to find when we took profiles of it.

In this zone the rocky bottom consists of highly fossiliferous limestone, dating from the Miocene. The surface of the rocky substratum shows abundant perforations due to small bivalves, whose shells are still preserved in most of the holes. This presumes that sometime before the wreck, this rocky outcrop was free from sediment long enough to allow the growth of colonies of barnacles and small bivalves, apparently of the same species that attacked the upper surface of the wreck's timbers. Above the rocky base there was a fairly constant and clear stratigraphy (Table VI.1)

To the north of the hull a natural depression on the bottom followed the rocky outcrop that protected the wooden hull, and immediately suggested a perfect area for a trial excavation. The abundance of cultural materials found here determined the excavation of an area of around 100 m² that has produced an important collection of artefacts (FIG. VI.4).
FIG. VI.3 - Map of SJB2 hull after the 1997 field season. Drawing: Filipe Castro after CNANS plan.
Table VI.1  
SJB2 – Stratigraphy

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Variable</td>
<td>Highly movable siliceous sand layer with variable thickness. Very rich in cultural materials but highly contaminated with garbage of several possible proveniences, and mostly related with sports and professional fishing: lines, hooks, lead weights, abandoned and lost traps, ropes, nets, bottles, cans, etc.</td>
</tr>
<tr>
<td>B</td>
<td>5-30 cm</td>
<td>Dark sediment with sand, littered with lead straps from the caulking of SJB2’s hull.</td>
</tr>
<tr>
<td>C</td>
<td>20-60 cm</td>
<td>Pebbles (mostly of limestone and basalt) with diameters between 4 and 15 cm, sometimes impregnated with peppercorns. In certain areas this layer was not contaminated, and produced only shards dated from the time of the SJB2 wreck.</td>
</tr>
<tr>
<td>D</td>
<td>5-30 cm</td>
<td>Coarse sand with organic materials, mostly pepper, reasonably stable and generally not contaminated with more recent cultural materials. This layer has produced some interesting and sometimes intact artifacts, such as porcelain dishes.</td>
</tr>
<tr>
<td>E</td>
<td>2-5 cm</td>
<td>Yellow sand, very fine and very compacted. Archaeologically sterile.</td>
</tr>
<tr>
<td>F</td>
<td>-</td>
<td>Rocky bottom of Miocene fossiliferous limestone, heavily altered in certain zones, presenting a clayish consistency.</td>
</tr>
</tbody>
</table>

Among the most important were three astrolabes, of which two were found together with two dividers in an area of around 10 m². One of these astrolabes bore the date 1605 and the maker’s mark of the famous Goes’ family workshop in Lisbon (FIG. VI.10). A stack of seven porcelain dishes still with a layer of straw in between each and an iron gun that accreted the shards missing from a large porcelain platter fragment found nearby, were among many finds, including pewter plates, green and yellow Chinese glazed earthenware, Martaban stoneware, lead shot and cannonballs.

To the south, the increasing thickness of the sediments also promised some interesting troves. However, a large number of grenades dating from between World War I and World War II were discovered concreted to the bedrock. The excavation of this area was suspended until a thorough investigation could be performed by Navy divers. No one seeming to know how many, when nor why, these grenades were deposited. Work on the southern edge of the site was discontinued. At the end of the summer of 1997, a small number was detonated in situ by the Navy. After the
detonations a few 'rocks' that had shown a metallic content when surveyed with a metal detector broke and proved to be large lumps of concretions, housing many artefacts, and possibly rigging material. These were all left in situ, having neither the equipment to lift them properly, nor the capacity to treat them in the laboratory. A curious piece of wood with an engraved monogram was found in the presumed area of the bow, where the deck boys would have lived and kept their meagre possessions.

FIG. VI.4 - Map of squares Q1 to Q3, from the area excavated in 1996 and 1997. Drawing: Filipe Castro.

To the east there was a rocky surface, slightly elevated, where Remigy de Halut's bronze gun had been found near a small anchor. A series of fissures crossing this outcrop were excavated to the depth of an arm, producing a considerable amount of pot shards, peppercorns, peach pits, and coconut shells. Here a very interesting Japanese piece was found, the tsuba or hand guard of a small sabre made of a copper alloy (FIG. VI.5).

To the west the very thin layer of sediments covering the rough terrain did not allow for many artefact finds. Under a thin covering of sand (layer A) was a layer of pebbles of unknown thickness (layer C) that was not excavated for lack of time. However, a small and thin strata of planking, heavily eaten by wood worms, of 2.5 m by
1 m was atop layer C. Again, this section of the hull was not fully exposed for lack of time.

![Diagram of a Japanese tsuba](image)

FIG. VI.5 - Japanese tsuba. Photo: Pedro Gonçalves, CNANS. Printed with permission of CNANS.

Altogether four areas were excavated during the 1996-97 field season. The wooden hull, covering around 80 m², the north area, covering around 100 m², the east area fissures, covering another 100 m², and a small portion of the southern area, covering less than 50 m².

**Excavation**

The conditions surrounding the project were very complicated. The wreck site is situated at the entrance of the Lisbon harbor and is also a military zone, requiring a permit from the harbor authority and another from the Navy. Unfortunately, the permits were slow in coming and we began in late October of 1996, instead of early July.
The conditions of the sea are very difficult in the winter, with low visibility and strong tides. Also, we could only work during the ebb tide periods in order to avoid the strong and dangerous currents. This meant that we had to adjust the work schedule each day, many times getting out of bed early and out of the water late in the day. The team was quickly exhausted by the schedule and demanding conditions. The accessibility of the site was another problem. Every day we had to pack our equipment in one pickup truck and two or three private cars and drive to the Navy dock in Paço d'Arcos. This small stretch took between 30 and 45 minutes in the winter, and around one hour in the summer. Then we had to unload the equipment and pile all the tanks, pumps and pipes into three small boats. Finally we had to sail down the Tagus to the wreck site, around another 30 minutes, position our four large buoys in the corners of the working area, and set all the water dredges and airlifts in place before we started working. No equipment could be left on the bottom, both because of the swell and current, but also because our buoys and cables soon became much coveted by fishermen and sport divers, and would disappear over night if left on site.

FIG. VI.6 - The first days of work at São Julião da Barra in 1996.
Photo: Francisco Alves, CNANS. Printed with permission of CNANS.
Although the team was given one or two days' rest every week, determined by
the hours of the tides and the conditions of the sea, the directors had no other choice but
to work all week. In the summer of 1997 the conditions and the workload were
improved as a result of the participation of many sport divers, some of whom were
highly skilled and could be given tasks to perform with minimal supervision.

Methodology

A grid of datum points was first established on the site using climbing spikes
driven into the rocks. These points were then numbered and connected with cables. The
positions of the hull and the artifacts were referenced to this grid by triangulation.
Additional objects and topographic features were positioned in relation to at least two
datum points. All artifacts and lots were numbered, photographed, positioned, and
marked on a general plan at the end of each day of diving. As we analyze this
information, we are finding many flaws, both because of the inexperience of the great
majority of the team, and because of the hectic pace imposed by the timing of this
project within the program of the Portuguese pavilion at EXPO'98. In spite of mistakes
committed the map of the site produced over these two years can be considered quite
accurate, although incomplete in recording the details of certain bottom characteristics,
such as the limits of the rocky outcrops, the depth of the crevices, or the thickness of the
sediments on several points.

The hull was fully recorded at 1:1 scale on plexiglas slates of 1 m by 50 cm and
the drawings later transferred to plastic sheets and reduced in a photocopier to 1:10
scale. This process proved very intensive, complicated, and inaccurate due to the many
different projections obtained, and the inevitable parallax errors involved. In addition,
the violent surge tended to tear the plexiglas slates and throw them around with the
divers many times every dive. However, many additional measurements were taken, and
the plan was eventually and painstakingly corrected to a very good standard of accuracy.

During the subsequent field seasons of 1999 and 2000 some of the timbers were
raised and drawn in a dry environment. This allowed for verifying a large part of the
plan which proved to be accurate and reliable, with small mistakes and parallax of less than one percent of the overall dimensions. The only important deformations were due to the horizontal projection obtained in the drawing, in the longitudinal direction, the direction of the slope, where the planks were generally shorter than what would be expected. However, these errors were found to be consistently less than 2 percent.

FIG. VI.7 - Raising timbers during the 1999 field season.
Photo: Guilherme Garcia, CNANS. Printed with permission of CNANS.

The 1999 excavation season lasted two months. The first month entailed intense underwater work to record important construction details and to raise most of the remaining structure (FIG. VI.7). Unfortunately since the 1997 excavation season the
wood remains have been heavily damaged by rough sea conditions. Most of the second month was spent recording the timbers and preparing an exhibition of the artifact collection for Lisbon’s Naval Museum.

The 2000 excavation season consisted primarily of the recovery of the planking which had been wrapped and stored the previous year. Then followed a period of recording all timbers at an 1:10 scale and many at 1:1 scale. The last weeks of the season were spent surveying newly reported sites and inquiring about the location of artifacts known to exist in private collections. Finally, the remains of the hull were covered with sand bags and sand, and the raised timbers stored in the warehouse of the Centro Nacional de Arqueologia Náutica e Subaquática (CNANS) in Belém.

Identifying the wreck

The SJB2 wreck site is located within an archaeological complex, a relatively small stretch of sea bottom containing several shipwrecks. The strong dynamics of the sea and annual shift of sediments have combined to mix the artifacts of several wrecks, making this site at once an interesting and rich ship graveyard, but also a true nightmare for archaeologists, since the material culture represented in the collection of artifacts from this site encompasses a period of over 350 years.

It is not possible to state with entire confidence that this wreck is undoubtedly the Nossa Senhora dos Mártires. However, there is no other record of an Indiaman wrecked against the rocks of the São Julião da Barra promontory, and it is hard to imagine that a ship so large and richly laden could be lost in such a prominent spot and recorded as being lost somewhere else.

According to a database generated by CNANS many wrecks were lost at the mouth of the Tagus, a general designation that encompasses a very extensive area. Fortunately, the area of the fortress of São Julião da Barra is small, well defined and having such a precise toponymy, most vessels lost here are specifically referred to in official documents as being lost off the fort, rather than at another, less precise
designation. The records often correspond with and explain the provenience of artifacts retrieved or located near São Julião da Barra.

<table>
<thead>
<tr>
<th>Year</th>
<th>Ship</th>
<th>Nationality</th>
<th>Wreck site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1587</td>
<td>San Juan Baptista</td>
<td>Spanish</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1594</td>
<td>Galleon</td>
<td>Portuguese</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1606</td>
<td>N.ª S.ª dos Mártires</td>
<td>Portuguese</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1669</td>
<td>Saint Charles</td>
<td>French</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1733</td>
<td>Union</td>
<td>French</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1753</td>
<td>Merchantman</td>
<td>Dutch</td>
<td>Presumably E of the fortress</td>
</tr>
<tr>
<td>1783</td>
<td>N.ª S.ª da Conceição Africana</td>
<td>Portuguese</td>
<td>Beach of São Julião da Barra</td>
</tr>
<tr>
<td>1802</td>
<td>Ship</td>
<td>English</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1824</td>
<td>Boat</td>
<td>Local craft</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1867</td>
<td>Brig Oletim</td>
<td>Danish</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1870</td>
<td>Patacho Aliança</td>
<td>Portuguese</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>WWI</td>
<td>Maria Eduarda</td>
<td>Portuguese</td>
<td>Presumably W of the fortress</td>
</tr>
<tr>
<td>1917</td>
<td>Steamship Porto Alexandre</td>
<td>Portuguese</td>
<td>Near the fortress</td>
</tr>
<tr>
<td>1966</td>
<td>Santa Mafalda</td>
<td>Portuguese</td>
<td>Near the fortress</td>
</tr>
</tbody>
</table>

These known wrecks date from the late 16th century to the middle 20th century. But no database of shipwrecks is ever complete, and there are so many other references of shipwrecks in the area of the Tagus mouth, that I have divided the collected data into two major groups.

The first group – with 15 references – encompasses all wrecks registered as having been lost around the fortress of São Julião da Barra. This is a small group but references suggest that all this shipwrecks have a very strong probability of having occurred around the fortress (Table VI.2).

The second group – with 116 references – is referred to as having been lost in the area of the Tagus mouth, sometimes also referred to as the Cachopos, a vague designation that applies to the two rocky formations situated at the mouth of the river that create the two channels leading to Lisbon harbor. The small Cachopo Norte stands
between the northern and southern channel, and the large and very silted Cachopo Sul limits the southern channel. The wrecks listed in this group have occurred in the wide area of the Tagus mouth, which may sometimes include the estuary, but have a small probability of having occurred close to São Julião da Barra. They are referred to in the documents as 'leaving Lisbon', 'in the Lisbon sandbar', in the 'Tagus sandbar', or on the 'coast of Cascais', which encompasses the stretch of coast from Cascais to São Julião da Barra, including the area around the fortress. For the more recent wrecks, I have also included other references to the local toponymy whenever mentioned, such as 'Bugio', 'Ponta da Rana', or others (Table VI.3).

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<tr>
<th>Year</th>
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<th>Wreck site</th>
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Based on the most probable dates of the artifacts it seems reasonable that the Pepper Wreck has only four possible candidates for its identity. The first is the most obvious *Nossa Senhora dos Mártires* of 1606. The three other candidates are the Spanish nau *San Juan Baptista* wrecked in 1587, an unidentified Portuguese galleon wrecked in 1594, and the French vessel *Saint Charles* lost in 1669.

The clues leading to the tentative identification of the SJB2 wreck as the 1606 *Nossa Senhora dos Mártires* can be clustered in three main categories. Firstly, the artifacts found on this site match the expected period, around the turn of the century and not before 1605. Secondly, the materials employed in the construction of this vessel match those expected for an India Route nau. Thirdly, the relation between the dimensions of the timbers match both the units and the construction methods in use at the Portuguese shipyards around the turn of the 16th to the 17th century.

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FIG. VI.8 - Text incised on the base ring of the bronze culverin.
Photo: Pedro Gonçalves, CNANS. Printed with permission of CNANS.
Let us start with the artifacts that can be linked to this wreck site. The bronze culverin was founded by Remigy de Halut, head of the Flemish foundry at Malines, today's Mechelen, between 1536 and 1568 (FIG. VI.8). These dates do not exclude any of the possibilities, from 1587 to 1669, for old bronze guns have been found in many wrecks.

The porcelains belong to the Wan-Li period (1572-1620) and have been dated to 1595 to 1600 based on the typologies of the cartouches, rims and cavettos displayed on the whole vessels and fragments (FIG. VI.9). These typologies were subjected by fashions and therefore allow a more precise dating interval, precisely around 1606.

The three astrolabes, two of which (São Julião da Barra II and São Julião da Barra III) were found together with two dividers, pottery, and pewter plates, proved very
interesting. Firstly, because once we had identified which portion of the hull was preserved, they were found precisely abaft the ship's master frames, on the starboard side, the area where we would expect to find the quarters of the pilots, on the gun deck. Secondly, because the third astrolabe to be found, and therefore known as São Julião da Barra III, is perhaps one of the most important clues since it bears the date 1605, the date of departure of the *Nossa Senhora dos Mártires* from Lisbon (FIG. VI.10).

![FIG. VI.10 - Astrolabe São Julião da Barra III.](image)

Other, less precisely dated artifacts, agree with an Asian origin for the SJB2 vessel, excluding both the Spanish nau *San Juan Baptista* wrecked in 1587 as she was living Lisbon, and the unidentified Portuguese galleon wrecked in 1594, also lost on her way out. Three Chinese brown stoneware pots were found on the site, together with countless shards of the same kind (FIG. VI.11).

Also of Chinese origin were the green and yellow glazed earthenware shards (FIG. VI.12), as well as the blue and white Wan-Li shards (FIG. VI.13).
FIG. VI.11 - Chinese stoneware pots from SJB2. Photo: José Pessoa. Printed with permission of CNANS.

FIG. VI.12 - Chinese glazed green and yellow earthenware pot from SJB2. Photo: José Pessoa, CNANS. Printed with permission of CNANS.
From Martaban, in today's Burma, came the many stoneware shards with the characteristic dots imitating the rivets of copper pots. Finally, some shards of Japanese pots were found among the wreckage. And we cannot forget the Japanese sabre *tsuba*, which it is tempting to relate to the young Japanese Miguel who was coming to Portugal in company of Father Francisco Rodrigues (FIG. VI.5).

The remains of the ship itself suggest a Portuguese origin, ruling out both the Spanish nau *San Juan Baptista*, and the French vessel *Saint Charles* lost in 1669. This nau was built of cork oak (*Quercus suber*) and umbrella pine (*Pinus pinea*), and fastened with iron nails, typical Portuguese materials of the time, and not of other kind of European oak, as should be expected from the Spanish and French vessels. Furthermore, it was caulked with a string of lead in each seam, a practice only paralleled by the Portuguese Indiaman of the late 16th century found in the Seychelles and presumed to be the *Santo António* wrecked in 1589.\footnote{1.3}

More construction-related clues point in this direction, but these can only be fully understood when we analyse the remains of this hull in depth, as I will do in the next two chapters.
CHAPTER VII
HULL DESCRIPTION

The hull

Two features are immediately apparent when this hull is first examined: the scantlings are impressively large, and the wood utilized is of poor quality. As we will see further on, this large structure was built with timbers that were very small for the needs of the shipwright. All structural pieces were cut from relatively small cork oaks (Quercus suber), the species believed by Portuguese shipwrights to be most suitable for the construction of large ships. In contrast, all the hull planks were cut from fairly large umbrella pines (Pinus pinea), likewise thought to be the best material for planking these vessels.

The preserved portion of the hull was essentially flat at its north end, and the frames — floors and futtocks — rose and narrowed gradually towards the south. For this reason, the remains seemed almost immediately to correspond to the central part of the bottom of the ship, and are now believed to be situated immediately forward of the master frames. The ship was better preserved on one of its sides — the east, presumably port, side — due to the morphology of the sea bottom (FIG. VII.1).

![Level of sediments before excavation](image_url)

FIG. VII.1 - Schematic section of the wreck. Drawing: Filipe Castro.
FIG. VII.2 - Plan of the hull after the 2000 field season. Drawing: Filipe Castro.
A longitudinal fracture exists on this side, along a line inboard of the overlapping connections of the floors and futtocks, which were recessed down along the seabed, and survived to an extent of several meters (FIG. VII.2).

At the south (forward) end of the hull, the strakes were completely splintered along a fracture zone also related to the morphology of the bottom. No remains of the stem were found.

The wooden remains occupied an area of about 50 m², with a preserved length of 12 m in longitudinal axis and a maximum preserved breadth of about 7 m. This corresponds roughly to 2/5 of the estimated original length of the keel and approximately the width of the flat of the floors, plus 1/3 of the extension of the frames to the main deck.

The excavated portion of the hull consisted only of the keel, an apron, eleven frames, and twenty-six strakes of hull planking (Table VII.1). As explained above in Chapter VI, a dark colored silt layer impregnated with peppercorns filled the spaces between the floor timbers and extended over a large area around the hull, constituting a well defined archaeological layer with a thickness varying between 3-4 cm and 20-25 cm.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Section</th>
<th>Number of timbers</th>
<th>Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keel</td>
<td>sided: 25 cm;</td>
<td>4 timbers: Q0 and</td>
<td>Cork Oak</td>
</tr>
<tr>
<td></td>
<td>molded: unknown</td>
<td>Q1-Q3</td>
<td>(Quercus suber)</td>
</tr>
<tr>
<td>Apron</td>
<td>sided: 38 cm</td>
<td>1 timber: E1</td>
<td>Cork Oak</td>
</tr>
<tr>
<td></td>
<td>molded: 25 cm</td>
<td></td>
<td>(Quercus suber)</td>
</tr>
<tr>
<td>Floors</td>
<td>sided: 23-25 cm</td>
<td>11 timbers: C1-C11</td>
<td>Cork Oak</td>
</tr>
<tr>
<td></td>
<td>molded: 23-24 cm</td>
<td></td>
<td>(Quercus suber)</td>
</tr>
<tr>
<td>Futtocks</td>
<td>sided: 21-25 cm</td>
<td>18 timbers: B2W-B10W; B3E-C11E</td>
<td>Cork Oak</td>
</tr>
<tr>
<td></td>
<td>molded: 23-24 cm</td>
<td></td>
<td>(Quercus suber)</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>sided: 24 cm</td>
<td>1 timber: A4E</td>
<td>Cork Oak</td>
</tr>
<tr>
<td></td>
<td>molded: 24 cm</td>
<td></td>
<td>(Quercus suber)</td>
</tr>
<tr>
<td>Planking</td>
<td>sided: 15-35 cm</td>
<td>-</td>
<td>Umbrella Pine</td>
</tr>
<tr>
<td></td>
<td>molded: 11 cm</td>
<td></td>
<td>(Pinus pinea)</td>
</tr>
</tbody>
</table>
No traces of the keelson, footwales or ceiling were found on the site, undoubtedly due to the combined actions of the salvors, the shipworms, and the strong winter storms endured every year since the wrecking. Our crew learned firsthand just how violent the dynamics of this bottom can be — even on relatively sheltered portions of the hull. Towards the end of the 1997 season, before the hull had been reburied, a southern gale covered the wreck with over a meter of sand, making it impossible to re-expose the wreck and cover the structure with a protective layer of sand bags, before reburying it. During inspection the following summer, the timbers were found to be stable and were still covered with a thick layer of sand. However, the following winter, strong currents exposed the timbers, and the winter swells destroyed part of it, tearing away several floors, and depositing them several hundred yards away (Table VII.2).

Table VII.2
Status of the timbers after the 2000 field season

<table>
<thead>
<tr>
<th>Designation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keel</td>
<td>50 recovered in 1997</td>
</tr>
<tr>
<td></td>
<td>Q1, Q2 and Q3 recovered in 1999</td>
</tr>
<tr>
<td>Apron</td>
<td>E1 recovered in 1997</td>
</tr>
<tr>
<td>Floors</td>
<td>C1 lost during the field season of 1996</td>
</tr>
<tr>
<td></td>
<td>C2 and C3 recovered in 1997</td>
</tr>
<tr>
<td></td>
<td>East parts of C4, C5, C6 and C7 recovered in 1999</td>
</tr>
<tr>
<td></td>
<td>West parts of C4, C5, C6 and C7 lost between 1997 and 1999</td>
</tr>
<tr>
<td></td>
<td>C8, C9, C10 and C11 lost between 1997 and 1999</td>
</tr>
<tr>
<td>Futtocks</td>
<td>B2W, B3W and B3E recovered in 1997</td>
</tr>
<tr>
<td></td>
<td>B4E, B5E, B6E, B7E and B8E recovered in 1999</td>
</tr>
<tr>
<td></td>
<td>B4W to B10W and B9E to B11E lost between 1997 and 1999</td>
</tr>
<tr>
<td>Planking</td>
<td>1 plank recovered in 1997 (T11W)</td>
</tr>
<tr>
<td></td>
<td>4 planks recovered in 1999 (T1W(1), T1W(2), T2W(2) e T8W)</td>
</tr>
<tr>
<td></td>
<td>2 planks lost between 1997 and 1999 (T9W and T10W)</td>
</tr>
<tr>
<td></td>
<td>6 planks recovered in 2000 (T1W(3), T2W(1), T3W, T4W, T5W, T6W)</td>
</tr>
<tr>
<td></td>
<td>an undetermined number of planks remains in situ</td>
</tr>
</tbody>
</table>
Keel

The lower portions of the surviving keel timbers were badly eroded as a consequence of repeated abrasion against the rocky bottom during the wrecking. The keel's section measures 25 cm sided along the three portions preserved, and shows a maximum molded dimension of 20 cm (FIG. VII.3). The rabbets maintain a constant angle of 23° and an average depth of around 4.5 cm, occupying the upper part of the keel along 11 cm of its molded dimension.

![Diagram of keel section]

FIG. VII.3 - Best preserved section of the keel.  
Drawing: Filipe Castro.

As the keel shattered against the rocky bottom, two spikes and three of the bolts connecting the floors and the keelson to the keel were bent and preserved as imprints or concretions on the lower surface of the keel (FIG. VII.4).

Since these bolts exhibited different lengths as measured from the upper surface of the keel, it can be assumed that they were either pushed in or pulled out when the keel struck the bottom. It appears that two of the bolts were pushed inwards, resulting in lengths of 19 and 29 cm (measured from the upper surface of the keel), and that the third bolt may have been pulled out after the keelson broke loose, as it has a length of 46 cm, too long in relation to the remaining scantlings (Table VII.3).

In any case it seems fair to assume that the keel's molded dimension was between 29 and 46 cm.
FIG. VII.4 - Bolt linking the keel to the keelson at frame C7 (V).
Drawing: Filipe Castro.

<table>
<thead>
<tr>
<th>Keel timber</th>
<th>Floor</th>
<th>Length preserved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>C10 (II)</td>
<td>29 cm</td>
</tr>
<tr>
<td>Q2</td>
<td>C7 (V)</td>
<td>46 cm</td>
</tr>
<tr>
<td>Q3</td>
<td>C0 (XII)</td>
<td>19 cm</td>
</tr>
</tbody>
</table>

Table VII.3
Bolts connecting keel / keelson preserved

All sections of the keel exhibited a slight rocker, possibly designed to counteract the predictable hogging of the ship during use (FIG. VII.5).

The three preserved sections of the keel are very short, and are linked to each other by long, flat, vertical scarves, supporting the assumption that large straight oak timbers were not available to the shipwright (Table VII.4).
FIG. VII.5 - Sections Q1, Q2, and Q3 of the keel. Drawings: Filipe Castro.
Table VII.4
Keel - Length of scarves

<table>
<thead>
<tr>
<th>Section</th>
<th>Length preserved on the north side</th>
<th>Length of the keel between scarves</th>
<th>Length preserved on the south side</th>
<th>Percentage of the total length taken by the scarves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q0</td>
<td>-</td>
<td>-</td>
<td>34 cm</td>
<td>?</td>
</tr>
<tr>
<td>Q1</td>
<td>35 cm</td>
<td>176 cm</td>
<td>75 cm</td>
<td>46 %</td>
</tr>
<tr>
<td>Q2</td>
<td>75 cm</td>
<td>180 cm</td>
<td>41 cm</td>
<td>46 %</td>
</tr>
<tr>
<td>Q3</td>
<td>76 cm</td>
<td>157 cm</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

On each section there were two round holes bored to receive the bolts that connected the keel and keelson, placed one before and one abaft each keel scarf. The fully-preserved scarves presented tables around 75-76 cm long, a measure close to 3 palmos de goa (77 cm). Only one of these scarves was preserved well enough to show traces of a transverse spike, inserted from the port side, 15 cm below the upper surface of the keel, and 10 cm from the end of the scarf. This position, very close to the end of the scarf, suggests the existence of at least another two spikes in this connection. As in the outer planking, there was a counter-sink hole to house the head of this spike. The table was caulked with a thin and highly dense vegetable felt.

**Apron**

Situated at the south end of the site were the remains of an apron, still aligned with the axis of the keel, and retaining the concretions of two iron bolts bent by the violence of the impact against the rocky bottom (FIG. VII.6). The apron was cut from a single timber and measured 40 cm on its sided dimension, and 23 cm on its molded dimension. It was preserved along its full length, measured 1.79 m, and was notched to receive four floors on its top face, spaced at uneven intervals.
The apron was designed to sit on top of the keel and stem, and was bevelled to receive the lower planks, which made an angle of 135° with the top of the keel at this point. On its side faces this timber displayed notches to receive the four frames it supported (FIG. VII.7). As mentioned above, it seems that these frames were not placed at even intervals, given measures for the room-and-space between 40 and 53 cm (53, 40, 44, and 38+ cm). This represents a variation of more or less 6.5 cm around the average room-and-space measured on the preserved structure, which was 46.2 cm.

The upper surface of the apron showed two round holes from bolts, certainly connecting the keel and keelson through the frames and apron, two counter-sunk holes opened to receive the heads of two spikes connecting the apron to the keel, and four holes from the spikes connecting the frames to the apron. On its sides were holes left by the spikes used to fasten the garboards to the apron.
Frames

Eleven floors, designated C1 to C11, were preserved over the keel (FIG.VII.2). Futtocks were partially preserved on both the port and starboard ends of the floors. The floors and futtocks were joined with double dovetail scarves and fastened with three or
four iron spikes, all driven through pre-augered holes from the after side of the floor. These spikes had square shanks more or less 60 cm long with sides 1.8 to 2.0 cm; the squared heads with round corners were lodged in circular countersink holes, with diameters of ranging from 5 - 6 cm, and depths around 1.5 cm. On the forward faces of the futtocks the spikes were clenched and embedded in grooves.

Limber holes were cut under each floor, with a semi-elliptic form, 7 - 8 cm wide and 5 cm high. They seem to have been cut with a curved blade less than 1 cm wide - something similar to a gouge – in what was apparently a labor-intensive manner.

![Diagram of SJB2 - Position of the master frames]

FIG. VII.8 – Presumed position of the master frames. Drawing: Filipe Castro.

Only six futtocks were preserved to a substantial extent, the rest being preserved only along the extent of the overlapping joints with the respective floors. All the futtocks were attached to the forward side of the floors. To the north, nail marks on the
planking indicated the position of another four frames that were not preserved. These corresponded to floors C12, C13, C14 and C15. Of these, the first three were erected without any space between them (FIG. VII.8). In the space between floors C14 and C15 nail marks on the port and starboard sides showed the position of the futtocks of floor C14.

To the south (forward) end, the positions of another nine frames were clearly marked on the planking by the nail holes and butted joints of the planks (FIG. VII.9).

![Diagram](image)

FIG. VII.9 – Presumed positions of the nine frames to the south. Drawing: Filipe Castro.

While amidships the futtocks were attached to the floors at an average of 225 cm from the center of the keel, normally leaving three of four plank strakes exposed, the lower ends of the futtocks towards the bow gradually approach the keel axis (see Table VII.9).
Due to the extremely degraded state of the upper surfaces of the floors and futtocks, and the large variation in depth and extension of the tenons, it is difficult to determine whether all the joints were attached with double dovetail scarves, or if in some cases a single dovetail was used.

A single filling timber (A4) extended floor C4 to the east, between futtocks B5E and B4E. It probably functioned as an isolated reinforcement of a particularly weak and irregular futtock as B4E proved to be. The sided dimensions of the floors, futtocks and room-and-space measured in situ varied slightly, depending on the longitudinal section from where they were taken. This is explained by both the natural irregularity of the wood and by the distortions that occurred in the hull after the wreck, when the sides broke apart and collapsed to the bottom. In fact, many of these timbers were very crudely cut, and some even exhibited surfaces with preserved cork bark. To complete the full sections required for the frames, patches were extensively used. This was the case for futtocks B3E, B5E and B8E on the east side, and B1W and B10W on the west side (Table VII.5).

Marks from clenched nails were clearly visible on most of the top surfaces of both floors and futtocks. Only a small number of holes from nails driven from the frames upper faces were preserved—presumably corresponding to the footwale runs—leading to the conclusion that there was no ceiling in this central zone of the hull.

<table>
<thead>
<tr>
<th>Futtock</th>
<th>Patch</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3E</td>
<td>On its lower face, a patch with a length of 95 cm, and a maximum thickness of 7 cm</td>
</tr>
<tr>
<td>B5E</td>
<td>On the zone of the first dovetail, a patch with the dimensions: 47 x 15 x 10 cm</td>
</tr>
<tr>
<td>B7W</td>
<td>On the zone of the first dovetail, a patch with a preserved length of 12 cm, and a preserved thickness of 12 cm that covered the full molded dimension of the timber</td>
</tr>
<tr>
<td>B8E</td>
<td>On the zone of the second dovetail, a patch with a preserved length of 77 cm, and a preserved thickness of 10 cm that covered the full molded dimension of the timber</td>
</tr>
<tr>
<td>B10W</td>
<td>On the zone of the second dovetail, a patch with a preserved length of 39 cm, and a preserved thickness of 10 cm that covered the full molded dimension of the timber</td>
</tr>
</tbody>
</table>
Some floors and futtocks had wooden plugs filling nail cavities on the lower, external, faces (Table VII.6). Of these, some were only preserved on the frames (FIG. VII.10) and others were observed on the planking, after the removal of the floor (FIG. VII.11).

<table>
<thead>
<tr>
<th>Place</th>
<th>Dimensions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under floor C3</td>
<td>1 cm</td>
<td>Pyramidal</td>
</tr>
<tr>
<td></td>
<td>h = 4.5 cm</td>
<td>Only preserved on the floor</td>
</tr>
<tr>
<td>Under floor C4 at T11E</td>
<td>2 cm on the base</td>
<td>Frustum of pyramid</td>
</tr>
<tr>
<td></td>
<td>1 cm on the top</td>
<td>Preserved on the planking (damaged</td>
</tr>
<tr>
<td></td>
<td>h = 7 cm (+11)</td>
<td>during the raising of floor C7)</td>
</tr>
<tr>
<td>Under futtock B5E at T15E</td>
<td>2-1 cm on the base</td>
<td>Frustum of pyramid</td>
</tr>
<tr>
<td></td>
<td>h = 3 cm (+11)</td>
<td>Inserted at an angle</td>
</tr>
</tbody>
</table>

FIG. VII.10 – Plug under floor C3. Photos: Miguel Aleluia, CNANS. Printed with permission of CNANS.

In considering the dimensions of these timbers, it is interesting to note that the average sided dimensions of the floors as measured in situ was 24.6 cm, roughly four percent shorter than one palmo de goa (25.67 cm). The median value was 25 cm, less than three percent shorter than one palmo de goa (Table VII.7).
FIG. VII.11 – Plug on plank T11E, under floor C4. Photo: Augusto Salgado, CNANS. Printed with permission of CNANS.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Sided dimension</th>
<th>Dist. between frames (1)</th>
<th>Room-and-space</th>
<th>Dist. between frame axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11</td>
<td>26 cm</td>
<td>20 cm</td>
<td>46 cm</td>
<td>45.5 cm</td>
</tr>
<tr>
<td>C10</td>
<td>25 cm</td>
<td>24 cm</td>
<td>49 cm</td>
<td>47.5 cm</td>
</tr>
<tr>
<td>C9</td>
<td>22 cm</td>
<td>22 cm</td>
<td>44 cm</td>
<td>45.5 cm</td>
</tr>
<tr>
<td>C8</td>
<td>25 cm</td>
<td>20 cm</td>
<td>45 cm</td>
<td>45.5 cm</td>
</tr>
<tr>
<td>C7</td>
<td>26 cm</td>
<td>24 cm</td>
<td>50 cm</td>
<td>50 cm</td>
</tr>
<tr>
<td>C6</td>
<td>26 cm</td>
<td>23 cm</td>
<td>49 cm</td>
<td>48 cm</td>
</tr>
<tr>
<td>C5</td>
<td>24 cm</td>
<td>23 cm</td>
<td>47 cm</td>
<td>47.5 cm</td>
</tr>
<tr>
<td>C4</td>
<td>25 cm</td>
<td>18 cm</td>
<td>43 cm</td>
<td>42.5 cm</td>
</tr>
<tr>
<td>C3</td>
<td>24 cm</td>
<td>20 cm</td>
<td>44 cm</td>
<td>44.5 cm</td>
</tr>
<tr>
<td>C2</td>
<td>25 cm</td>
<td>20 cm</td>
<td>45 cm</td>
<td>44.5 cm</td>
</tr>
<tr>
<td>C1</td>
<td>24 cm</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(1) Corresponding sided dimensions of the futtocks.
The molded dimensions of the floors were very close to 25 cm at their extremities (between 24 and 26 cm), and grew in height towards the axis of the keel, where the concretions of the iron fastenings had preserved the sections almost in their entirety. This increase in height is significant, as it follows a curve that closely matches the curve proposed by Fernando Oliveira (see Chapter 4) for the rising of the floors at the forward end of an India nau (Table VII.8).

<table>
<thead>
<tr>
<th>Frame</th>
<th>After Oliveira (cm)</th>
<th>N.° S.° Mártires (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11 (I)</td>
<td>25,8</td>
<td>-</td>
</tr>
<tr>
<td>C10 (II)</td>
<td>26,4</td>
<td>31</td>
</tr>
<tr>
<td>C9 (III)</td>
<td>27,2</td>
<td>25</td>
</tr>
<tr>
<td>C8 (IV)</td>
<td>28,5</td>
<td>27</td>
</tr>
<tr>
<td>C7 (V)</td>
<td>30,0</td>
<td>36</td>
</tr>
<tr>
<td>C6 (VI)</td>
<td>31,9</td>
<td>31</td>
</tr>
<tr>
<td>C5 (VII)</td>
<td>34,0</td>
<td>35</td>
</tr>
<tr>
<td>C4 (VIII)</td>
<td>36,5</td>
<td>37</td>
</tr>
<tr>
<td>C3 (VIII)</td>
<td>39,2</td>
<td>39</td>
</tr>
<tr>
<td>C2 (X)</td>
<td>42,2</td>
<td>42</td>
</tr>
<tr>
<td>C1 (XI)</td>
<td>45,4</td>
<td>46</td>
</tr>
<tr>
<td>XII</td>
<td>48,8</td>
<td>-</td>
</tr>
<tr>
<td>XIII</td>
<td>52,3</td>
<td>-</td>
</tr>
<tr>
<td>XIII</td>
<td>56,1</td>
<td>-</td>
</tr>
<tr>
<td>XV</td>
<td>59,9</td>
<td>-</td>
</tr>
<tr>
<td>XVI</td>
<td>63,8</td>
<td>-</td>
</tr>
<tr>
<td>XVII</td>
<td>67,8</td>
<td>-</td>
</tr>
<tr>
<td>XVIII</td>
<td>71,9</td>
<td>-</td>
</tr>
</tbody>
</table>

The futtocks exhibited sided dimensions slightly narrower than those of the floors (Table VII.9) with an average of 21.4 cm, again less than three percent smaller than one palmo de vara, with molded dimensions varying between 24 - 26 cm. All futtocks were evenly cut on their external, forward, and aft faces, but were sometimes roughly finished on their internal faces.
Another result of the irregularity of the wood utilized is the variation in the length of the overlap between the floors and the futtocks. In fact, neither the dovetail scarves nor the spikes fastening them seem to have been positioned with any consideration of the location of the turn of the bilge (Table VII.9).

<table>
<thead>
<tr>
<th>Floor</th>
<th>Distance to the extremity (W)</th>
<th>Distance to the first dovetail (W)</th>
<th>Distance to the first dovetail (E)</th>
<th>Distance to the extremity (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11</td>
<td>-</td>
<td>129 cm</td>
<td>155 cm</td>
<td>180 cm</td>
</tr>
<tr>
<td>C10</td>
<td>223 cm</td>
<td>130 cm</td>
<td>180 cm</td>
<td>206 cm</td>
</tr>
<tr>
<td>C9</td>
<td>224 cm</td>
<td>153 cm</td>
<td>144 cm</td>
<td>246 cm</td>
</tr>
<tr>
<td>C8</td>
<td>228 cm</td>
<td>127 cm</td>
<td>139 cm</td>
<td>264 cm</td>
</tr>
<tr>
<td>C7</td>
<td>225 cm</td>
<td>Not visible</td>
<td>165 cm (1)</td>
<td>108+170 cm (1)</td>
</tr>
<tr>
<td>C6</td>
<td>206 cm</td>
<td>132 cm</td>
<td>140 cm (1)</td>
<td>152+134 cm (1)</td>
</tr>
<tr>
<td>C5</td>
<td>206 cm</td>
<td>145 cm</td>
<td>148 cm (1)</td>
<td>119+120 cm (1)</td>
</tr>
<tr>
<td>C4</td>
<td>197 cm</td>
<td>129 cm</td>
<td>164 cm (1)</td>
<td>205+88 cm (1)</td>
</tr>
<tr>
<td>C3</td>
<td>188 cm</td>
<td>115 cm</td>
<td>150 cm (1)</td>
<td>148+112 cm (1)</td>
</tr>
<tr>
<td>C2</td>
<td>175 cm</td>
<td>98 cm</td>
<td>163 cm (1)</td>
<td>165+77 cm (1)</td>
</tr>
<tr>
<td>C1</td>
<td>150 cm</td>
<td>97 cm</td>
<td>-</td>
<td>89 cm</td>
</tr>
</tbody>
</table>

(1) Estimated distance between the rupture surfaces discounted

**Construction marks**

Perhaps the most important feature presented by the frames is the collection of construction marks engraved on the faces of some of the floors. Although carefully recorded, the precise positions of the marks situated to portside of the keel were very difficult to establish because of the longitudinal fracture that split the hull in two.

This longitudinal fracture was carefully recorded in the 2000 field season, and although the seams along which the hull had split were often badly eroded, it has been possible to close the fracture and obtain corrected measures for the distances between some of these marks and the keel axis within a fair degree of accuracy (3 cm of maximum error).
The marks identified on the timbers preserved can be divided into five different types:

a) a sequential numbering of the frames using Roman numerals (Table VII.10 and FIG. VII.12);

<table>
<thead>
<tr>
<th>Floor</th>
<th>Marks</th>
<th>Position</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>‘X’</td>
<td>On the aft side, to starboard</td>
<td>-</td>
</tr>
<tr>
<td>C3</td>
<td>‘VIII’</td>
<td>On the aft side, to starboard</td>
<td>Incomplete: “…III”</td>
</tr>
<tr>
<td>C7</td>
<td>‘V’</td>
<td>On the aft side, to starboard</td>
<td>Inverted</td>
</tr>
<tr>
<td>C8</td>
<td>‘III’</td>
<td>On the aft side, to starboard</td>
<td>-</td>
</tr>
<tr>
<td>C9</td>
<td>‘III’</td>
<td>On the aft side, to starboard</td>
<td>-</td>
</tr>
</tbody>
</table>

FIG. VII.12 – Roman numeral "X" on floor C2. Photo: Miguel Aleluia, CNANS. Printed with permission of CNANS.
b) a series of vertical lines, marking the edges – in Portuguese *astilhas* – and the axis of the keel (Table VII.11 and FIG. VII.13);

<table>
<thead>
<tr>
<th>Floor</th>
<th>Marks</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2 (X)</td>
<td>Vertical grooves</td>
<td>On the aft side, on the axis and edges</td>
</tr>
<tr>
<td>C9 (III)</td>
<td>Vertical grooves</td>
<td>On the aft side, on the axis and edges</td>
</tr>
<tr>
<td>C10 (III)</td>
<td>Vertical grooves</td>
<td>On the aft side, on the axis and starboard edge</td>
</tr>
</tbody>
</table>

FIG. VII.13 – Marks of keel axis and edges on floor C10. Photo: Miguel Aleluia, CNANS. Printed with permission of CNANS.
c) a series of lines marking the turn of the bilge (Table VII.12 and FIG. VII.14);

Table VII.12
Position of the construction marks – Turn of the bilge

<table>
<thead>
<tr>
<th>Floor</th>
<th>Marks</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 (VIII)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 202 cm (in situ) from the keel axis. 189 cm after correction</td>
</tr>
<tr>
<td>C5 (VII)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 202 cm (in situ) from the keel axis. 193 cm after correction</td>
</tr>
<tr>
<td>C6 (VI)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 203 cm (in situ) from the keel axis. 197 cm after correction</td>
</tr>
<tr>
<td>C7 (V)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 203 cm (in situ) from the keel axis. 200 cm after correction</td>
</tr>
</tbody>
</table>

FIG. VII.14 – Mark indicating the turn of the bilge on floor C6 (VI). Photo: Filipe Castro.
d) a series of marks whose significance is not clear, presumably made during early stages of the construction (Table VII.13 and FIG. VII.15);

<table>
<thead>
<tr>
<th>Floor</th>
<th>Marks</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2 (X)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 63 cm from the keel axis</td>
</tr>
<tr>
<td>C3 (VIII)</td>
<td>Vertical groove</td>
<td>On the aft side, to port side, 159 cm from the keel axis</td>
</tr>
<tr>
<td>C3 (VIII)</td>
<td>Vertical groove</td>
<td>On the aft side, to starboard, 169 cm from the keel axis</td>
</tr>
<tr>
<td>C3 (VIII)</td>
<td>Horizontal groove</td>
<td>On the base, to port side, 108 cm from the keel axis</td>
</tr>
</tbody>
</table>

FIG. VII.15 – Mark on the base of floor C3, at the precise point where the futtock ends.  
Photo: Filipe Castro
(3) a series of marks that seem to have no precise meaning, presumably resulting from gouging during the construction process, and only mentioned here because of their occurrence on the Angra D wreck (Table VII.14 and FIG. VII.16). VII.1

<table>
<thead>
<tr>
<th>Floor</th>
<th>Marks</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>Curved groove</td>
<td>On the aft side, to port, coming out of one of the countersink holes</td>
</tr>
<tr>
<td>C3</td>
<td>Curved groove</td>
<td>On the aft side, to port, coming out of one of the countersink holes</td>
</tr>
</tbody>
</table>

FIG. VII.16 – Groove on floor C3. Photo: Miguel Aleluia, CNANS. Printed with permission of CNANS.

The inversion of the number 'V' on floor C7 is paralleled by similarly inverted numerals on other wrecks, such as the 14th century ship from Catalonia known as Culip VI, the 15th century Ria de Aveiro 'A' wreck and the 16th century Cais do Sodré ship (Table VII.15).
<table>
<thead>
<tr>
<th>Name of the ship</th>
<th>Preserved marks</th>
<th>Master frame</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Nossa Senhora dos Mârtires</em> (early 17th century)</td>
<td>Of 3 types: numbering the floors, the marks ‘III’, ‘III’, ‘V’, ‘VIII(?)’ and ‘X’ marking the keel, vertical lines on floors ‘III’, ‘III’, and ‘X’</td>
<td>probably 3 master frames probably numbered 0</td>
<td>on the side facing the master frame on the starboard side at least one inverted on the side facing the master frame</td>
</tr>
<tr>
<td></td>
<td>marking the turn of the bilge, vertical lines on floors ‘V’, ‘VI’, ‘VII’ and ‘VIII’</td>
<td>not preserved</td>
<td>on the side facing the master frame</td>
</tr>
<tr>
<td><em>Cais do Sodré</em> (late 15th century)</td>
<td>Of 2 types: numbering the floors, the marks ‘XVI’, ‘XVII’ and ‘XVIII’, to the bow, and a complete sequence from ‘III’ to ‘XVII’ to the stern for the marking of the keel, vertical lines on almost all 18 numbered floors (fore and aft) and on some of the others</td>
<td>not preserved</td>
<td>on the side facing the master frame on the side facing the master frame both on port and starboard sides both inverted and straight on the side facing the master frame</td>
</tr>
<tr>
<td><em>Ria de Aveiro A</em> (middle 15th century)</td>
<td>Of the first type: numbering the floors, the marks ‘V’, ‘XII’ and ‘XV’</td>
<td>1 master frame numbered ‘I’</td>
<td>number ‘V’ facing the stern, number ‘XII’ on the upper face, number ‘XV’ facing master frame numbers ‘V’ and ‘XV’ on starboard, ‘XII’ on portside numbers ‘V’ and ‘XV’ inverted</td>
</tr>
<tr>
<td><em>Culip VI</em> (early 14th century)</td>
<td>Of 3 types: numbering the floors, the marks ‘I’ to ‘X’ to the stern, and ‘I’ to ‘XXVI’ to the bow marking the keel, vertical lines on all preserved central floors ‘I’ to ‘XXV’, and ‘I’ to ‘XI’</td>
<td>2 master frames each one numbered ‘I’</td>
<td>facing the master frame on port side to the bow and on starboard side to the stern All inverted, some repeated on the upper face on both master frames facing the master frame</td>
</tr>
<tr>
<td></td>
<td>marking the turn of the bilge, vertical lines on all preserved central floors ‘I’ to ‘XXV’, and ‘I’ to ‘XI’</td>
<td>on both master frames</td>
<td>on both master frames facing the master frame</td>
</tr>
</tbody>
</table>

The first and most obvious conclusion to reach about the existence of these marks, which are typical of, and well-described in, the Portuguese shipbuilding treatises
of the late 16th and early 17th centuries, is that the floors C12, C13 and C14, whose existence is known from nail holes, were the three master frames of this vessel, and would not have borne Roman numerals (as shown on FIG. VII.8).

The second conclusion that can be drawn is that, because the numbers inscribed on the floors match the ones on the theoretical curve proposed by Oliveira (see Table VII.8), there is a possibility that these floors belonged to a sequence of 18 pre-designed floors, as proposed by this author.

The next logical step was to check whether the marks indicating the turn of the bilge match Oliveira's model. After closing the longitudinal fracture that separates the starboard ends of floors C4, C5, C6, and C7, these marks were found to correspond to Oliveira's design (see Table VII.12).

FIG. VII.17 - Vertical marks (indicated by arrows) on floor C3.
A fourth archaeological parallel is currently under study: the late 17th century Belle, the vessel of Chevalier de La Salle's expedition to the Mississippi between 1682 and 1686. This ship also bears an impressive collection of construction marks. In the Belle all frames were numbered before and abaft the midship frame, which corresponded to the number zero.

As for the remaining marks, they undoubtedly had clear meanings for the shipwrights who built the Nossa Senhora dos Mártires, and some seem to mark more or less evident construction features. For example, the shallow groove incised on the lower face of floor C3, exactly marks the position of the tip of the mating floor. However, the meaning of many of these surmarks remains a mystery for the time being, especially in the case of the more or less faded vertical grooves marked on each side of floor C3, located almost exactly one palmo de goa from the turn of the bilge (FIG. VII.17).

As previously mentioned, of the 18 futtocks preserved on the site, 12 were preserved only along the extent of their overlap with the floors, and these timbers did not yield much information pertaining to the extension and radius of the hull's curves. However, the remaining six futtocks – B3E, B4E, B5E, B6E, B7E, and B8E – were much better preserved, measuring around three meters in length, allowing for the study of their curvatures (Table VII.16).

<table>
<thead>
<tr>
<th>Futtock</th>
<th>Extension (cm)</th>
<th>Sided (cm)</th>
<th>Molded (cm)</th>
<th>Futtock</th>
<th>Extension (cm)</th>
<th>Sided (cm)</th>
<th>Molded (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2W</td>
<td>108</td>
<td>21/20</td>
<td>24/26</td>
<td>B2E</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B3W</td>
<td>129</td>
<td>24/22</td>
<td>24/26</td>
<td>B3E</td>
<td>316</td>
<td>24/19</td>
<td>24/26</td>
</tr>
<tr>
<td>B4W</td>
<td>147</td>
<td>22/18</td>
<td>24/26</td>
<td>B4E</td>
<td>315</td>
<td>25/18</td>
<td>24/26</td>
</tr>
<tr>
<td>B5W</td>
<td>113</td>
<td>25/22</td>
<td>24/26</td>
<td>B5E</td>
<td>315</td>
<td>25/23</td>
<td>24/26</td>
</tr>
<tr>
<td>B6W</td>
<td>119</td>
<td>22/21</td>
<td>24/26</td>
<td>B6E</td>
<td>286</td>
<td>24/22</td>
<td>24/26</td>
</tr>
<tr>
<td>B7W</td>
<td>157</td>
<td>24/22</td>
<td>24/26</td>
<td>B7E</td>
<td>287</td>
<td>25/22</td>
<td>24/26</td>
</tr>
<tr>
<td>B8W</td>
<td>160</td>
<td>24/21</td>
<td>24/26</td>
<td>B8E</td>
<td>289</td>
<td>27/24</td>
<td>24/26</td>
</tr>
<tr>
<td>B9W</td>
<td>123</td>
<td>24/23</td>
<td>24/26</td>
<td>B9E</td>
<td>168</td>
<td>25/20</td>
<td>24/26</td>
</tr>
<tr>
<td>B10W</td>
<td>157</td>
<td>24/20</td>
<td>24/26</td>
<td>B10E</td>
<td>171</td>
<td>-</td>
<td>24/26</td>
</tr>
<tr>
<td>B11W</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>B11E</td>
<td>132</td>
<td>-</td>
<td>24/26</td>
</tr>
</tbody>
</table>
The study of the curvature of these futtocks was difficult and somewhat inconclusive. Not only was the construction generally crude, with no smooth surfaces on any of the preserved futtocks, but the lower faces of the futtocks had undergone heavy dubbing during the construction of the vessel in order to bevel the outer face of the frames to receive the planking. The small number and poor preservation of the extant futtocks made their analysis even more difficult.

An attempt was made to determine the arcs of the futtocks with the best possible accuracy, resulting in very interesting, but puzzling results. The methodology adopted in the analysis of the futtocks was largely determined by the assumptions that the futtocks had one single arc, as indicated by Oliveira in his drawings and that all the futtocks had the same radius. Both of these assumptions were proven to be faulty.\textsuperscript{VII.2}

![Diagram](image)

**FIG VII.18** - Graphic method used to find the center of curvature of the futtocks. Drawing: Filipe Castro.
To find the values of the arcs of these six futtocks, three different methods were used. The first, a very simple geometric method, consisted of the graphic resolution of the center of the circle for a given group of three points (FIG. VII.18). This technique was quickly dismissed after a small number of tests, since the values obtained for the radius varied largely with the points chosen. These tests were made on 1:10 scale drawings obtained by reducing the full scale tracings using a computer-aided design program, and it is possible that any errors made during tracing were compounded during the scanning process.

The second method consisted of the use of templates with circular curves which were overlaid on the drawings of the futtocks to determine which curve fit best over each futtock. This method was also not very accurate, as the average preserved length of only three meters allowed a very wide number of arcs to fit equally well over the outline of each futtock.

The third method consisted of a mathematical analysis of the lists of coordinates (x,y) that define each one of the lower surfaces of the futtocks at 10 cm intervals. This analysis was performed with the help of two computer programs developed by Dr. Thomas Vogel of Texas A&M University Mathematics Department, which run on a Maple V® environment. The first of these programs finds the best fit circular curve for a given number of points. The second program finds the radius of each three consecutive points and lists the series of radii obtained.

The available data was run through the two programs with rather inconclusive results. The radii obtained using the first program clearly showed the existence of a turn of the bilge arc and a futtock arc, and suggested the existence of a tumblehome arc in the longer futtocks. However, the results varied too widely to allow for any further analysis, and thus the second program was employed. Convinced that the x and y values taken at the extremities of the futtocks might create some form of noise in the computation of the values of the radii if there were three arcs, several combinations of points were tested. As a result, the radius of the best fit circular curve for each futtock was determined, for nine different combinations of points: for the whole extension of the futtocks every 10
cm and every 30 cm, and excluding 50 cm in each one of the extremities, for five points, and for five different combinations of three points. I have built a table with all the values given by the computer program (Table VII.17).

<table>
<thead>
<tr>
<th>Futtock</th>
<th>// 10 cm</th>
<th>// 30 cm</th>
<th>5 Points</th>
<th>3 Points</th>
<th>3 Points</th>
<th>3 Points</th>
<th>3 Points</th>
<th>3 Points</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3E</td>
<td>4.08</td>
<td>4.30</td>
<td>4.70</td>
<td>5.02</td>
<td>4.87</td>
<td>4.77</td>
<td>4.68</td>
<td>5.43</td>
<td>4.73</td>
</tr>
<tr>
<td>B4E</td>
<td>3.48</td>
<td>3.63</td>
<td>3.77</td>
<td>3.83</td>
<td>3.51</td>
<td>4.03</td>
<td>3.80</td>
<td>3.75</td>
<td>3.73</td>
</tr>
<tr>
<td>B5E</td>
<td>5.17</td>
<td>5.25</td>
<td>4.81</td>
<td>4.71</td>
<td>4.58</td>
<td>5.14</td>
<td>4.80</td>
<td>4.71</td>
<td>4.90</td>
</tr>
<tr>
<td>B6E</td>
<td>4.39</td>
<td>4.43</td>
<td>4.85</td>
<td>4.96</td>
<td>5.04</td>
<td>4.65</td>
<td>4.76</td>
<td>4.92</td>
<td>4.75</td>
</tr>
<tr>
<td>B7E</td>
<td>4.44</td>
<td>4.36</td>
<td>5.22</td>
<td>5.45</td>
<td>4.65</td>
<td>5.87</td>
<td>4.74</td>
<td>5.54</td>
<td>5.03</td>
</tr>
<tr>
<td>B8E</td>
<td>5.95</td>
<td>6.20</td>
<td>6.05</td>
<td>6.02</td>
<td>6.77</td>
<td>6.06</td>
<td>5.91</td>
<td>6.40</td>
<td>6.17</td>
</tr>
</tbody>
</table>

(1) and (2) calculated for the whole length; (3) to (7) for the central portion of the futtock in the following way: (4) x=50/150/250; (5) x=60/160/260; (6) x=40/140/240; (7) x=40/150/260; and (8) x=60/150/240.

The computerized values were then compared with the ones obtained from the templates (Table VII.18), using the two columns of Table VII.17 that seem most reliable or relevant to this analysis; the values obtained for the central portion considering five points along the curve; and the average of the eight values.

<table>
<thead>
<tr>
<th>Futtock</th>
<th>Templates</th>
<th>Central Portion (5 points)</th>
<th>Average of the best-fit curves</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3E</td>
<td>18-19 pg</td>
<td>4.70 m = 18.3 pg</td>
<td>4.73 m = 18.4 pg</td>
</tr>
<tr>
<td>B4E</td>
<td>19 pg</td>
<td>3.77 m = 14.7 pg</td>
<td>3.73 m = 14.5 pg</td>
</tr>
<tr>
<td>B5E</td>
<td>19 pg</td>
<td>4.81 m = 18.7 pg</td>
<td>4.90 m = 19.1 pg</td>
</tr>
<tr>
<td>B6E</td>
<td>22 pg</td>
<td>4.85 m = 18.9 pg</td>
<td>4.75 m = 18.5 pg</td>
</tr>
<tr>
<td>B7E</td>
<td>22 pg</td>
<td>5.22 m = 20.3 pg</td>
<td>5.03 m = 19.6 pg</td>
</tr>
<tr>
<td>B8E</td>
<td>22-23 pg</td>
<td>6.05 m = 23.6 pg</td>
<td>6.17 m = 24 pg</td>
</tr>
</tbody>
</table>
All futtocks displayed a clear bevel in the direction of the bow, fairly constant and varying from 15 - 25 mm between the aft and the forward faces, and therefore from 30 - 50 mm between the aft face of the floor and the forward face of the futtock.


A particularly interesting feature of these frames is that three futtocks and one floor exhibited a treenail on their aft faces, near the external face, cut flush with its surface (Table VII.19).
### Table VII.19
Frames - Treenails

<table>
<thead>
<tr>
<th>Timber</th>
<th>Treenails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor C3</td>
<td>Ø 25 mm, octahedral, 12 mm from the lower edge, and 0.15 m from the keel axis</td>
</tr>
<tr>
<td>Futtock B3E</td>
<td>Ø 32 mm, octahedral, 8 mm from the lower edge, and 3.18 m from the keel axis</td>
</tr>
<tr>
<td>Futtock B4E</td>
<td>Ø 27 mm, 55 mm from the lower edge, and 3.82 m from the keel axis</td>
</tr>
<tr>
<td>Futtock B6E</td>
<td>Ø 27 mm, 25 mm from the lower edge, and 3.46 m from the keel axis</td>
</tr>
</tbody>
</table>

The treenail was extracted from futtock B3E, and a mold was cast of the hole in which it had been inserted in order to determine the type of auger used. The hole turned out to be fairly shallow, with 8 cm of depth at the center, and was done with an auger with a conical point. The treenail is octagonal and the wood is still under analysis for species identification (FIG. VII.19 and 20).

![FIG. VII.20 - Treenail extracted from futtock B3E and treenail on B4E. Drawing: Brian Jordan.](image)
It is not clear at this point if these treenails result from previous utilizations of the timbers or if they were used during the some phases of the construction, to fasten the futtocks to the ship's cradle, or even just to single poles used to secure the frames in place.

**Planking**

The preserved planking was a major source of information, as a result of its relatively large extent when compared with the framing, and the regular pattern of nail holes that it presented, which marked the position of thirteen missing frames.

With slight variations, each plank was attached to the framing with two spikes per frame, showing a clear pattern that indicated the positions of the frames that were not preserved, and thus enhancing our knowledge of the framing pattern.

Curiously, it seems that not much care was taken to position the plank butts precisely in the middle of a floor or a futtock, and in a few rare cases the butt joints seem to have been positioned very close to the edge of a floor or a futtock. Another interesting feature was the careful and complex way in which the planks were cut and fitted together, more similar to a jigsaw puzzle than to a stright wooden floor. Some planks displayed a number of notches and bevels along their seams that prevented them from sliding longitudinally – for instance when the hull suffered torsional stresses – giving extra strength to the already-solid shell composed by these strakes.

In the field seasons of 1996 and 1997 the planking was drawn at a 1:1 scale, and a small part of the nail holes were positioned with great precision in relation to each plank. In the field seasons of 1999 and 2000 these drawings were completed and corrected. The final plan elaborated in the Winter of 2000 from the data obtained in the four excavation seasons showed a generally agreement between the different sources in the central portion of the planking, and some discrepancies towards the southern and northern extremities. Here there were differences of almost 10 cm in the position of some of the nail holes (FIG. VII.21).
FIG. VII.21 - Planking plan after the 2000 field season. Drawing: Filipe Castro.
All of the planks were cut from straight stone pines (*Pinus pinea*) of varying ages.

Fifty-three planks were preserved along 28 strakes (Table VII.20).

<table>
<thead>
<tr>
<th>Strake</th>
<th>Plank</th>
<th>Length</th>
<th>Preservation</th>
<th>Starboard</th>
<th>Port side</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW1</td>
<td>1</td>
<td>4.14 m</td>
<td>Broken</td>
<td>T1E</td>
<td>1 2.16 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.36 m</td>
<td>Complete</td>
<td></td>
<td>2 4.70 m</td>
</tr>
<tr>
<td>TW2</td>
<td>1</td>
<td>0.82 m</td>
<td>Broken</td>
<td>T2E</td>
<td>1 2.97 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.53 m</td>
<td>Complete</td>
<td></td>
<td>2 3.95 m</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.55 m</td>
<td>Complete</td>
<td></td>
<td>2 3.95 m</td>
</tr>
<tr>
<td>TW3</td>
<td>1</td>
<td>5.48 m</td>
<td>Complete</td>
<td>T3E</td>
<td>1 4.93 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.43 m</td>
<td>Complete</td>
<td></td>
<td>2 3.28 m</td>
</tr>
<tr>
<td>TW4</td>
<td>1</td>
<td>4.64 m</td>
<td>Broken</td>
<td>T4E</td>
<td>1 2.54 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.87 m</td>
<td>Complete</td>
<td></td>
<td>2 6.44 m</td>
</tr>
<tr>
<td>TW5</td>
<td>1</td>
<td>5.82 m</td>
<td>Complete</td>
<td>T5E</td>
<td>1 1.51 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.82 m</td>
<td>Complete</td>
<td>T6E</td>
<td>1 4.37 m</td>
</tr>
<tr>
<td>TW6</td>
<td>1</td>
<td>5.31 m</td>
<td>Complete</td>
<td>T7E</td>
<td>1 1.02 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.70 m</td>
<td>Broken</td>
<td>T8E</td>
<td>1 0.61 m</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.77 m</td>
<td>Broken</td>
<td>T9E</td>
<td>1 2.68 m</td>
</tr>
<tr>
<td>TW7</td>
<td>1</td>
<td>3.38 m</td>
<td>Complete</td>
<td>T10E</td>
<td>1 2.53 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.77 m</td>
<td>Broken</td>
<td>T11E</td>
<td>1 2.96 m</td>
</tr>
<tr>
<td>TW8</td>
<td>1</td>
<td>2.34 m</td>
<td>Broken</td>
<td>T12E</td>
<td>1 1.58 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.83 m</td>
<td>Broken</td>
<td>T13E</td>
<td>1 2.43 m</td>
</tr>
<tr>
<td>TW9</td>
<td>1</td>
<td>3.58 m</td>
<td>Broken</td>
<td>T14E</td>
<td>1 3.83 m</td>
</tr>
<tr>
<td>TW10</td>
<td>1</td>
<td>3.80 m</td>
<td>Broken</td>
<td>T15E</td>
<td>1 4.58 m</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.67 m</td>
<td>Broken</td>
<td>T16E</td>
<td>1 3.32 m</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.76 m</td>
<td>Broken</td>
<td>T17E</td>
<td>1 4.56 m</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.85 m</td>
<td>Broken</td>
<td>T18E</td>
<td>1 1.73 m</td>
</tr>
</tbody>
</table>

1. \(3.40 + 0.55\) m; 2. \(1.50 + 1.78\) m; 3. \(3.57 + 0.65 + 2.22\) m; 4. \(4.50 + 0.60\) m.
The garboards exhibited the same thickness as the rest of the planking and were beveled to fit the rabbets. At two different points they were spiked to the keel from the outside. No pattern was found for these diagonal spikes, and it seems that they were used to remedy weaknesses or imperfections perceived as dangerous during the building process (FIG. VII.22).

FIG. VII.22 - Garboard T1W(1) showing the diagonal spikes that reinforced the fastening between the keel and garboard. Drawing: Filipe Castro.

All planks were placed without regard to the direction of the heartwood, some with the growth rings placed with their concave side to the interior, some to the exterior. This parallels the practice still in use today in Portuguese shipyards of placing the planks against the frames with consideration to their natural warping after seasoning, rather than the direction of the grain (FIG. VII.23).
The planking was 11 cm thick, among the highest values known for Iberian ships, as shown in Table VII.21.

<table>
<thead>
<tr>
<th>Ship</th>
<th>Country</th>
<th>Route</th>
<th>Date of wreck</th>
<th>Estimated length overall</th>
<th>Planking thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>N.ª S.ª Mártires</td>
<td>Portugal</td>
<td>India Route</td>
<td>1606</td>
<td>&gt; 40 m</td>
<td>11 cm</td>
</tr>
<tr>
<td>Cais do Sodré</td>
<td>Portugal</td>
<td>(?)</td>
<td>1500</td>
<td>&gt; 40 m</td>
<td>7 cm</td>
</tr>
<tr>
<td>San Diego</td>
<td>Spain</td>
<td>Manila</td>
<td>1600</td>
<td>&gt; 30 m (?)</td>
<td>6.5 - 7 cm</td>
</tr>
<tr>
<td>Seychelles</td>
<td>Portugal</td>
<td>India Route</td>
<td>1600</td>
<td>&gt; 30 m (?)</td>
<td>9 cm</td>
</tr>
<tr>
<td>Emanuel Point</td>
<td>Spain</td>
<td>New World</td>
<td>1550</td>
<td>&gt; 20 / 21 m</td>
<td>5 / 8 cm</td>
</tr>
<tr>
<td>San Esteban</td>
<td>Spain</td>
<td>New World</td>
<td>1554</td>
<td>&gt; 30 m (?)</td>
<td>10 cm</td>
</tr>
<tr>
<td>Cattewater</td>
<td>England</td>
<td>-</td>
<td>1500 - 1550</td>
<td>&gt; 30 m (?)</td>
<td>6 - 7 cm</td>
</tr>
<tr>
<td>San Juan</td>
<td>Spain</td>
<td>New World</td>
<td>1565</td>
<td>&gt; 22 m</td>
<td>5 / 6 cm</td>
</tr>
<tr>
<td>Hightborn Cay</td>
<td>Spain</td>
<td>New World</td>
<td>1500</td>
<td>&gt; 20 m (?)</td>
<td>6 cm</td>
</tr>
<tr>
<td>Corpo Santo</td>
<td>Portugal</td>
<td>(?)</td>
<td>1400</td>
<td>&gt; 15/16 m</td>
<td>4 - 5 cm</td>
</tr>
<tr>
<td>Molasses Reef</td>
<td>Portugal</td>
<td>New World</td>
<td>1500</td>
<td>&gt; 20 m</td>
<td>4.5 cm</td>
</tr>
<tr>
<td>Ria de Aveiro A</td>
<td>Portugal</td>
<td>Coaster</td>
<td>1450</td>
<td>15/16 m</td>
<td>4 cm</td>
</tr>
<tr>
<td>Western Ledge Reef</td>
<td>Spain</td>
<td>New World</td>
<td>1575 - 1600</td>
<td>&gt; 20 m</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>Nª Sª de Atocha</td>
<td>Spain</td>
<td>New World</td>
<td>1622</td>
<td>?</td>
<td>10 cm</td>
</tr>
</tbody>
</table>

(1) - See a bibliography for the Iberian wrecks on Appendix II
This value is only surpassed by the theoretical value of 12.5 cm indicated by Manoel Fernandez in the *Livro das Traças de Carpintaria* for the bottom planking of an Indiaman. The width of the planks varied between 15 - 35 cm.

The planking's interior surface was very well preserved, under a layer of a resinous substance that is still being analyzed, but that exuded a strong smell of pine. Under floor C6, plank T2E(2) showed the mark of a recessed spike head, suggesting that it had been reused, or just turned over, after being nailed to a few frames, for a better fit.

In contrast, the external faces of the planks are very abraded and were destroyed over large sections due to the violence of collision against the rocky bottom during the wreck. Where original surfaces were preserved, they show a consistent thin charred layer (FIG. VII.24).

---

FIG. VII.24 - Outer surface of plank T6W showing evidence of charring.
Photo: Filipe Castro
This practice was utilized in Portuguese shipyards before the first coating of pitch and between the first and second coatings of that substance, and was said to help the first layer of pitch to penetrate more deeply into the wood, and the second to adhere better to the first. The interior of the hull was well preserved under a layer of a resinous substance that exuded a strong smell of pine.

With very few exceptions, all planks were spiked to the frames with two iron spikes per frame and the heads of each spike were recessed into countersunk holes. The countersink holes varied in diameter, from 4 - 7 cm, in depth, from 1 - 3 cm, and in shape, from perfectly circular holes to square holes, with rounded corners.

In three different locations, wooden plugs were used to fill nail holes in the planking that were not in use (Table VII.22).

<table>
<thead>
<tr>
<th>Local</th>
<th>Dimensions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under floor C3</td>
<td>d = 1 cm</td>
<td>Only preserved on the floor</td>
</tr>
<tr>
<td></td>
<td>h = 4 cm</td>
<td></td>
</tr>
<tr>
<td>Under floor C4 / T11E</td>
<td>d = 2 cm base, 1 cm at the top</td>
<td>Left in situ</td>
</tr>
<tr>
<td></td>
<td>h = 7.5 cm</td>
<td></td>
</tr>
<tr>
<td>Under futtock B5E / T15E</td>
<td>h = 1.5 cm at the base</td>
<td>Inserted at a = 60° angle with the planking</td>
</tr>
<tr>
<td></td>
<td>h = 3 cm</td>
<td></td>
</tr>
</tbody>
</table>

All these plugs were bevelled into a pyramidal shape and tightly inserted into the planking and framing (FIG. VII.10 and FIG. VII.11).

**Fastenings**

All the fastenings found on the wreck were made of iron. Each timber exhibited spike holes of several dimensions, the majority having square sections. Impressions of the fastening heads were visible on the countersink holes, showing that they were square with rounded corners.
As previously mentioned, some of the floors had round holes in addition to the square ones, corresponding to the bolts that linked the keel to the keelson. These round holes were also found in the apron. Two bolts were placed in each section of the keel, before and abaft of each scarf.

All fastening holes were bored with augers prior to driving the spikes and bolts. Spikes were manufactured with pyramidal shanks to facilitate their insertion – some spikes were 60 cm long – and to ensure a good sealing of the holes. Caulking – probably oakum – was found in the concretions around the heads. Similarly, the bolts had conical shanks that enlarged around 5 mm over their last 10 cm to plug the augered holes, but no caulking remains were found on either of the two concretions that preserved the shape of bolt heads.

<table>
<thead>
<tr>
<th>Joinery</th>
<th>Length</th>
<th>Section</th>
<th>Head</th>
<th>Counter sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planking to frames</td>
<td>≈ 25 cm</td>
<td>□ = 1.6-1.8 cm</td>
<td>□ = 4.0 cm, w/ round corners</td>
<td>□ = 4-6 cm</td>
</tr>
<tr>
<td></td>
<td>≈ 50 cm</td>
<td>□ = 2-2.5 cm</td>
<td>□ = 5.0 cm, w/ round corners</td>
<td>1-2 cm deep</td>
</tr>
<tr>
<td>Floors to futtocks</td>
<td>≈ 60 cm</td>
<td>□ = 2-2.5 cm</td>
<td>□ = 3.5 x 4.0 cm, w/ round corners</td>
<td>□ = 5-7 cm</td>
</tr>
<tr>
<td>Floors to keel</td>
<td>≈ 60 cm</td>
<td>□ = 2-2.5 cm</td>
<td>?</td>
<td>1-3 cm deep</td>
</tr>
<tr>
<td>Keel to keelson</td>
<td>&gt; 1.00 m</td>
<td>Ø = 3.5-4 cm</td>
<td>Ø = 7 cm</td>
<td>Ø = 6 cm</td>
</tr>
<tr>
<td>Apron to Keelson</td>
<td>&gt; 1.00 m</td>
<td>Ø = 3.5-4 cm</td>
<td>Ø = 7 cm</td>
<td>2.0 cm deep</td>
</tr>
</tbody>
</table>

The fastening pattern is clear and simple. Floors and futtocks were joined with spikes about 60 cm long, with square shanks 2 - 2.5 cm on a side and square heads with rounded corners. Floors and keel were joined with spikes around 60 cm long, with square shanks 2 - 2.5 cm on a side and square heads with rounded corners. Planks and floors were fastened with spikes of two types: the first is around 25 cm long, with square shanks 1.8 - 2 cm on a side, and the second type is around 50 cm long, with
square shanks 2 - 2.5 cm on a side. Both types had square heads with rounded corners. The longer spikes were clenched on the upper surfaces of the floors. Keel and keelson, and keel and apron were joined with bolts over 1 m long, with round shanks 3.5 - 4 cm in diameter and round heads 7 cm in diameter (Table VII.23).

Casts were taken from two fastener concretions: a bolt from keel section Q2 and garboard T1W (1) and a spike from floor C6 (FIG. VII.25 and VII.26).

FIG. VII.25 - Cast of the bolt Q2 / C7(V) joining keel and keelson. Photos: Pedro Gonçalves, CNANS. Printed with permission of CNANS.
Caulking

The caulking was performed with great care. Each plank seam, including the hood ends, was caulked with a strip of lead twisted into a 5 - 9 mm thick string (FIG. VII.27), and two layers of oakum thread were then pressed against it from the outside (FIG. VII.28). At many points, a thread of oakum was also found on the inside of the seam, presumably indicating that it was inserted in at least some of the seams before the lead string, creating a four-layer caulking protection between the planks.
All seams were then protected from the outside with long, narrow straps of lead 2 - 8 cm wide, some nailed along the plank seam's central axis, some along both edges.
The lead straps were held with one or two lines of iron tacks, with shanks 4 mm on a side and round large heads 27 - 30 mm in diameter, spaced 4 - 8 cm apart (FIG. VIII.29 and 30).

![Diagram of a lead strap with tacks]

FIG. VII.30 - Marks of the heads of the tacks on a lead strap. Drawing: Filipe Castro.

Lead sheets of square or rectangular shape were also found on the site. These were pierced along their perimeters with the same 4 mm square holes, spaced from 4 - 8 cm apart. These sheets presented greatly varying dimensions, the smallest being with 12 by 13.5 cm and the largest 40.5 x 23 cm, and may correspond to repairs made during the trip. All sheets and straps of lead presented thicknesses between 1 - 2 mm (FIG. VII.31).

The seam between the keel and the garboard was also caulked with a string of lead, two layers of oakum, and a continuous lead strap (FIG. VII.32).

The tables of the keel scarves were caulked with a vegetable felt that has not yet been analyzed.
FIG. VII.31 - Lead sheets. Drawing: Filipe Castro

FIG. VII.32 - Lead caulking strap found under the seam of the keel and garboard. Drawing: Filipe Castro.
Wood

As previously mentioned, there were two different species of wood used in the construction of this vessel. In 1996, ten samples were taken and sent for analysis and species identification (FIG. VII.32). The results indicate that the keel, apron and frames were cut from cork oaks (Quercus suber), and the planks were made from umbrella (stone) pines (Pinus pinea) (FIG. VII.33). These results came as no surprise, as these species are indicated in the late 16th and early 17th centuries literature as the proper trees to build ships.

It appears that the cork oaks used were relatively small considering the dimension required for the structural timbers – as suggested by the number of sections composing the keel and the number of patches on the futtocks. As for the planking, it was cut out of large and straight pine trees, with regular grain and very few knots.

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**FIG. VII.33** - Samples removed for wood species identification [Scale: 2 Rumos, 3 m].

Drawing: Filipe Castro.
FIG. VII.34 - Woods used in the construction of the SJB2 vessel [Scale: 2 Rumos, 3 m].

Drawing: Filipe Castro.

Since there is no dendrochronological series for Portugal, no further analysis was conducted on the wood from this vessel. Dendrochronological analysis might help to determine the relative ages of the timbers found on the vessel, to investigate questions related to the management of the forests and timber supply problems, as well as times of seasoning, storage, and possible re-use. Nevertheless, the size of the oak timbers suggests that there was a shortage of large trees, and indicates that there was little or no forest management, pruning, or long time storing, at least for the oaks.

**Tool marks**

As mentioned before most timbers were badly preserved, showing rounded corners, eroded surfaces and, were exposed, extensive damage, mainly due to the action of wood worms. However, a number of timbers showed tool marks in their preserved surfaces.
Most floors and futtocks were clearly shaped and finished with adzes (FIG. VII.34).

FIG. VII.35 - Adze marks on floor C4. Photo: Filipe Castro.

Where they could be measured, the blades of the adzes seemed to be 7 to 10 cm wide (FIG. VII.35).

FIG. VII.36 - Adze marks on floor C6. Photo: Filipe Castro.
All surfaces that did not need to be smooth still showed saw marks (FIG. VII.36). As mentioned above, the hole on futtock B3E from where the treenail was extracted had been opened with an auger with a conic tip.

FIG. VII.37 - Saw marks on patch from futtock B3E. Photo: Filipe Castro.

Ballast

Although no clear evidence of the ballast has been found, the hull lies above a thick layer (archaeological stratus C) of round pebbles of small diameter (5 - 15 cm) mostly from a Cretaceous limestone with Eocene basalt intrusions characteristic of the Lisbon region. These pebbles are abundant in the northern banks of the Tagus and are known to have been used as ballast in other ships, such as the Molasses Reef Wreck, although stones of larger dimension seem to have been preferred.\textsuperscript{VII.3} However, it is important to remember that this site comprises the remains of many shipwrecks, and that
most wrecks that occurred here had very violent impacts on the vessels' hulls. Neat, coherent ballast piles cannot be expected to exist in this area. Adding to the puzzle, the remains of the several sections of the fortress walls destroyed by winter storms and reconstructed in the subsequent summers are scattered all around, including fairly recent concrete shards. Samples of some of the intrusive stones, such as granite, have been retrieved for analysis.

FIG. VII.38 - Long stones, possibly carved, found to the north of the wreck (Square Q2). Drawing: Filipe Castro.
A group of stones found near the hull deserves mention, because of their weight and possible connection with the shipwreck under study. These are: a grinding stone with a diameter of 83 cm; three long stones with roughly rectangular sections, around 10 cm thick and measuring 13 by 79 cm, 22 by 110 cm and 15 by 119 cm respectively, and one stone which may be an old anchor stock around 1.50 m long.

The long stones with roughly rectangular sections were recorded in situ in 1997, but could not be relocated during the 1999 and 2000 field seasons due to the heavy silting of the north area of the wreck (FIG. VII.38). A geological origin should therefore not be excluded.
CHAPTER VIII
ANALYSIS AND RECONSTRUCTION

The reconstruction of the hull of a 17th century Portuguese nau proved to be a difficult task given the large gaps in the available data. The undertaking therefore involved much speculation and conjecture regarding the little information that exists on this subject. Nevertheless, even the sparse remains of the Nossa Senhora dos Mártires provide enough data to justify such a study, particularly when combined with the important body of theoretical information available from this period as discussed in Chapter III.

The three most important texts pertaining to Portuguese shipbuilding during the late 16th and early 17th centuries are Father Fernando Oliveira's Liuro da Fabrica das Naus (1580), João Baptista Lavanha's Livro Primeiro de Arquitectura Naval (c. 1610), and Manoel Fernandez' Livro de Traças de Carpintaria (1616). To these treatises can be added the already mentioned late 16th century manuscript from the codex known as the Livro Náutico and two early 17th century manuscripts, the Coriosidades de Gonçallo de Sousa, and the Harvard manuscript, containing the expenses of the construction of two India naus in the 1620s. Additional information can be retrieved from the Livro de toda a fazenda de Figueiredo Falcão (1607) and the contracts for the construction of the naus of Gonçalo Roiz and Sebastião Themudo (1598), transcribed by João Baptista Lavanha, to which should be added the comments of the commissions gathered in the 1620s to discuss the size of India naus.\textsuperscript{VIII.1}

Analysed together with the information contained in these texts, the surviving timbers of the Nossa Senhora dos Mártires speak volumes, and in the following pages each of the structural components of the hull will be analyzed in view of the theories related in the texts on shipbuilding from the Habsburg period in Portugal (1580-1640).
Size

The East Indiamen, which averaged about 500 tons capacity - probably around 1,000 tons displacement - were said to be the largest vessels built at their time, and this may very well be true as no other route required larger vessels. In other words, other larger vessels had been constructed before these naus, but these were not built following a prototype, as a specialized type of working craft designed to perform a given task on a regular basis.

By the early 17th century there was a long list of large round ships sailing the seas of the known world. It is difficult to compare the sizes of various ships using historical sources, because the way in which tonnage was calculated changed from port to port and through time, and the relations between the numerous units given in the written sources are seldom clear or absolutely reliable. However, it is important to mention that the India naus were by no means the giants of their time. In fact, as early as the mid-13th century, the galleys of Genoa failed to capture the Venetian ship Roccaforte, said to have had a capacity of around 500 tons.\textsuperscript{VIII.2} In the early 15th century the Italian merchant Luca di Maso described the English lapstrake vessel Grâce Dieu as having a capacity of around 1,500 tons.\textsuperscript{VIII.3} Although the Grâce Dieu was considered unfit to sail and can hardly be considered a success from the point of view of the history of shipwrightry, she was astoundingly big for her time, and her tonnage was certainly not matched by many other vessels during the 15th century. There are references to some large vessels in Portugal in the late 15th and early 16th centuries, such as the large ship mentioned in Garcia de Resende's chronicle of John II (1455–1495), or the São João, a ship said to have been one and a half times the size of an India nau in the 1530s.\textsuperscript{VIII.4} However, like the Grace Dieu, this vessel did not perform well at sea.

Large vessels were not very popular among English shipwrights before 1650. Only three ships are credited with keels over 30 m (100 ft.) before 1600, and until 1649 only eight are mentioned in the English records, the larger being Phineas Pett's Prince Royal (1610), with 35.05 m (115 ft.) of keel, and Peter Pett's Sovereign of the Seas (1637), with a keel of 38.71 m (127 ft.).\textsuperscript{VIII.5}
However, the popular accounts that portray the India Route naus as immense floating cities are very exaggerated. François Pyrard de Laval and Jan Huigen van Linschoten wrote two of the most popular accounts of voyages to India aboard Portuguese naus. The first of these authors, travelling in India between 1601 and 1611, left us very interesting, if at times exaggerated, descriptions of these ships:

(...) These naus have commonly fifteen hundred until two thousand tons and more, being the largest vessels in the world, as far as I have seen, and cannot sail in less that ten braças [20.54 m] of water.\textsuperscript{VIII.6}

He goes on to say that the vessels had four decks, and that in each one could fit a standing man, no matter how tall he might be, leaving still two feet above his head. According to François Pyrard each of these naus carried 35 to 40 large bronze guns to which were added other smaller guns, such as esperas and pedreiros, placed at the tops. He claims that the tops were large enough to accommodate ten or twelve men, and that all the masts were so enormous that there were no trees to make them, and they had to be assembled from several pieces:

(...) All masts are commonly made of several pieces, and covered around by chûmeas which are thick timbers tightly inlaid on the required thickness. And these timbers, very well adjusted, are tightly fastened with ropery and iron bands very well tightened so that they don't collide with the raising and lowering of the yard, which is proportionately thick to the mast, and has got 20 braças [41.07 m] of length. It takes more than 200 men to raise one of these yards, and always two thick capstans.\textsuperscript{VIII.7}

It makes sense that the main yard measured close to 20 braças (40.96 m), since the author of the Livro Náutico gives its length as being as many braças (2.048 m) in length as the keel had in rumos (1.54 m), claiming that this is the equivalent to three
quarters of the length of the weather deck. But the size of crews is fairly well documented, as mentioned in Chapter IV, and it is hard to believe that it would take more than 200 men to raise the main yard, for which we know there was a specific windlass on the gun deck. Eventual distortions and exaggerations apart, the India naus were large vessels, specifically designed for long voyages. Many other nations also had large ships, and by the late 16th century there were several types of vessels with keels around 30 m long. Chances are that the keel of the Nossa Senhora dos Mártires was shorter than that.

Indiamen had to be large to sustain crews and passengers during the long voyages, and it seems that a larger than usual vessel was occasionally built in the Lisbon shipyards. Good examples of these are ships such as the São João of 1550-52 and the São Bento of 1551-54, both of 900 tons, the Garça of 1556-59 of 1,000 tons, or the Madre de Deus, captured by the British in 1592, and said to have been a three decker of 1,600 tons burden. However, the average India nau was comparatively smaller, with a keel length of around 27 m, and a capacity of 500 or 600 tons. This trend is referred to by Father Fernando Oliveira in the late 16th century:

(...) in the time of King D. Manuel and King D. João, his son, when the voyage to India began and flourished, it was entrusted to men of singular understanding and knowledge, who did not neglect the profit: (...) From that time until now, that voyage has always been made in ships of more than 500 tons, and some 800 and 1000: and these have always been the ones that make the best and safest voyages: for they cope with the sea better. Which, on that track, is great and requires large ships to dominate it.

The entry of the northern nations into the eastern trade, and the development of mathematics and engineering induced a trend to build larger vessels, and the size of both merchantmen and war vessels increased steadily during the 17th century. Discussions regarding the size of the India Route merchantmen were held in Portugal and Spain in
the 1620s, following a letter from Admiral João Pereira Corte Real to the new king, Filipe IV of Spain and III of Portugal (1621-1640), showing that at least in these two countries there was a political effort to impose reasonable limits on this growth. It seems however that this effort was merely political, and neither the shipwrights nor the theoreticians analyzed here appear to have been concerned with the increase in size of the India naus.

Given the information available in the Portuguese texts on shipbuilding described in Chapter III, it is evident that the India nau was a standardized vessel. With rather small variations, they had a capacity between 500 and 600 tons, three or four decks, around 26 - 28 m of keel length, 39 - 41 m of length overall, 10 m of maximum breadth measured slightly below the weather deck, around 10 m of depth in hold, and a length to beam ratio around 3:1. They presented wide bows and quite full sterns, and a characteristic flat midship section. Quite understandably, many references to vessels that did not fit this standard exist. These were the giants that fascinated everybody, except sometimes the few who had to sail them, as we will see further on. The Madre de Deus (1592) and the large ships of the mid 16th century São João (1552), São Bento (1554), and Garça (1559) have already been mentioned, but there were others, such as the Santa Catarina do Monte Sinai built in Cochin in 1512 with a capacity of 800 tons, and believed to be represented in the painting Portuguese Carracks in the National Maritime Museum in Greenwich.\textsuperscript{VIII.11}

In order to understand the magnitude of this growth it is important to examine the standard size of vessels (see Table VIII.1 on page 193).

In the Liuro da Fabrica das Naus (1580), Father Oliveira describes a nau with three decks, 18 rumos of keel (27.72 m), 39.04 m of length overall, a maximum beam of 12.32 m, a depth in hold of 9.24 m and 600 tons of capacity. Its length to beam ratio is 3.17:1.

In the Livro Náutico, dated to the 1590s, its author considers the proper size of an India nau is considered to be three decks, a keel of 17 rumos (26.18 m), 37.86 m of
length overall, a beam of 12.83 m, a depth in hold around 8.19 m, and 600 tons of capacity. Its length to beam ratio is 2.95:1.

In the Livro Primeiro de Arquitectura Naval João Baptista Lavanha finds the best model around 1610 a four decker with a keel of 17½ rumos (26.95m), 39.27 m of length overall, not considering the sterncastle extension over the transom, a beam of 13.86 m, and a depth in hold of 9.67 m. He does not indicate any capacity. Its length to beam ratio is 2.83:1.

In the Livro de Traças de Carpintaria (1616), Manoel Fernandez proposes a four decker nau with a keel of 17½ to 18 rumos (26.95 to 27.72 m), 40.04 to 40.82 m of length overall, a beam of 13.86 to 14.38 m, a depth in hold of around 10 m, and 600 tons of capacity. Its length to beam ratio is 2.83 or 2.89:1.

Gonçalo de Sousa shares the same opinion, as he used the same original documents Fernandez used when he wrote his Coriosidades.

The sets of measurements that survive today from the master builders Gonçalo Roiz and Sebastião Themudo, (1598) are similar, with three decks and very bulky hulls. The keel length is still of 26.95 m (17 ½ rumos), the overall length remains between 38.95 and 39.86 m, depending on the rake of the sternpost and the beam is equal to one third of the overall length. Gonçalo Roiz gives 13.61 m for his maximum beam, on the gun deck, and the depth of hold is estimated at around 10 m, for no measurements are given for the thickness of the deck timbers:

$$3.58 \text{ m (hold)} + 1.79 \text{ m (3rd deck)} + 1.79 \text{ m (2nd deck)} + 1.79 \text{ m (main deck)} = 8.96 \text{ m}$$

When the larger vessels of the 17th century are considered, it is evident that they a continuation of designs which had already been developed, rather than a new type of vessel. The description of the nau Madre de Deus captured by the British in 1592 mentions three decks and an overall length of 50.29 m (165 feet), from the beak head to the stern. Her maximum breadth, measured on the second closed deck, was 14.27 m (46 foot and 10 inches) and her length of keel is said to have been 30.48 m (100 feet), but it seems more likely that it was 30.80 m, the equivalent of 20 rumos. As for the draft, it
seems very exaggerated no matter what the conditions of load may have been: "(...) She
drew in water 31 feet at her departure from Cochin in India, but not above 26 at her
arrival in Dartmouth, she being lightened in her voyage by diverse means."\textsuperscript{VIII.12}

It is a fact that these ships could not sail with light cargoes in the hold – such as
pepper – and heavy artillery on the decks. As a result, they had to load as much as 9
_palmos de goa_ (2.31 m) of ballast in the hold, leaving very little space for the pepper
lockers, but it is difficult to imagine how a vessel with slightly more than 30 m of keel
could draw 9.45 m of water (Table VIII.1).\textsuperscript{VIII.13}

The best insight to these larger vessels is given by the reports of a committee
created by the king to analyze the claims of Admiral Corte Real regarding the alleged
poor performance of the naus built in Lisbon in the 1620s. In 1624, the king ordered two
naves to be built for the armada of 1625 with three decks and 20 rumos (30.80 m) of
keel.\textsuperscript{VIII.14} These were the _São Bartolomeu_ and _Santa Helena_, inspected by a committee
of experts in the Ribeira das Naus, Lisbon's shipyards, in order to inform the king about
their quality.

These two vessels were meant to be equal in size and had a length of keel of
30.03 m (19 \( \frac{1}{2} \) rumos), an overall length of 43.89 m, a beam of 14.76 m, and a depth in
hold of 9.63 m. Their length to beam ratio was 2.97:1. Their stern castles were each
1.97 m high, the first extending to the main mast, and the forecastle was 2.31 m high.

Master shipwright Valentin Themudo, one of the members of this committee,
found these ships unsuitable for the India Route. In his opinion, they were too wide at
the bow, their scantlings were too heavy, and the hull was too bulky amidships.
According to his experience, ships should not have length to beam ratios out of the range
3 to 4:1. Valentin Themudo thought that the ideal keel length was 30.80 m (20 rumos),
for an overall length of 41.70 m and a beam of 13.35 m on the second deck. The length
to beam ratio of should therefore be 3.12:1 and not 2.97:1, which he considered
unacceptable. Another criticism put forth by Valentin Themudo was that the stern castle
should not extend too far abaft of the sternpost to avoid the enemy putting fire
underneath it. Finally he thought that additional gun ports should be opened at the bow and stern, to allow four cannon in the stern and at least two culverins in the bow.

The committee met again in 1627 and the question of the best model for the India Route was once more raised. Curiously, this time Valentim Themudo argued that the best ships for the voyage should have 600 *toneladas* of capacity and 18 *rumos* (27.72 m) of keel, disagreeing on this point with all the other members of the committee, who voted for a 700 to 800 *toneladas* vessel, with 19 to 20 *rumos* of keel (29.26 to 30.80 m). VIII.15

<table>
<thead>
<tr>
<th>Ship</th>
<th>N. of decks</th>
<th>Length of keel (m)</th>
<th>Overall length (m)</th>
<th>Beam (m)</th>
<th>Depth in hold (m)</th>
<th>Length to beam ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oliveira, 1580</td>
<td>3</td>
<td>27.72</td>
<td>39.04</td>
<td>12.32</td>
<td>9.24</td>
<td>3.17</td>
</tr>
<tr>
<td><em>Livre Náutico</em>, 1590s</td>
<td>3</td>
<td>26.18</td>
<td>37.86</td>
<td>12.83</td>
<td>8.21</td>
<td>2.95</td>
</tr>
<tr>
<td><em>Madre de Deus</em>, 1592</td>
<td>3</td>
<td>30.80</td>
<td>50.29</td>
<td>14.27</td>
<td>?</td>
<td>3.52</td>
</tr>
<tr>
<td>V. Themudo, 1598</td>
<td>3</td>
<td>26.95</td>
<td>38.95/39.86</td>
<td>13.61</td>
<td>≈10</td>
<td>2.86/93</td>
</tr>
<tr>
<td>Gonçalo Roiz, 1598</td>
<td>3</td>
<td>26.95</td>
<td>38.95/39.86</td>
<td>13.61</td>
<td>≈10</td>
<td>2.86/93</td>
</tr>
<tr>
<td>Lavanha, 1610</td>
<td>4</td>
<td>26.95</td>
<td>39.27</td>
<td>13.86</td>
<td>9.67</td>
<td>2.83</td>
</tr>
<tr>
<td>Fernandez, 1616</td>
<td>4</td>
<td>26.95/27.72</td>
<td>40.04/40.82</td>
<td>13.86/14.38</td>
<td>≈10</td>
<td>2.89/83</td>
</tr>
<tr>
<td><em>S. Bartolomeu</em>, 1625</td>
<td>3</td>
<td>30.03</td>
<td>43.98</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Still there were too many factors in favor of, and against, the larger ships for a clear answer to be found. One of the problems evoked was related to the helmsman's position in the four-deckers. It was difficult to place the whipstaff at a point which allowed the helmsman to see the rig and the sails, and therefore frequently were at risk of being torn apart during the maneuvers. Also, by now there was a problem with the loading of even the smallest ships, because over a century of dumping ballast at the anchorage of Goa had made it so shallow in some areas that they sometimes hit bottom in rough seas. Perhaps the only tendency that attained a degree of consensus among all the experts was the necessity of lowering the castles. Other aspects were discussed, and
a recommendation was formed about not cutting any gun ports before the ship was ready, rigged, and floating, and those responsible for the defense of the ship were consulted.

The last documents from these discussions date from 1629 and contain a recommendation, which was refused, for the construction of three-decked ships of very large dimensions: a keel of 32.34 m (21 rumos), an overall length of 47.48 m, a beam of 14.89, and a depth in hold of 9.63 m, giving a length to beam ratio of 3.2:1.

Whatever the political circumstances, large ships continued to be built throughout the 17th century, some of them being praised for their characteristics like the Bom Jesus, about which the German traveler Johan Albrecht von Mandelslo said in 1639 that it was the noblest vessel he ever saw, or the great galleon Santissimo Sacramento, lost in 1647 on the first trip from India to the kingdom, but said to have been one of the best naus ever built. VIII.16

Keel

As mentioned above, the keel of the SJB2 wreck was 25 cm sided and was not preserved in its complete molded dimension. However, the sizes of the three bolts that linked the keel to the keelson, preserved in the concretions under the keel, suggest the possibility that it may have been as much as 46 cm molded. As mentioned in Chapter VII, it is obvious that the keel splintered in many places after hitting the rocky bottom, and that some of the bolts were pushed in and bent to port side, as were the spikes that linked the floors to the keel. In addition, the bolt preserved under floor C7(V) may have been pulled out as the keelson broke (FIG. VII.4). It must be stressed however that it is much more difficult to pull a bolt out than to push it in under these circumstances, and that therefore the possibility that this keel was 46 cm molded must be considered.

The keel was assembled from very short sections of less than 3 m, each roughly a tenth of its total length. If no larger pieces than these were used, and the keel was close to 27 m in length, it can be assumed that it was assembled from seven small straight pieces and two couces, the stem and stern knees.
The texts considered in the analysis and reconstruction of this nau describe keels between 17 and 18 rumos long (26.18 and 27.72 m). Measurements given in contemporary written sources are summarized in Tables VIII.2 and VIII.3.

<table>
<thead>
<tr>
<th>Author</th>
<th>Keel length</th>
<th>Bibliographic ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Oliveira</td>
<td>18 rumos = 27.72 m</td>
<td>Oliveira :86 and 165</td>
</tr>
<tr>
<td>Livro Náutico</td>
<td>17 rumos = 26.18 m</td>
<td>Livro Náutico :fl. 1</td>
</tr>
<tr>
<td>Sebastião Themudo</td>
<td>17½ rumos = 26.95 m</td>
<td>Lavanha :115 and 237</td>
</tr>
<tr>
<td>Gonçalo Roiz</td>
<td>17½ rumos = 26.95 m</td>
<td>Lavanha :117 and 240</td>
</tr>
<tr>
<td>João Baptista Lavanha</td>
<td>17½ rumos = 26.95 m</td>
<td>Lavanha :34-35 and 148, fl. 56</td>
</tr>
<tr>
<td>Manoel Fernandez</td>
<td>17½ - 18 rumos = 26.95 - 27.72 m</td>
<td>Fernandez :23</td>
</tr>
</tbody>
</table>

As for the scantlings, it seems that all agreed that the keels should be 25 cm (1 palmo de goa) sided and between 30 and 36 cm molded:

<table>
<thead>
<tr>
<th>Author</th>
<th>Keel section</th>
<th>Bibliographic ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Oliveira</td>
<td>&quot;(...) heavier than the ribs (...)&quot;</td>
<td>Oliveira :116 and 197</td>
</tr>
<tr>
<td>Livro Náutico</td>
<td>Sided: 1 pg; Molded: 1 pg + 2 dedos</td>
<td>Livro Náutico :fl. 1</td>
</tr>
<tr>
<td>João Baptista Lavanha</td>
<td>Sided: 1 pg; Molded: 1 pg plus rabbet molded</td>
<td>Lavanha :44 and 154, fl. 62 vº</td>
</tr>
</tbody>
</table>

There is no consensus on the question of whether a keel should be carved out of a single piece of timber or made of assembled sections. Oliveira asserts that the optimal solution is to carve the keel from a single piece of wood, and if that were not possible, that its sections should be very well joined together.¹⁷ However, Lavanha states that
this is a poor solution as long timbers tend to warp, and therefore all keels should be assembled from several sections.\textsuperscript{VIII.18} The author of the \textit{Livro N\u{a}utico} states that a keel takes five timbers plus the \textit{couces}, with no further comments.\textsuperscript{VIII.19} A scarf between the keel and the posts does not seem to have been an acceptable option for any of the authors. The solution that best accommodated the need for strength at these two important points of the hull was the use of the knees on both the extremities of the keel called \textit{couces}, and linking them with flat scarves to the keel and posts. It is understandable that care was taken to ensure great strength at the extremities of the keel, as all kinks are points of concentration of stress in any structure. Furthermore, the stem was generally designed as a circular arc tangential to the keel at its base, creating a smooth transition and therefore avoiding the accumulation of stress at that particular point. All connections between the keel and posts were accomplished by flat scarves, vertical over the keel, and horizontal on the posts (FIG VIII.1).\textsuperscript{VIII.20}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure.png}
\caption{FIG VIII.1 - Stern \textit{couce} after Lavansa, fl. 63. Drawing: Filipe Castro.}
\end{figure}
These discussions of the assembly of keels cannot be separated from the very important question of timber availability. Comparison of the Portuguese and southern Spanish shipbuilding traditions in the 16th century with the northern European traditions makes evident the much greater quantity of wood used in northern hull construction and the larger dimension of the scantlings. Good timber for shipbuilding was very scarce in Portugal and Spain by this time, and in spite of legislation issued by Filipe II to protect oaks and straight trees, the problem may have been beyond solution. These preoccupations are passionately expressed in 1580 by Father Oliveira:

(...) this timber [cork oak] is so appropriate for the work and is necessary on this earth, and as, furthermore, we have no other that is equal for this use, it should be saved and the felling of cork-oak trees for charcoal or tanning bark, or any other purpose less necessary than our naval construction, should be proscribed. VIII.21

And later, in 1628, by the shipwright Manuel Galego:

(...) the cork oak timbers that are felled today are not anymore long enough to be fastened and connected together as they were in the past (...) and what can be found today is so little that in a few years there will be no more timber to build naus (...). VIII.22

Cork oaks are not straight trees, and therefore it does seem a good idea to build keels out of such crooked trees. However, cork oak was at that time considered the best timber for building the keels, posts, and frames of India naus by several authors. Oliveira says:

(...) the cork oak is very hard and does not rot in water, but freshens, rather, and is revigorated: for it is naturally dry and is preserved by humidity. In addition to this, its branches are twisted and the crooks have forms that are suitably shaped for bow and stern timbers, and knees, and other parts of this assemblage, being of
such shapes that they seem, without any alteration, to have been born for this
VIII.23

In view of the shortage of timber and the large scantlings required in the
construction of these ships, the short sections forming the building blocks of the SJB2
keel make more sense. Since no full section was preserved and only a partial spike hole
exists (FIG. VIII.2), it is not even possible to state how many spikes were used in each
flat vertical scarf connection. However, Lavanha provides a very detailed drawing of a
flat vertical scarf with three spikes that can be assumed a plausible solution (FIG.
VIII.3). Another reinforcing measure used by the shipwright was to fasten each section
of keel to the keelson with two strong iron bolts, placed before and abaft each of the
scarves.

FIG. VIII.2 - Keel section Q2, the best preserved of the three sections of keel found.
Drawing: Filipe Castro.
As mentioned in Chapter VII, the rabbets have a constant angle that does not change along the preserved portion of the keel. This shows only that the curvature of the floors must match the angle of the garboards, and therefore will have a slightly concave curve near the keel axis towards the extremities of the keel.

**Apron**

The apron is basically a large cork oak timber in which notches were cut to fit the foot of the floors.

---

**FIG. VIII.3** - Flat vertical scarf after Lavanha, fl. 62v°.
Drawing: Filipe Castro.

**FIG. VIII.4** - Section of the apron and reconstructed arrangement of the keel, floor, and planking.
Drawing: Filipe Castro.
There was no preserved keel under the apron but a fair reconstruction of the arrangement used can be made employing the angles on the lower sides of the apron, to which was attached the planking (FIG. VIII.4).

Based on the pattern established by the nail holes in the planking, it is evident that the apron received floors XVI, XVII, and XVIII.

Frames

The frames yielded many important clues for the reconstruction of the hull. All futtocks were fastened to the floors with three or four spikes and a pair of dovetail scarves with rectangular tables. This method is well described by Lavanha for the central, pre-designed floors:

(... all the eleven floors of account are joined with their braços [futtocks] on the ground (...) with great care, and have to come one on another very precisely, and account has to be taken only of these lines of the wrongheads [the surmarks] in the joining together of the floors with the futtocks, and in ones, and in others, mortises are made, with which they are adjusted. VIII.24

However, there were other ways to build a frame-first hull. Manoel Fernandez claims that pre-designed frames should be erected every two rumos:

To the bow and to the stern you will set frames every two rumos (...). VIII.25

The mating surface between the floors and futtocks was always the face that looked toward the extremity of the vessel, a hallmark of the Mediterranean frame-first shipbuilding tradition. In other words, the futtocks of the Pepper Wreck are attached to the floors from the side of the posts. This practice may have resulted from two main factors. The first is relates to the bevels required to fit the planks over the frames. If the design surface was the closest face to the master frame(s) the shipwrights always had to
cut timber to get the appropriate bevels. If the frames were designed from the other side, the mating surface, the bevels would have to be cut on the futtocks and added on the floors (FIG. VIII.5).

![Diagram of ship structure]

FIG. VIII.5 - Pairs floors / futtocks and respective bevels. Drawing: Filipe Castro.

The second factor is very logical and pertains to the building sequence. Because the master floor and its fore and aft futtocks were spiked over the keel before the other frames, it seems reasonable that the next frames added would have had the floor placed against the futtocks to obtain a sequence of alternate floors and futtocks with a regular room-and-space.

**Design**

It has been suggested that these frames were pre-designed and pre-assembled according to the rules expressed by the Portuguese treatises and texts of shipbuilding of their time. That they were in fact pre-assembled is obvious. All spikes were clenched on the side of the futtocks and encased in recessed cavities. Their heads were encased in
countersink holes on the floors, at the side of the heads, and grooves were adzed on the futtocks to house the clenched points of the spikes. The floors leaned against the futtocks of the previous frame without any space between them, and this arrangement would have been impossible if the floors were not already attached to the futtocks.

The evidence for the pre-design of the frames is redundant, since it is impossible to cut and assemble them without designing them first. There are some clues, and many doubts as to the way in which they were pre-designed. Different authors present or suggest different ways to design the frames to obtain a good hull shape, with fair runs and smooth ends, that could cut through the water without plunging the bow, and steer efficiently without sinking the stern. Table VIII.4 lists the several different arrangements described in the historical sources.

<table>
<thead>
<tr>
<th>Author</th>
<th>Master Frames</th>
<th>Pre-designed frames</th>
<th>Bibliographic ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Oliveira</td>
<td>3</td>
<td>18 before; 18 abaft</td>
<td>Fernando Oliveira:94 and 174</td>
</tr>
<tr>
<td>Livro Náutico</td>
<td>1</td>
<td>17 before; 17 abaft</td>
<td>Fl. 2</td>
</tr>
<tr>
<td>Sebastião Themudo</td>
<td>1</td>
<td>5 before; 5 abaft</td>
<td>Lavanha:115 and 238</td>
</tr>
<tr>
<td>Gonçalo Roiz</td>
<td>1</td>
<td>15 before; 15 abaft</td>
<td>Lavanha:117 and 240</td>
</tr>
<tr>
<td>João Baptista Lavanha</td>
<td>1</td>
<td>5 before; 5 abaft</td>
<td>Lavanha:57 and 163, fl. 72</td>
</tr>
<tr>
<td>Manoel Fernandez</td>
<td>3</td>
<td>15 before; 15 abaft</td>
<td>Fernandez: fl.1 v.º</td>
</tr>
</tbody>
</table>

(1) As many pre-designed floors as the number of ramos in the keel.

Other authors indicate different solutions. In Spain, Diego Garcia de Palacio mentions nine pre-designed floors to the bow and six to the stern, and Tomé Cano prescribes 14 pre-designed floors on each side of the master frame.

The clues left on the structure of the Pepper Wreck are scarce yet speak volumes. As mentioned in Chapter VII, only eleven floors were partially preserved, and of these only a few were not badly broken. All the floors that were not broken were lost during the period between 1997 and 1999, due to lack of means to expose and protect the
structure after it was covered by several meters of sand during a series of storms in the winter of 1997.

Profiles recorded in 1996 and 1997 using an electronic goniometer revealed the position of the planking, rather than the curves of the lower face of the floors, and are not very useful for the analysis of the shape of the frames. Moreover, many construction marks could not have been observed \textit{in situ}, as the timbers required thorough cleaning before most of the marks could be exposed.

However, the available evidence allows a tentative reconstruction of the process followed by the shipwrights of the Pepper Wreck. The most important clues for the understanding of the construction process are the numbers engraved on the floors, the rate at which the height of the floors grows over the keel, the surmarks which suggest the position of the turn of the bilge, and the curves of the futtocks.

The construction features exhibited by the hull remains appear to represent the signature of a particular shipbuilding tradition. The Iberian-Atlantic tradition is documented by João Baptista Lavanha who wrote perhaps the first treatise on shipbuilding where the theoretical role is clearly ascribed to an architect, and not to a shipwright. His remarks on the building sequence include several references to the surmarks as part of the common construction routine:

\textit{(...) then the straight line MS, the middle of the floor, may be marked with a scribe, and two others that terminate the astilha, set off from MS half a palmo each side, which make the breath of the keel, and thus with the same escopro the straight line OP of the wronghead may be marked too \textit{(...)}.

\textit{VIII.27}}

João Baptista Lavanha also explains the necessity of numbering the floors during construction:
And at each floor with the same scribe its number may be marked on it, first, second or third, etc, whatever it may be, so that it may be known where it has to be set, and what its place is. \textsuperscript{VIII.28}

He goes on to make a very interesting reference to the insufficiency of the sections of the timbers, which may not allow the mold to touch the whole perimeter to be drawn. Such care must have applied to the design of the Pepper Wreck, for many of the large timbers clearly show the difficulties of obtaining adequate compass wood for the construction of large ships. When the mold floats above the surface of the timber to be cut, Lavanha recommends the use of a prismatic weight:

And when on the frames of the said timbers there may be wany edge [falta = lack] (which often happens) (...) a small stick may be used, with four faces, ending in a point, called in this Art chincho, hung along the template (...). \textsuperscript{VIII.29}

We have seen in the last chapter that in the case of the Pepper Wreck there was evidence for three master frames, and an undetermined number of pre-designed frames of which only 11 were preserved, numbered with roman numerals, and pre-assembled before being mounted on the keel. Each frame was numbered counting from the master frames, which bore the number zero. The height of each floor over the keel rose as distance from the master frames increased, and the values of this rising closely match the rule defined by Father Oliveira (Table VIII.8) for the rising of the turn of the bilge points.

It follows that the four turns of the bilge surmarks should match the predicted narrowing of the floor timbers described in Oliveira's model. If this is the case, it will be interesting to analyse the design of the floors and futtocks preserved and recorded over the templates built after Oliveira's theoretical model.
Rising of the Bottom

Both Fernando Oliveira and João Baptista Lavanha state that the floors should be 1 *palmo de goa* molded, as shown below (Table VIII.5).

<table>
<thead>
<tr>
<th>Author</th>
<th>Keel length</th>
<th>Bibliographic ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Oliveira</td>
<td>Sided: 1 pg</td>
<td>Oliveira:116 and 197</td>
</tr>
<tr>
<td></td>
<td>Molded: 1 pg</td>
<td></td>
</tr>
<tr>
<td>Sebastião Themudo</td>
<td>Sided: 1 pg</td>
<td>Lavanha:115 and 237</td>
</tr>
<tr>
<td>Gonçalo Roiz</td>
<td></td>
<td>Lavanha:117 and 240</td>
</tr>
<tr>
<td>João Baptista Lavanha</td>
<td>Sided: 1 pg</td>
<td>Lavanha:38 and 150, fl. 58 νª</td>
</tr>
<tr>
<td></td>
<td>Molded: 1 pg</td>
<td></td>
</tr>
</tbody>
</table>

This is an important measurement, not only because the floors of the Pepper Wreck were in fact 1 *palmo de goa* square, but also because when this value is subtracted from the total height of the floors measured over the keel, a series of values are produced that follow closely a sequence of numbers obtained through a mathematical algorithm called *graminho* and clearly defined by Fernando Oliveira.

(...), our carpenters call *graminho* (...) the distribution of increments by which the bottom, and the waist and the beam, of the ship are raised and narrowed. Which distribution is marked on a board, following the art that is indicated now. This art results in the making of an instrument which is also called *graminho*: for it indicates the apportionment by lines of certain fractions of the *compartida* (or length that is divided).\textsuperscript{30}

The *graminho* was a gauge with a series of incised grooves and was used in the design of the floors through a system that is today known as whole-molding. Using a single straight half mold and two gauges, one for the rising and another for the
narrowing, each floor was designed and sent to the sawyers in the manner shown on the figure below (FIG. VIII.6).

FIG. VIII.6 - Rising and narrowing of the bottom of a vessel using the whole-molding system. Drawing: Filipe Castro.

Each floor was plotted from the original flat mold, which corresponded to the master frames. Then the first floor before the master frames was designed using the master frame’s mold by narrowing one point and rising one point, the second by narrowing two points and rising two points, continuing to the last pre-designed frames which were called the tail frames or, in Portuguese, *almogamas* (FIG. III.2).

The two rising scales and the single narrowing scale were designed through a series of possible methods which had already been explained by Zorzi Timbotta in the
middle 15th century. In his book Oliveira uses the old Italian mezzaluna, called besta or meia lua in Portuguese, a word that means cross-bow (FIG. III.3). The values for the total rising to the stern and to the bow, and for the respective total narrowing varied from author to author. Designating the value of the total rising or narrowing as compartida, Oliveira proposes the following:

Each of the scales related to the rise of the bottom has its own compartida: one for the stern and another for the bow, and they are different: one more and the other less: that of the stern more, and of the bow less (…) The after scale usually rises one twelfth part of the length which, with eighteen pairs [floor and futtock], gives us one ‘pair and a half’: and the one for the bow rises one half or one third less, resulting in almost a single ‘pair.’ VIII.31

In other words, the bottoms should rise 1.5 times the value of room-and-space to the stern, and one time the room-and-space to the bow. Further on Oliveira proposes that the narrowing be a sixth of the flat amidships.

These values were tested and a very close match was obtained, as shown in Table VII.8. The procedure is quite simple. The besta method consists of dividing half a circumference in two, and then in dividing each half into equal parts, as many as the number of floors over which one wants to spread the rising of the narrowing of bottom. Under the symmetrical axis is placed the wooden gauge used to mark the horizontal grooves corresponding to the increments to be applied on each floor (FIG. III.3). The total rising or narrowing is the radius of the circumference (FIGs. VIII.6 and III.3). When each division of the circle, on each side of the half circumference, is united with its equivalent over the wooden gauge, a new point is marked on the sequence. Moving down the arc of the circumference, starting from the centre, at 90°, larger increments are produced. The last division is equal to the base line, and the angle is 0°. Using H to represent the total rising or narrowing, and n the number of pre-designed frames, the distance between each incremental line and the top of the gauge, h_i, will be given by the equation:
\[ h_i = l - \sin \left( \frac{90}{n_i} \right) \times H \]

It is therefore easy to generate by computer all the required values from this equation, and this was precisely what I have done, using an Excel® spreadsheet. The values obtained are listed below (Table VIII.6).

It was necessary to test the other formulae for the design of ship's bottoms, as proposed by the other authors, in order to determine whether or not the rising of the bottom of the Pepper Wreck followed Oliveira's rule.

<table>
<thead>
<tr>
<th>Frame number</th>
<th>Besta - 1 1/2 pares (cm)</th>
<th>Besta - 1 par (cm)</th>
<th>Pepper Wreck (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25.9</td>
<td>25.8</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>26.7</td>
<td>26.4</td>
<td>31</td>
</tr>
<tr>
<td>III</td>
<td>28.0</td>
<td>27.2</td>
<td>25</td>
</tr>
<tr>
<td>IIII</td>
<td>29.8</td>
<td>28.5</td>
<td>27</td>
</tr>
<tr>
<td>V</td>
<td>32.2</td>
<td>30.0</td>
<td>36</td>
</tr>
<tr>
<td>VI</td>
<td>35.0</td>
<td>31.9</td>
<td>31</td>
</tr>
<tr>
<td>VII</td>
<td>38.2</td>
<td>34.0</td>
<td>35</td>
</tr>
<tr>
<td>VIII</td>
<td>41.9</td>
<td>36.5</td>
<td>37</td>
</tr>
<tr>
<td>VIIIII</td>
<td>46.0</td>
<td>39.2</td>
<td>39</td>
</tr>
<tr>
<td>X</td>
<td>50.4</td>
<td>42.2</td>
<td>42</td>
</tr>
<tr>
<td>XI</td>
<td>55.2</td>
<td>45.4</td>
<td>46</td>
</tr>
<tr>
<td>XII</td>
<td>60.3</td>
<td>48.8</td>
<td>-</td>
</tr>
<tr>
<td>XIII</td>
<td>65.7</td>
<td>52.3</td>
<td>-</td>
</tr>
<tr>
<td>XIIIII</td>
<td>71.3</td>
<td>56.1</td>
<td>-</td>
</tr>
<tr>
<td>XV</td>
<td>77.0</td>
<td>59.9</td>
<td>-</td>
</tr>
<tr>
<td>XVI</td>
<td>82.9</td>
<td>63.8</td>
<td>-</td>
</tr>
<tr>
<td>XVII</td>
<td>88.9</td>
<td>67.8</td>
<td>-</td>
</tr>
<tr>
<td>XVIII</td>
<td>95.0</td>
<td>71.9</td>
<td>-</td>
</tr>
</tbody>
</table>

João Baptista Lavanha presented two different solutions for the rising of the bottom of an India nau. Both these methods have one thing in common: the master frame is not flat. In fact, Lavanha can be excluded from the list of candidates who might
have written down the rules describing the building of the bottom of the Pepper Wreck by stating that the master frames should have a foot, in Portuguese pé, of one dedo. I have estimated 1 dedo as 2/3 of a common polegada, or 1.83 cm, a value substantially larger than the Spanish dedo in use in Seville at the time, which was equal to 1.74 cm. 

Since the planking preserved under the master frames of the Pepper Wreck was perfectly flat, and the garboards make an angle of 180° with the upper face of the keel, it is quite clear that whoever built this ship made the master frames flat. Nevertheless, Lavanha’s rules were tested, and very interesting results for both his methods were obtained (Table VIII.7).

<table>
<thead>
<tr>
<th>Floors</th>
<th>Bow &amp; Stern</th>
<th>Pepper Wreck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main floor</td>
<td>30.2</td>
<td>-</td>
</tr>
<tr>
<td>I</td>
<td>30.6</td>
<td>-</td>
</tr>
<tr>
<td>II</td>
<td>31.9</td>
<td>31</td>
</tr>
<tr>
<td>III</td>
<td>33.9</td>
<td>25</td>
</tr>
<tr>
<td>III</td>
<td>36.5</td>
<td>27</td>
</tr>
<tr>
<td>V</td>
<td>39.3</td>
<td>36</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>37</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>42</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>46</td>
</tr>
</tbody>
</table>

The first is presented by Lavanha and appears in his transcription of a document with the rules for an India nau by Sebastião Themudo in 1598. It implies a foot of 2.5 dedos (4.575 cm) and a rising of five dedos before and abaft a single master frame, distributed over five pre-designed frames to each side. The second appears in Lavanha’s transcription of the rules for the making of the nau Conceição in 1598 by the master
shipwright Gonçalo Roiz, and considers a foot of 1 polegada (3.67 cm) on the master frame, and a rising of 2 palmos de vara (44 cm) forward and 3.5 palmos de goa (89.83 cm) abaft the three master frames, distributed over 15 to 17 pre-designed frames to each side.

The results are presented below (Tables VIII.7 and VIII.8) and show clearly that both of these solutions contain a much sharper dead rise than the one recorded on the remains of the Pepper Wreck.

<table>
<thead>
<tr>
<th>Floors</th>
<th>Bow</th>
<th>Stern</th>
<th>Pepper Wreck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main floor</td>
<td>29.3</td>
<td>29.3</td>
<td>-</td>
</tr>
<tr>
<td>I</td>
<td>29.5</td>
<td>29.8</td>
<td>-</td>
</tr>
<tr>
<td>II</td>
<td>30.2</td>
<td>31.2</td>
<td>31</td>
</tr>
<tr>
<td>III</td>
<td>31.4</td>
<td>33.6</td>
<td>25</td>
</tr>
<tr>
<td>IIII</td>
<td>33.1</td>
<td>37.0</td>
<td>27</td>
</tr>
<tr>
<td>V</td>
<td>35.2</td>
<td>41.3</td>
<td>36</td>
</tr>
<tr>
<td>VI</td>
<td>37.7</td>
<td>46.4</td>
<td>31</td>
</tr>
<tr>
<td>VII</td>
<td>40.6</td>
<td>52.3</td>
<td>35</td>
</tr>
<tr>
<td>VIII</td>
<td>43.8</td>
<td>58.9</td>
<td>37</td>
</tr>
<tr>
<td>VIII</td>
<td>47.4</td>
<td>66.2</td>
<td>39</td>
</tr>
<tr>
<td>X</td>
<td>51.3</td>
<td>74.1</td>
<td>42</td>
</tr>
<tr>
<td>XI</td>
<td>55.4</td>
<td>82.4</td>
<td>46</td>
</tr>
<tr>
<td>XII</td>
<td>59.7</td>
<td>91.2</td>
<td>-</td>
</tr>
<tr>
<td>XIII</td>
<td>64.1</td>
<td>100.2</td>
<td>-</td>
</tr>
<tr>
<td>XIII</td>
<td>68.7</td>
<td>109.5</td>
<td>-</td>
</tr>
<tr>
<td>XV</td>
<td>73.3</td>
<td>118.9</td>
<td>-</td>
</tr>
</tbody>
</table>

When plotted graphically it becomes even clearer how the only rule that approximates the values of the Pepper Wreck is that of Oliveira (FIG. VIII.7).
FIG. VIII.7 - Rising of the bottom after the authors analyzed. Graphic: Filipe Castro.

From the graph above we must conclude that the only values that fit the Pepper Wreck are the ones for the rising to the bow in Oliveira's model (FIG. VIII.8).

By the early 17th century, when the Nossa Senhora dos Mártires sank at São Julião da Barra, this was already an old rule to build vessels, as Oliveira had presented it first in 1570, in his Latin manuscript Ars Nautica. However, although it seems that there may have been a trend towards reducing the number of pre-designed frames during the first half of the 17th century, Manoel Fernandez still proposed 15 pre-designed frames in 1616.
Narrowing of the bottom

If the rising of the bottom seems so clearly to follow Oliveira's rule, how does the narrowing behave, according to the data available? The answer is not so clear. However, it seems quite close to the values predicted by Father Oliveira.

Fortunately, the remains of 11 floors were preserved, of which ten still had the full section, over the keel, preserved by the concretions of thick bolts that once linked the keel to the keelson. The positions of the surmarks along the turn of the bilge could not be observed prior to the dismantling of the hull, as they were obscured by the adjacent futtocks. After the partial break-up of the hull remains in the winter of 1997, only four of these marks could be retrieved, and each was separated from the keel by the longitudinal fracture that runs along the hull. It is therefore harder to relate them properly to the keel axis, and much harder to build or test a theory using four of the 39 frames believed to have been pre-designed. Nevertheless, an attempt was made to reconstruct their design.
The first task consisted of closing the fracture to try to get an accurate measurement of the distance between the surmarks and the keel axis. This was done in several different ways, and all have produced slightly different values primarily due to two major problems. First, the seams of this fracture are eroded along several meters, and do not allow a good drawing of the seam. Second, the eastern sections of the floors which still carry the turn of the bilge surmarks were separated from the planking with the exception of one (C4), which was kept in place by a wooden plug (Table VII.22).

The values obtained for the distances from the turn of the bilge marks to the keel axis are therefore fairly accurate before correction (Table VII.12), and highly conjectural after correction (Table VIII.9). The seams were closed in three different ways. The first method consisted in measuring the width of the seam in situ, under each of the floors C4 to C7, and then subtract the values obtained from the total distance between the mark and the keel axis before correction. The second method consisted in rotating the planking in a paper model in order to close the seam, and again subtract the values obtain from the distances between the marks and the keel axis before correction. The third way consisted in rotating the planking and sliding the floors over the planking in order to align the two portions separated by the fracture (except number C4(VIII), which was kept in place on the planking by a wooden dowel). The different values are presented below and compared to the values expected following the model proposed by Oliveira.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Values before correction</th>
<th>Corrected values (1)</th>
<th>Corrected values (2)</th>
<th>Corrected values (3)</th>
<th>Values after Oliveira</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4</td>
<td>202 cm</td>
<td>189 cm</td>
<td>182 cm</td>
<td>189 cm (1)</td>
<td>189 cm</td>
</tr>
<tr>
<td>C5</td>
<td>202 cm</td>
<td>193 cm</td>
<td>188 cm</td>
<td>188 cm</td>
<td>193 cm</td>
</tr>
<tr>
<td>C6</td>
<td>203 cm</td>
<td>196 cm</td>
<td>194 cm</td>
<td>195 cm</td>
<td>196 cm</td>
</tr>
<tr>
<td>C7</td>
<td>203 cm</td>
<td>199 cm</td>
<td>198 cm</td>
<td>198 cm</td>
<td>199 cm</td>
</tr>
</tbody>
</table>

(1) Fixed.
Oliveira proposes a narrowing that is a sixth of the flat of the master frame, which should measure between a third and a half of the maximum beam, and a maximum beam that should measure between a third and a half of the keel length. He defines the ideal beam as being between 8 and 9 rumos and the flat as a third of the maximum beam, that is, 16 to 18 palmos de goa. The two possible values were plotted for the flat and compared to the values from the four series of measures presented above (Table VIII.9). The results were very exciting, as shown in FIG. VIII.9.

FIG. VIII.9 - Narrowing of the bottom. Comparison of the values predicted by Oliveira and those obtained for SJB2. Graphic: Filipe Castro.

These sets of values were then tested against the models of Lavanha, Fernandez, and Gonçalo Roiz. The values involved in these calculations are summarized below, for each of the authors considered (Table VIII.10).
The results were consistent with the ones obtained in the analysis of the rising. The values that match the measures from the Pepper Wreck are again those obtained by Oliveira's rule (FIG. VIII.10).

![SJB2 / Graminhos / Narrowing](image)

FIG. VIII.10 - Narrowing of the bottom. Comparison of the values predicted by Lavanha, Fernandez, and Ruiz, and those obtained for SJB2. Graphic: Filipe Castro.
It seems therefore that both the rising and the narrowing of the bottom of the Pepper Wreck follow quite closely Oliveira's rule.

**Futtock arcs**

The analysis of the futtocks was certainly the most frustrating task in this tentative reconstruction. Not only do the arcs not seem to be constant, but they do not even seem to follow a clear rule as they decrease towards the bow.

There is plenty of evidence for the construction of ships through the whole-molding system using futtocks with just one circular arc. This system was much easier from the point of view of the timber suppliers, who could go to the woods with only one template and fell all the trees necessary to fulfill a certain request, but above all it was much easier for the contractor, who could handle the timbers with much more freedom, in terms of storing and moving around in the shipyard. If the futtocks of a particular vessel were cut from compass timbers with too many different arcs the management of the stocks would have been much more difficult.

Many authors mention a fairly simple and widespread method used to vary the breadth of the frames according to the needs of the shipwright along the sequences of frames before and abaft the master frame. This method was already implied in Matthew Baker's *Fragments of Ancient Shipwrightry* and in Fernando Oliveira's *Liuro da Fábrica das Naus*, and is still in use in the Mediterranean's traditional shipyards.\textsuperscript{VIII.34} It consists mainly in sliding the mold of the futtock down over the mold of the floor in order to open the breadth of the frame at its upper end (FIG. VIII.11). Another way to achieve this consists of rotating the mold of the futtock around the turn of the bilge.

If this widening of the upper tip of the first futtocks is not performed, the narrowing of the bottom is reflected upwards, generally narrowing the decks more than required. For this reason it was common to draw the main deck before assembling the frames, and to fix the breadth at several levels for each station to determine the overture of the first futtocks that would guarantee these pre-determined measures.
This practice is probably much older than the whole molding tradition, and is already documented by Zorzi Timbotta.

Both Fernando Oliveira and Matthew Baker mention this technique, the first by referring to the drawing of the main deck, and the second by showing three curves on one of his best known diagrams, being the first for the rising of the bottom, the second for its narrowing, and the third for the narrowing of the weather deck.\textsuperscript{VIII.35}

However, the puzzling aspect of Oliveira's work is that in one of his drawings he defines a system that implies a different radius for each futtock (FIG. VIII.12).
I had always thought that this was a misunderstanding of Father Oliveira, who knew very much about shipbuilding but had never built a ship. However, the futtocks of the Pepper Wreck do decrease their radius as they move away from the master frame, even considering the odd results obtained for futtock B4E. It seems that in this section of the vessel, two sizes of futtocks were used, the ones with larger radii closer to the midships frame, and those with smaller radii towards the bow. Although this practice is not documented to my knowledge anywhere except in Oliveira's *Liuro da Fabrica das Naus*, it seems possible that the frames were assembled with futtocks with radii that vary gradually towards the extremities by steps rather than continuously, as Oliveira seems to suggest. This solution would be a compromise between his system, which suggests a different radius for each futtock in all of the pre-designed frames, and the normal way, which implies the use of different extensions of a set of futtocks with the same radii. It is unfortunate that insufficient data exists for this wreck, precluding a clear understanding of the method used to cut the first futtocks of this vessel.
A proposed reconstruction

A lines drawing of an India nau was produced, based on Fernando Oliveira's data and on the six floors and futtocks preserved in situ. The first task consisted of putting them together over the keel, and then fairing the lines obtained. The results were fairly good, discounting some minor discrepancies that may have resulted from the degradation of the remains and the recording process (FIG. VIII.13).

It was fairly easy to put the frames over a pre-designed set of rising and narrowing lines determined for the working hypothesis described before, which implied a total narrowing of 1/6 of the flat amidships on each side, and a total rising of 1 room-and-space, both distributed over 18 floors. However, as mentioned above, there are a few discrepancies that deserve mention here:

a) The turn of the bilge marks of floor C5 (VII) and C6 (VI) are clearly below their theoretical position, which should be on a straight line between C8 (III) and C2 (X);
b) It was not possible to fair the waterline WL2. It would be possible to run a line parallel to WL1 over the intersection points from the stations C2 (X) and C4 (VIII) but the futtock C3 (VIII) would be 3 to 4 cm centimeters short of the planking;

c) The small arc on the outer extremity of futtock C5 (VII) stands too low and does not match the curvature of the remaining futtocks;

Some of these discrepancies can be explained by the fact that oak timber can distort over time.

The second task consisted of an attempt to create a set of lines for the complete vessel, following Oliveira's instructions. I have considered the basic measures presented by him for the nau of 18 rumos of keel (Table VIII.11).

The final drawing shows a consistent, plausible hull with a transom plunging very low in the water, as frequently shown in the illustrations of the treatises and in most of the iconography of this period (FIG.VIII.14).

The quarterdeck hangs far abaft the transom, reminiscent of Valentim Themudo's remarks on the danger of the enemy placing a boat under the stern to try to set the vessel on fire. And finally the load waterline, whose position is suggested around the level of the lower deck by the placement of the stringers and whales, seemed quite low and unstable, and certainly did not fit the accounts of the overloaded Madre de Deus, allegedly drawing 31 feet as mentioned above on page 187. I chose to put the load waterline at the level of waterline number 3 on the figure below (FIG. VIII.14), 4.62 m above the bearding line amidships, and got a displacement of 1,096 tons. For a load waterline at the level of waterline 4, running 6.16 m above the bearding line amidships I got a displacement of 1,684 tons. The volumes before and abaft the midship section are more or less the same for both theoretical load waterlines, the after part displacing 49% of the total volume below the theoretical load waterlines. This suggests that this vessel sat almost flat on the keel, with a minor drag, the true load waterline running almost horizontal.
Table VIII.11
Basic measures for the construction of Oliveira’s India nau

<table>
<thead>
<tr>
<th>Element</th>
<th>Rule of Proportion</th>
<th>Value (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Keel</td>
<td>18 rumos for 600 tonéis</td>
<td>27.72</td>
</tr>
<tr>
<td>B. Spring of the stem post</td>
<td>1/3 of A</td>
<td>9.24</td>
</tr>
<tr>
<td>C. Height of the stem post</td>
<td>1/3 of A</td>
<td>9.24</td>
</tr>
<tr>
<td>D. Rake of the stem post</td>
<td>1/4 of A/3</td>
<td>2.31</td>
</tr>
<tr>
<td>E. Height of the transom</td>
<td>1/3 of A</td>
<td>9.24</td>
</tr>
<tr>
<td>F. Maximum breath</td>
<td>1/3 to 1/2 of A</td>
<td>12.32</td>
</tr>
<tr>
<td>G. Flat amidships</td>
<td>1/3 to 1/2 of D</td>
<td>4.10</td>
</tr>
<tr>
<td>H. Room and space</td>
<td>1 palmo de goa + 1 palmo de vara</td>
<td>0.48</td>
</tr>
<tr>
<td>I. Rising of the bottom</td>
<td>Forward: H; Aft: 1.5 H</td>
<td>0.48/0.72</td>
</tr>
<tr>
<td>J. Narrowing of the bottom</td>
<td>1/6 of G</td>
<td>0.68</td>
</tr>
<tr>
<td>K. Height of the fashion pieces</td>
<td>Start at 1/3 of E</td>
<td>3.08</td>
</tr>
<tr>
<td>L. Breath of the transom</td>
<td>1/2 of F</td>
<td>6.16</td>
</tr>
<tr>
<td>M. Maximum breath on main deck</td>
<td>F - (= 1+1 palmos de goa)</td>
<td>11.81</td>
</tr>
<tr>
<td>N. Depth of the hold</td>
<td>14 palmos de goa</td>
<td>3.59</td>
</tr>
<tr>
<td>O. Depth of the second deck</td>
<td>9 palmos de goa</td>
<td>2.31</td>
</tr>
<tr>
<td>P. Depth of the gun deck</td>
<td>9 palmos de goa</td>
<td>2.31</td>
</tr>
<tr>
<td>Q. Length of the quarter deck</td>
<td>1/2 of length of deck (D+A+B)</td>
<td>20.46</td>
</tr>
<tr>
<td>R. Height of the quarter deck</td>
<td>8 palmos de goa</td>
<td>2.05</td>
</tr>
<tr>
<td>S. Length of the poop deck</td>
<td>1/2 of Q</td>
<td>13.86</td>
</tr>
<tr>
<td>T. Height of the poop deck</td>
<td>7 palmos de goa</td>
<td>1.80</td>
</tr>
<tr>
<td>U. Length of the forecastle</td>
<td>1/2 of M</td>
<td>5.90</td>
</tr>
<tr>
<td>W. Height of the forecastle</td>
<td>1/3 of M</td>
<td>3.94</td>
</tr>
<tr>
<td>V. Height of bulwarks on the deck</td>
<td>1 rumo</td>
<td>1.54</td>
</tr>
<tr>
<td>X. Height of bulwarks on the castles</td>
<td>3 palmos de goa</td>
<td>0.77</td>
</tr>
<tr>
<td>Y. Length overall</td>
<td>A+B+D</td>
<td>39.27</td>
</tr>
</tbody>
</table>

Fairing the lines proved very difficult and in the end a set of lines was produced where the futtocks have more or less the same radii, contradicting both the theoretical data supplied by Father Oliveira, and the archaeological data retrieved from the seabed off São Julião da Barra.
FIG.VIII.14 - Tentative reconstruction of an India nau after Fernando Oliveira and the Pepper Wreck remains. Drawing: Filipe Castro
Planking

As mentioned above, all planking was cut from stone pines (*Pinus pinea*) as was to be expected from contemporary accounts:

For planking, we use pine, because it is flexible and close grained, free of fissures and does not crack: furthermore, its sap is resinous and resists the humour of water, which does not penetrate it, And it is also contrary to the shipworm: which it does not create in itself, nor admits from the outside: Vitruvius says that this wood becomes bitter and will not consent the penetration of the shipworm, nor support it. The pine of which he speaks is the stone pine, which provides the seeds that we eat: and by this, we must understand that it is good for the planking of ships, contrary to the cluster pine, which has long cones without seeds of any use: because the wood of this cluster pine is dry and without the resin that resists the humour of the water: which penetrates it and causes it to rot: this why it is useless except for upper works which are situated above the water.\textsuperscript{VIII.36}

The planking was preserved over a relatively large extent, but was not attached to the frames since the iron spikes had long decayed. Several profiles were taken of the interior planking surface with a goniometer, but these show instead the profile of the bottom underneath, and even if some of the planks did retain part of their original curvature it was not possible to use this curvature in the reconstruction of buttock lines.

As stated above in Chapter VIII, the maximum widths of the planks varied from 15 to 35 cm. The lengths varied between 3.38 (T8W(1)) and 5.83 m (T9W(2), broken).

The angle formed between the upper face of the garboard and the upper face of the keel varied along the preserved section of the hull, and it was clear that the angles to the surface of the keel narrowed towards the bow. The values taken *in situ* are presented below, on Table VIII.12. At the apron, this angle was 136°, as indicated below, but since the apron could not be accurately positioned along the keel axis, this information does
not give definitive clues for the design of the bow. The indication XVI means only a presumption that the first floor sits on the apron.

<table>
<thead>
<tr>
<th>Table VIII.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of the garboard / keel</td>
</tr>
<tr>
<td>Section</td>
</tr>
<tr>
<td>C10 (II)</td>
</tr>
<tr>
<td>C1 (XI)</td>
</tr>
<tr>
<td>Apron (XVI)</td>
</tr>
</tbody>
</table>

All the planking was elaborately carved and carefully fitted to the frames. Because of its thickness (11 cm) and the design of its seams, which were at times joggled by the introduction of notches and bevels, it conveys a sense of strength and rigidity (FIG. VII.21 and VIII.15).

Since only the portion of the planking situated amidships was preserved, where the runs are generally smooth and many times almost flat, it is difficult to reconstruct the building sequence. It is possible that the construction of such planking entailed some defining runs or, in other words, planks that were placed before the others, running from post to post at certain pre-defined heights. This procedure is described by João Baptista Lavanha in the last pages of his unfinished manuscript, and consists of the placement of two wales that have fixed paths over the 11 pre-designed frames to the sternpost and stem. However, no wales were found on the hull of the Pepper Wreck, and this may be explained by Father Oliveira's assertion that wales should not be placed below the water line, the longitudinal strength being provided by stringers.
The care taken to keep the surface of the hull as smooth as possible makes sense if one considers that it must have been fairly well understood by shipwrights and officers that at low speeds the shape of the hull had almost no importance in determining the drag during long trips, and that the most important factor for better performance under full sail was the smoothness of the surface immersed. Perhaps for this reason all nail heads were lodged in counter sink holes, although there was no evidence for any protection or covering of these.

An attempt was made to find symmetrical planking strakes that looked regular enough to be used to define these runs. No clear longitudinal runs could be identified, and it seems that the bottom of this hull was designed transversally, at least in this central part, and faired only at the ends, after the placement of the ribbands, or *armadouros*. (see FIG.VII.21).
Fastenings

As previously described, all fastenings consisted of iron spikes and bolts. This practice was advised by all the authors who address this issue, since treenails were believed to be easily eaten by shipworms. Oliveira claimed that treenails were a good solution for smaller craft, the best being of chestnut, but should not be employed on these vessels, for the lengths required implied impractical thickness.\textsuperscript{VIII.38} Lavanha agreed with these observations and added that since the shipworms eat the wood along the grain, and the grain of the treenails runs perpendicularly to the planking, these large treenails could easily become preferential paths for water leaks.\textsuperscript{VIII.39}

The list of expenses for the construction of two India naus in 1624-25 contains no mention of treenails whereas the "assorted nails and bolts" category accounted for several tons.\textsuperscript{VIII.42} Although Oliveira advised against the use of spikes completely punched through the timbers, many were clenched over the insides of floors and futtocks.

Marks left by the fastening indicated the positions of several floors and futtocks that had already disappeared. Similarly, several spike holes on the upper surface of the preserved floors and futtocks suggest that although there was no ceiling in the central portion of the bilge of this vessel, more or less 1 m to each side of the keel, beyond that line there was a ceiling loosely fastened to the frames (FIG. VIII.16).

It was not possible to guess where the footwales ran from the positions of these spike holes, although there is no doubt that somewhere in the overlapping zone of the floors and futtocks there were one or two footwales spiked to the frames. Here again, the existence of through holes on these timbers does not allow clear understanding of the direction from which the spikes were driven in.
Caulking

The caulking arrangement seen on the Pepper Wreck is not mentioned by any author or list of materials and prices consulted, except for Pyrard de Laval, who wonders why the Portuguese only cover the seams with lead straps instead of fully sheeting the hull "as we [the French] do." However, he mentions a second layer of planking on Portuguese ships that did not exist on this wreck. VIII.41

Oliveira supports the practice of placing a second layer of planking over the first, thereby alluding to the famous galagala, a caulking paste made of oil and chalk also mentioned by Pyrard and accounted for in the Harvard manuscript, and recommends that warships and vessels destined for transcontinental trips have hulls thicker than 4 dedos (7.32 cm). VIII.42

According to Fernando Oliveira, caulking was a very delicate operation, to be undertaken with care. The caulkers were obliged to check all the seams and parts of the
ship where water could penetrate or seep in, and had to caulk them with oakum and paint them with pitch. After caulking as many times as necessary to fill the seams with highly compressed oakum strings, the surface was burned to soften the pitch which had already been applied and to prepare the surface for another coat of pitch or tar. Then the oakum that had been burned by this phase of the caulking operation was replaced and the whole surface painted again with another pitch coating. Finally, a layer of lead plates was nailed over the pitch and the oakum, covering the seams or cracks, of the planking to protect them.\textsuperscript{VIII.43}

Building contracts stated frequently that the ship should be delivered ready and “black, in the water,” which meant that the final caulking was performed by painting layers of pine resin, the breu, obtained by a process that consisted of burning the wood in a furnace. This resin was then mixed with charcoal and vinegar and melted again for a complete hot coating of all the timbers.\textsuperscript{VIII.44}

Lavanha and Fernandez do not mention caulking. A short allusion to lead is made by Lavanha, who explains that among the materials for shipbuilding were "nails, linen, tow, tar, pitch, grease and lead (\ldots)."\textsuperscript{VIII.45}

Wood

Wood was naturally the most important material utilized in the construction of any vessel and it is predictable that much was written about which timbers to use, how to choose them, or where and how to cut them. Father Oliveira is clear in stating that in Portugal there were two kinds of wood suitable for shipbuilding, and that these were cork oak and stone pine:

In this, our land, there are two kinds of woods that are appropriated for these two parts of ships, respectively: they are the woods of cork-oak and of pine. The cork-oak for the frames and the pine for the planking.\textsuperscript{VIII.46}
Lavenha is of the same opinion, and so are the other authors consulted. References exist to the use of small quantities of other woods, such as European oak for some beams, and cluster pine for the planking of the upper decks, above the water line, as already suggested by Fernando Oliveira. \(^{87}\)

**Ballast**

At this point there is no data to support any speculation regarding the nature and the extent of the ballast pile. The most likely hypothesis is that the layer of pebbles found over and around the hull remains was part of the ship's ballast. However, since the ballast may have been loaded on one of the beaches nearby, it will be impossible to estimate the size and weight of the ballast carried on the Pepper Wreck.
CHAPTER IX
CONCLUSIONS

A Portuguese Indiaman

To conclude, it seems reasonable to state that in this dissertation I have developed a good working hypothesis regarding the size and shape of the Pepper Wreck, in spite of the relatively limited extent of the hull remains that were object of this study. As to the identification of this wreck, the Nossa Senhora dos Mártires, lost on September 1606 off São Julião da Barra, stands as the almost-certain candidate.

The collection of artifacts found on the SJB2 area, in and around the wreck, consistently matches both the type of assemblage expected to be found on a home bound Portuguese India nau, and the time frame of this particular shipwreck. The cargo of pepper, the porcelain dishes, the Chinese stoneware, and the green and yellow glazed earthenware, all typical of the late 16th century, as well as the date 1605 on the third astrolabe (FIG. VI.10 and IX.1) leave no doubt that this ship was returning from Asia and could not have left Lisbon earlier than 1605, the precise year of departure of the Nossa Senhora dos Mártires. This is particularly important when we consider that no other India nau wrecked near the fortress of São Julião da Barra after 1606 and before 1783, as shown in Table VI.2.

An in-depth study of the artifacts, the subject of a Master of Arts thesis at Texas A&M University, will certainly reinforce the assumptions made above.\textsuperscript{IX.1}

The most important aspects of this wreck site are related to the portion of the hull preserved, which after study reinforced the assumption that this is the wreck of the Nossa Senhora dos Mártires. The types of timbers used in its construction, cork oak and stone pine (see FIG. VII.32 and FIG. VII.33), are typically Portuguese and very probably exclusively Portuguese. The size and shape of the timbers also matched our expectations of a late 16th or early 17th century ship, built in a period when the scarcity of large suitable trees and good compass timber, mentioned by several authors (Chapter
VIII, pp. 191-192), forced shipwrights to build these large vessels as a patch work of small logs.

The design too, matches the guidelines expressed by Father Fernando Oliveira in his *Liuro da Fabrica das Naus* (1580), the building procedures expressed by João Baptista Lavanha in his *Livro Primeiro de Arquitectura Naval* (c. 1610), and the rules of Manoel Fernandez Fernandez' *Livro de Traças de Carpintaria* (1616). With many doubts still to be clarified in the future (when hopefully other India nau wrecks will be object of archaeological study) these timbers seem to have been designed following the methods in use in Portugal in the late 16th and early 17th century period.

A series of marks engraved by the shipwrights on the floors not only mirrored the set of construction rules and prescriptions presented by Lavanha in his book (Tables VII.10, VII.11, VII.12 and VII.13), but showed a logical pattern of design, with three master frames, just as Oliveira and Fernandez recommended for a standard India nau of 26.95 to 27.72 m of keel (Tables VIII.2 and VIII.4). Following their instructions I have
tested the rising and narrowing of the bottom found in situ with the theoretical values expressed in Oliveira, Lavanha, and Fernandez' works.

The rising of the bottom was clearly designed following an arithmetical algorithm that is known from many written sources to be very common in Portugal at the time (FIG. VIII.9). The narrowing also matches a similar arithmetical algorithm, although the conditions in which the data pertaining to this feature was retrieved were far from perfect – implying a tentative match of a very broken and distorted seam (FIG. VIII.10).

The study of the shape of the few preserved futtocks yielded the most disappointing results. Only six futtocks were preserved to some extent (FIG. VI.3) and no futtock was preserved entirely. Many of these timbers had large gaps in their sections and some had patches filling the larger gaps (Table VII.5), showing again the difficult situation the shipwrights faced when building such a large vessel with such small stock of suitable timber. When analyzed, the futtock curvatures did not match any of the expectations. Although they clearly show a turn of the bilge arc and a futtock arc, the radii found through the several methods of analysis utilized did not follow any particular pattern, at least in the way in which these timbers are believed to have been cut. (Table VII.17).

Instead of a regular design obtained by the application of a standard mold that would slide or tilt to allow the shipwright to obtain a fair set of longitudinal runs while rising and narrowing the bottom of the vessel (FIG. VIII.12), it seems that the futtock's radii diminish towards the bow, as Oliveira indicates in his book (FIG. VIII.13). The irregularity of the values obtained is far from the unlikely precision implied in Oliveira's drawing. This scheme (FIG. VIII.13) has often been interpreted as the result of a poor understanding of the building technique, because it seems very labor intensive to cut each pair of futtocks with a particular radius from a particular compass timber, for all the 39 pre-designed frames required. This practice would raise some problems with regard to provisioning, stocking and handling of compass wood in any shipyard, should this process be applied with the precision implied in Oliveira's drawing.
However, when we look at the values obtained from the six futtocks that were analyzed, there seems to be a trend towards the reduction of the futtock's arc as we move away from the master frames (Table VII.17). The irregularity of the values obtained suggests that the frames were assembled on the ground – as the fastening pattern between floors and futtocks shows without any doubt – over a template were the maximum beam and the beam on the main deck were marked with precision for each station, and the futtocks were chosen "by eye" from the pile of timber stock. The larger radii were naturally utilized on the frames that are closer to the midships, and the smaller radii in the extremities.

A pile of timber probably buried in the sand after the 1755 earthquake was found in 1996 on the site of Lisbon's 16th and 17th century shipyard, by a contractor who was building a large underground park on Praça do Municipio. Still under study, it encompasses a few keel sections with the rabbets already opened, stored next to a number of roughly cut flat, "V," and "Y" shaped timbers, obviously meant for the construction of floor timbers. No curved timbers were found anywhere nearby, perhaps suggesting that these were stored separately, and reinforcing the idea that the futtocks were chosen from a pile of more or less equally curved timbers, the bigger radii used to assemble wider frames, the smaller radii for the frames to be placed closer to the extremities.

The planking, cut from straight stone pines of several ages, from fairly young trees to some larger logs, was laid regardless of the grain, sometimes the heart to the interior, sometimes to the exterior, certainly profiting from the natural warp of each plank, as it is still done in Portuguese shipyards today (FIG. VII.23). No continuous runs were identified at any distance from the keel on the preserved area of the planking. We know that ribbands (armadouras) were used both to achieve a smooth longitudinal overall shape of the hull, and in shaping the portions of the hull before and abaft the pre-designed central portion of the hull, as is mentioned by Oliveira and Lavanha. The absence of continuous strakes suggests that either the ribbands were removed after the framing was completely fastened in place, or that the defining strakes ran above the
preserved area of the bottom. The thickness of the planks, the general irregularity of the disposition of the seams, the existence of joggled seams, and the caulking solution adopted are peculiar enough to deserve mention here. The caulking arrangement matches the only other archaeological information available about India naus, from the presumed wreck of the Santo António (1598), inspected in the Seychelles by Jeremy Green in the 1970s. Similar lead strings have been found in sediment dredged from the mouth of the Arade river, on the southern coast of Portugal, in the 1980s, which showed clear marks of having been wrapped in some type of fabric.

Despite the difficulties, it was possible to propose a reconstruction of the hull shape based upon the shape of the timbers recorded on this wreck and the extrapolations made from the shipbuilding treatises and texts mentioned in Chapter III. The reconstruction is shown in Chapter VIII (FIG. VIII.14 and FIG. VIII.15).

Regarding the central portion of the hull where I considered the supposed 39 pre-designed frames, I have followed the general scheme proposed by Father Oliveira, of three master frames and 18 pre-designed frames, before and abaft these midship frames.

The general dimensions were also defined according to Oliveira's proportions (Table VIII.11). As mentioned in Chapter VIII I have obtained a displacement of around 1,100 tons for a draft of 4.62 m amidships, the water line running about 75 cm above the lower whale at that point, which was supposed to run at the level of the lower deck. I have varied the draft above the projected load water line and obtained a maximum of 1,684 metric tons of displacement for a draft amidships of 6.16 m.

These values are not very far from the 1,200 tons displacement expected for a vessel of 600 tons burden. The coefficients calculated for the projected load water line are indicated below (Table IX.1). The length to beam ratio obtained was $39.27 / 12.32 = 3.19:1$, again within the values proposed in the literature of the late 16th and early 17th centuries.

The coefficients indicate some of the characteristics of this tubby hull, but how fine were its entries? For a waterplane coefficient of 0.74, which shows the low transom and the round bow it has a block coefficient of barely 0.50. One should note that
although its lower midship section is almost a perfect half circle and the central portion of the lower hull shows a slight deadrise before and abaft the tailframes, the hull quickly develops a wineglass shape forward and aft, already suggested on frames C10 and C11.

<table>
<thead>
<tr>
<th>Table IX.1</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water plane:</td>
<td>$C_w = 0.74$</td>
</tr>
<tr>
<td>Midships:</td>
<td>$C_m = 0.71$</td>
</tr>
<tr>
<td>Block:</td>
<td>$C_b = 0.49$</td>
</tr>
<tr>
<td>Prismatic:</td>
<td>$C_p = 0.69$</td>
</tr>
</tbody>
</table>

Iberian ships

I would like to conclude with a final word regarding the recent theoretical works pertaining to the definition of a possible Iberian shipbuilding tradition and the place of this wreck within this tradition. As mentioned before, all written sources considered in this study point to the existence of a standard India nau. Although varying in size and presenting a general tendency to grow as the 16th and 17th centuries went by, all India naus seem to have been built according to a well defined standard. There is no doubt either that these vessels belong to the well-established Mediterranean skeleton-based shipbuilding tradition. The question now under analysis is whether this India nau standard belongs to the Iberian Atlantic family of water craft, supposing that such a thing exists and can be defined.

Let us first attempt to define this Iberian Atlantic family of water craft, the scope of its cultural horizon, and the characteristics of its ships. In other words, what were the traits common to all Iberian Atlantic vessels, and how were these traits in the context of the post-Medieval European shipbuilding tradition.

Eric Rieth introduced the concept of "architectural signatures." He defined these signatures as secondary technological characteristics that are not decisive for the
definition of an architectural system but may indicate common practices or traditional techniques specific to a certain place and time span.\textsuperscript{IX.5} According to Rieth these "architectural signatures" are the equivalent of what Ole Crumlin-Pederson had already proposed as "fingerprints" on Scandinavian Medieval craft.\textsuperscript{IX.6} It was Thomas Oertling who first addressed the question of defining a certain number of traits that characterized the West-Atlantic Post-Medieval craft in Europe. In 1989 he proposed a series of 12 distinct traits shared by seven vessels that showed an Iberian association in a defined time period, the 16\textsuperscript{th} century.\textsuperscript{IX.7} His analysis was solely based on the archaeological record, and did not consider iconographic, ethnographic, or historical data, namely the treatises and other texts related to shipbuilding in the Iberian world for the period under analysis. The 12 common traits proposed by Oertling are nevertheless a very interesting set of construction features, understandably related to the bottoms of vessels. They emphasize mainly the existence of a central portion of the hull built skeleton first with pre-designed frames, the fastening process of the carvel planking over the frames, the arrangement of the connection between keel and sternpost, the keelson and maststep arrangement, the ceiling layout, a characteristic detail related to the attachment of the shrouds to the hull, the existence of a flat transom with a proud sternpost, and the shape of the garboard (Table IX.2).

The seven vessels analyzed in 1989 by Thomas Oertling were the Rye A vessel \textsuperscript{IX.8}, the Cattewater wreck \textsuperscript{IX.9}, and the Studland Bay wreck \textsuperscript{IX.10}, all found in English waters. The Basque whaler \textit{San Juan} found in Newfoundland, Canada \textsuperscript{IX.11}, the Caribbean wrecks of the \textit{San Esteban} \textsuperscript{IX.12}, the Highborn Cay wreck \textsuperscript{IX.13}, and the Molasses Reef wreck.\textsuperscript{IX.14} In spite of the great variety of types of vessels considered, and their different sailing routes, many similarities were found when analyzed with regard to the 12 traits presented below.
Table IX.2
Characteristics of the Iberian Atlantic vessels as proposed by Oertling in 1989

1. A given number of pre-assembled central frames bearing dovetail joints.
2. Carvel planking fastened with a combination of nails and treenails.
3. A knee joining the after end of the keel and the sternpost (couce).
4. A single piece deadwood knee over the couce upon which sit the Y-frames (coral).
5. Y-frames tabbed into the deadwood knee.
6. Keelson notched over the floors.
7. Maststep is an expanded portion of the keelson, part of which is cut to seat the ship's pump.
8. Buttresses supporting the maststep against the footwale.
9. Ceiling extending only over the floors, the last strake notched to receive filler planks.
10. Teardrop-shaped iron strop accepting a deadeye attached to 2 or 3 lengths of chain, the last link through an eyebolt.
11. Flat transom with proud sternpost.
12. Garboard carved from an extra thick plank.

The Rye A wreck was dated to the middle 16th century. It was found by a machine digging a pit for a new drainage system in St. Mary's Marsh, at Rye, Sussex, England, and was not excavated. Some timbers were abandoned near the site, and other broken timbers were kept in the local school and analyzed later. The Cattewater wreck was clearly ballasted in south England and although it may have been purchased somewhere in the Iberian Peninsula (it was built of oak and pine), or built in England by Iberian or Italian shipwrights, it is presumed to have been sailing in English hands. The other vessels considered in this study are certainly Iberian. The Studland Bay wreck was a Spanish trader sunk in the early 16th century in Poole Bay, Dorset, England, the San Juan was a Basque whaler sunk in 1565, the San Esteban a large nau sunk in the New World in 1554, and the Molasses Reef and Highborn Cay wrecks two small, early 16th century vessels engaged in the exploration of the New World. The Molasses Reef wreck is thought to have been ballasted in Lisbon.

The occurrence of these 12 traits in each one of the above mentioned wrecks is presented below. In spite of the scarcity of the data available at the time, which is expressed in the many empty spaces on the table below, it is interesting to notice how most of the traits are consistent within the group of vessels considered (Table IX.3).
This study was continued by Thomas Oertling a decade later considering the number of Iberian vessels found and excavated in the meantime, which more than doubled the sample under analysis. The eight vessels added to this study were the Caribbean wrecks of Emanuel Point, Western Ledge reef or IMHA3, and St. John's Bahamas, the presumably Spanish Angra D wreck, found in Angra Bay, Terceira, Azores, and the Portuguese wrecks of Ria de Aveiro A, Cais do Sodré, Corpo Santo, and Nossa Senhora dos Mártires.

The Caribbean wrecks present themselves as a fairly homogeneous sample, the Emanuel Point wreck presumed to have been lost on Tristan de Luna's expedition to Florida in 1559, the Western Ledge reef wreck being a small Spanish vessel dated to the last quarter of the 16th century, and the St. John's Bahamas also a fairly small Spanish ship dated to the 16th century. As to the Portuguese wrecks, both sizes and tentative dating show fairly different craft. The Aveiro A wreck is a small trader lost in the mid 15th century, the Corpo Santo wreck consists only of a fragment of a stern and has been dated to the late 14th century, and the Cais do Sodré wreck is a large derelict from the late 15th or early 16th century.

Again, in spite of the diversity of origins, the wider time frame considered, and diverse size and purpose of the ships under analysis, Oertling concluded that this larger group still had many features in common. Only the last point of his list of common
traits, referring to the existence of a garboard carved from an extra thick plank, could not be considered for lack of support in the archaeological data.

Oertling's new list of 15 wrecks is shown below with reference to the 11 common traits observed (Table IX.4).

<table>
<thead>
<tr>
<th>Wrecks / Arch. Sig.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye A vessel</td>
<td></td>
<td>N</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
</tr>
<tr>
<td>San Juan</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Catewater wreck</td>
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<td>San Esteban</td>
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<td>Highborn Cay wreck</td>
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<td>Molasses Reef wreck</td>
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<td>Studland Bay wreck</td>
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<td>Y</td>
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<td>Emanuel Point wreck</td>
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<td>Western Ledge wreck</td>
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<td>Y</td>
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<td>St. John's Bahamas wreck</td>
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<td>Ria de Aveiro A wreck</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Angra D wreck</td>
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<tr>
<td>N. S. dos Mártires</td>
<td>Y</td>
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<tr>
<td>Cats do Sodré wreck</td>
<td>Y</td>
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<tr>
<td>Corpo Santo wreck</td>
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<td>Y</td>
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</tbody>
</table>

Y - Yes / N - No

However incomplete the information presented in the table above may be it seems fair to accept the existence of these 11 common traits in the Iberian Atlantic vessels, even when we consider the differences between the Basque, the Portuguese, and the Andalusian cultural universes in the 16th century. Furthermore, we know that in the early 17th century the Hapsburg kings of Portugal and Spain issued legislation in order to unify and harmonize many aspects of the Iberian shipbuilding industry, regarding the types of vessels, their sizes, proportions and construction features (Chapter III).

When we analyze these features in light of the historical texts, it becomes even more obvious that there exists a certain air de famille in all these Iberian vessels, and
that there are undoubtedly a few common traits shared by all Iberian Atlantic vessels. However, it is quite clear that we need a larger sample and an in-debt analysis of the treatises, contracts, accounts of voyages and shipwrecks, iconography, and ethnography, in order to get a clear picture.

In the table above (Table IX.4) it can be seen that the preserved portion of the hull of the *Nossa Senhora dos Mártires* does not yield many clues as to whether or not this ship belongs to this family. No keelson, maststep arrangement, sternpost arrangement, or transom were found, no rigging details were preserved, and all fastenings were made of iron, no treenails being employed anywhere. For the time being we can only state that the central portion of the hull was undoubtedly pre-designed and pre-assembled, affiliating this ship with the Mediterranean skeleton-based shipbuilding tradition represented in a number of well-preserved wrecks in the Mediterranean and in the Atlantic, as well as in the smaller and more precisely defined standard of the India Route naus.
NOTES

CHAPTER I


CHAPTER II


II.5 - Boyajian, Portuguese Trade, 39-42.

II.6 - Boyajian, Portuguese Trade, 6.

II.7 - Boyajian, Portuguese Trade, 3 and 136-7.


II.9 - Boyajian, Portuguese Trade, 3.

II.10 - Boyajian, Portuguese Trade, 44.

II.11 - Godinho, Os descobrimentos e economia mundial, 2:183. For Tomé Pires, Godinho cited Armando Cortesão’s The Suma Oriental of Tomé Pires, Hakluyt Society, 2 Vols., 1944; for Duarte Barbosa, he used Mansel Longworth Dames’ The Book of Duarte Barbosa, also in the Hakluyt Society, 2 Vols., 1918-1921; finally, for Garcia de (H)Orta, he used the Colóquios dos Simples e Drogas e cousas medicinais da Índia, e assi de algumas frutas achadas nela, onde se tratam algumas cousas tocantes a medicina practica, e outras coisas boas para saber, 3rd ed. by Conde de Ficalho, 2 Vols., Lisboa: Academia Real das Sciencias, 1891 (hereafter cited as Colóquios).

FilMOTECA ultramarina portuguesa, Lisboa: Centro de Estudos Históricos Ultramarinos, 1949, 293-361.

II.13 - Marco Polo, II, Chapter 77, in Godinho, Os descobrimentos e economia mundial, 2:197.

II.14 - Godinho, Os descobrimentos e economia mundial, 2:197-198.

II.15 - Godinho, Os descobrimentos e economia mundial, 2:186.

II.16 - Linschoten, Jan Huyghen van, The Voyage of Jan Huyghen van Linschoten to the East Indies, 2 Vols., Burt Franklin, New York, 1970, 225 (hereafter cited as The Voyage...).

II.17 - Letters of D. Luis Bravo de Acuña to the king, Arquivo General de Simancas, Guerra y Marina, 668, in D'Intino, Raffaella "Appendix I" in Afonso, Nossa Senhora dos Mártires: The Last Voyage, 265-270.

II.18 - Orta, Colóquios, 2:6-9, quoted in Godinho, Os descobrimentos e economia mundial, 2:191.

II.19 - Godinho, Os descobrimentos e economia mundial, 2:191-193.

II.20 - Orta, Colóquios, 2: 213, quoted by Godinho, Os descobrimentos e economia mundial, 2:191.

II.21 - Godinho, Os descobrimentos e economia mundial, 2:194-195.

II.22 - Godinho, Os descobrimentos e economia mundial, 2:201-223.

II.23 - Boyajian, Portuguese Trade, 139.

II.24 - Boyajian, Portuguese Trade, 137.


II.26 - Linschoten, The Voyage..., 225.

II.27 - Perestrello, Manuel de Mesquita, "Relação sumária da viagem que fez Fernão d'Alvares Cabral, desde que partio deste reino por Capitão Mor da Armada que foi no ano de 1533 às partes da índia até que se perdeu no cabo da Boa Esperança no ano de 1554, escrita por Manuel de Mesquita Perestrello que se achou no dito naufrágio," in Brito, Bernardo Gomes de História Trágico-Marítima, 2 Vols., Lisboa: Coleção Livros de Bolso, n." 275, Publicações Europa-América.


II.29 - Castanheda, Fernão Lopes de, História do descobrimento e conquista da India pelos portugueses, 2 Vols., Porto: Editores Lello & Irmão, 1979, 1:211.

II.30 - Costa, Leonor Freire Naus e galeões na Ribeira de Lisboa. Cascais: Patrimónia, 1997, 277; and Luis de Albuquerque, Dicionário de história dos Descobrimentos

II.31 - Disney, *Twilight of the Pepper Empire*, 2-4.


II.34 - Barcelos, Christiano Senna “Construções de naus em Lisboa e Goa para a Carreira da India no começo do século XVII,” *Boletim da Sociedade de Geographia de Lisboa*, 17ª série, 1898-1899, 1:70.

II.35 - Linschoten, *The Voyage...*

II.36 - McAlister, Lyle *Spain and Portugal*, 291-304.


II.38 - Godinho, *Os descobrimentos e economia mundial*, 3:35.


II.46 - Guinote et al., *Naufrágios*, 431.
II.47 - Guinote et al., *Naufrágios*, 105.


II.52 - Not as popular as the S. João’s, the wreck of the S. Bento is perhaps better documented. See Perestrello, Manuel de Mesquita “Relação sumária da viagem que fez Fernão d’Alvares Cabral, desde que partiu deste Reino por Capitão Mor da Armada que foi no ano de 1553 às partes da India até que se perdeu no cabo da Boa Esperança no ano de 1554, escrita por Manuel de Mesquita Perestrello que se achou no dito naufrágio” in Brito, Bernardo Gomes de *História Trágico-Maritima*. It is also mentioned in Stuckenberg’s booklet and there is an article by Maggs, Tim and Auret, C. "The Great Ship S. Bento - Remains from a Mid-Sixteenth Century Portuguese Wreck on the Pondoland Coast" in *Annals Natal Museum* (1982) 25.1, Pietermaritzburg, October 1982, :1-39. Her collection of guns has been analyzed by Santos, Nuno Valdez dos, *A Artilharia Naval e os canhões do Galeão Santiago*, Lisboa: Academia da Marinha, 1986.

II.53 - The story of the Santiago is also part of the *História Trágico-Maritima*, written by Manuel Godinho Cardoso under the title “Relação do naufrágio da nau Santiago no anno de 1585, e itinerário da gente que dele se salvou, escrita por Manuel Godinho Cardoso, e agora novamente acrescentada com mais algumas noticias”. Once again, it is mentioned in Stuckenberg’s booklet and in his *The Story of the Wreck of the Santiago*, a brochure accompanying the exhibition in the Natal Museum. The Santiago is also mentioned by Linschoten, *The Voyage...,* 176-180. In the 1980s the wreck site was visited by a French state archaeologist, Michel l’Hour, and the treasure hunter Erick Surcouf but no data of any interest on the site has been published as a result. See l’Hour,

II.54 - The presumable wreck of the Santo António is the only India Route wreck of which some relevant information about the hull has been published so far. See Blake & Green, “A Mid-XVI Century Portuguese Wreck in the Seychelles”.

II.55 - There is very few information on this wreck site. It is mentioned by Stuckemberg, and by Bell-Cross, G., “A Brief Maritime History of the Coast Between the Kei and Fish Rivers, Part 1” The Coelacanth, (1982) 20.2, and “Part 2” in (1983) 21.1. It is also mentioned by Vernon, Gillian "Bounty on the Beach," Under Water, (Summer 1987), 3:37-39, and "A Portuguese Shipwreck site at Bonza Bay: is it the Santa Maria Madre de Deus of 1643?" The Coelacanth (June 1994) 32.1:28-33; and by Kennedy, R.F., Shipwrecks on and off the Coasts of Southern Africa, Johannesburg Public Library, Johannesburg, 1955. As to the story of the wreck, it has actually been written by João Baptista Lavanha and is part of the História Trágico-Maritima under the title “Relação do naufrágio da nau Sto. Alberto no Penedo das Fontes no ano de 1593, e itinerário da gente que dele se salvou até chegarem a Moçambique, escrita por João Baptista Lavanha, Cosmógrafo-mor de Sua Majestade, no ano de 1597”.

II.56 - The site of the probable Espírito Santo is mentioned by Bell-Cross, “A Brief Maritime History of the Coast Between the Kei and Fish Rivers”.


II.58 - Very few is known about this site. See Vernon "Bounty on the Beach," and "A Portuguese Shipwreck site at Bonza Bay: is it the Santa Maria Madre de Deus of 1643?"; and Bell-Cross “A Brief Maritime History of the Coast Between the Kei and Fish Rivers”.


II.61 - See again Vernon "Bounty on the Beach," and "A Portuguese Shipwreck site at Bonza Bay: is it the *Santa Maria Madre de Deus* of 1643?".


II.63 - The bibliography for the *N.S. da Atalaia* is the same as the one for the *Sacramento*.

Chapter III


III.6 – For the Plane 3 wreck see Ximenes, Serge, "Etude preliminaire de l'épave sarrasine du rocher de l'Estoué," *Cahiers de Archéologie Subaquatique* (1976) 5:139-

III.7 – Mathew Harpster personal communication. These texts were edited by H. Idris Bell, British Museum Dept. of Manuscripts


III.10 - Oliveira, O Livro da fabrica das naos, 76.


III.13 – Abreu, Lisuarte de, O livro de Lisuarte de Abreu, manuscript 525 from the Pierpoint Morgan Library, New York, Lisboa: Comissão Nacional para as Comemorações dos Descobrimentos, 1992, or the Memória das Armadas, manuscript from the Academia das Ciências de Lisboa, Macau: Instituto Cultural de Macau, 1995.


III.17 - Oliveira, O Livro da fabrica das naos, 63 and 140.


III.19 - See Rieth, Eric Le Maître-gabarit, la Tablette et le Trebuchet. Éssai sur la


III.27 - Chiggiato, Alvise, "Le Ragioni antique dell'architettura navale." 


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III.47 - Xavier, Novos elementos para o estudio da arquitectura naval portuguesa antiga, 21-27.


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III.61 - Costa, Naus e galeões na Ribeira de Lisboa, 133.
Chapter IV


IV.2 - Mallaina, *Spain's Men of the Sea*.


IV.7 - "Roteiro da viagem que fez a nao Nossa Senhora de Betancor, Capitânia em que hja Bras Telles de Meneses, vindo de Goa para Portugal, feito pelo ldo Anto de Misquita que vinha nella," manuscript in the Biblioteca Nacional de Lisboa, ms. 341, fol. 1-49 Vº, in Azevedo, Maria de Fátima Ferros de, *Uma viagem da India para o reino em 1605-1607*, Lisboa: Dissertation for a degree in History in the Falcaldade of Letras of the Universidade de Lisboa, 1964.


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IV.19 - “Relação sumária da viagem que fez Fernão d’Alvares , desde que partiu deste reino por capitão-mor da armada que foi no ano de 1553, às partes da Índia até que se perdeu no cabo de Boa Esperança no ano de 1554. Escrita por Manuel de Mesquita Perestrello que se achou no ditto naufrágio,” in Brito, Bernardo Gomes de *História Trágico-Marítima*, 275:46.


IV.24 - Ibid., 278:50.
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IV.31 - See for instance Duffy, Shipwreck and Empire. *Portuguese Maritime Disasters in a Century of Decline*; Disney, Twilight of the Pepper Empire; or Boxer, The Portuguese Seaborne Empire.

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IV.35 - Guinote, et al., *Nafrágios*, 232


IV.38 - Azevedo, Maria de Fátima Ferros de, *Uma viagem da India para o reino em 1605-1607*, 155.


IV.40 - Ibid., 157-159.

IV.41 - Ibid., 157-159.

Chapter V


V.2 - Torreano, Leonardo Discurso de Leonardo Torreano sobre el Fuerte de San Lourenço de Cabeça Ceca, Manuscript in the Biblioteca Nacional de Lisboa, fls. 70vº e 80.


V.4 - Vasconcelos, Frazão de "Sobre a Barra do Tejo," 89.

V.5 - D'Intino, "Appendix I" in Afonso, Nossa Senhora dos Mártires: The Last Voyage, 265-270.

V.6- Arquivo Histórico Ultramarino, Reino, Caixa 2, Date: June 2 1618.


Chapter VI


**Chapter VII**

VII.1 - Paulo Monteiro, personal communication


**Chapter VIII**

VIII.1 - See notes III.59 to III.71.

VIII.2 - Lane, Frederic, *Venetian Ships and Shipbuilders of the Renaissance*, Baltimore, 1934, 47; and Frederic Chapin Lane "Venetian Shipping during the Commercial Revolution" *The American Historical Review* (1933), 38:238; or Anderson, R. C. "Big Ships in History" *Mariner's Mirror* (1913) 3.1:43-45.


VIII.6 - Laval, *Viagem de Francisco Pyrard de Laval*, 2:137.


VIII.12 - Boxer, The Portuguese Seaborne Empire, 1415-1825, 208.

VIII.13 - Barcelos, "Construções de naus em Lisboa e Goa para a Carreira da India no começo do século XVII," 1:50.

VIII.14 - Manuscript 4794f from Harvard University's library, fl. 1

VIII.15 - Barcelos, "Construções de naus em Lisboa e Goa para a Carreira da India no começo do século XVII," 1:58, and J. Davies, Voyages & Travels of Albert de Mandelslo, 102, in Boxer, From Lisbon to Goa, 41.


VIII.17 - Oliveira, Liuro da fábrica das naus: 90 and 169.

VIII.18 - Lavanha, Livro primeiro de arquitectura naval. 44 and 154, fl. 62 v°.

VIII.19 - Livro Náutico, fl. 1.

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VIII.21 - Oliveira, Liuro da fábrica das naus, 63 and 141.


VIII.23 - Oliveira, Liuro da fábrica das naus. 63 and 141.

VIII.24 - Lavanha, Livro primeiro de arquitectura naval. 55 and 161, fl. 70.

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VIII.26 - Palacio, Intrvction navithica, 4-1:92; Cano, Arte para fabricar naos in Duro’s Disquisicions nauticas, 5:93.

VIII.27 - Lavanha, Livro primeiro de arquitectura naval, 52 and 159, fl. 68 v°.

VIII.28 - Ibid., 53 and 160, fl. 69.

VIII.29 - Ibid., 42 and 153, fl. 61 v°.

VIII.30 - Oliveira, Liuro da fábrica das naus, 95 and 174.

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VIII.34 - Damianidis, Kostas A. "Methods used to Control the Form of the Vessels in the Greek Traditional Boatyards".

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VIII.36 - Oliveira, Liuro da fábrica das naus, 64 and 142.

VIII.37 - Lavanha, Livro primeiro de arquitectura naval, 63, 167, and fl. 78.

VIII.38 - Oliveira, Liuro da fábrica das naus, 73 and 151.

VIII.39 - Lavanha, Livro primeiro de arquitectura naval, 33-34 and 146-47, fls. 53 v° to 54 v°

VIII.40 - Manuscript 4794f of Harvard University's library, fl. 2.


VIII.43 - Oliveira, Liuro da fábrica das naus, 119 and 200.


VIII.45 - Lavanha, Livro primeiro de arquitectura naval, 32 and 146, fl. 53 v°.

VIII.46 - Oliveira, Liuro da fábrica das naus, 63 and 140.

VIII.47 - Harvard MS 4794f :fl.2; and Oliveira, Liuro da fábrica das naus, 64 and 139.

Chapter IX


IX.4 - These lead strings are deposited in the CNANS conservation laboratory awaiting analysis.


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APPENDIX A
TONNAGE AND SYSTEMS OF UNITS

It is by no means fully understood what systems were in use to find the tonnage of seagoing vessels in different countries and harbors in the late 16th century; and today it remains a difficult task to compare sizes of vessels, especially if we only have their estimated tonnages.

In 16th century Portugal one tonelada was the measure of volume equivalent to the space occupied by a barrel (tonel). One rumo was the measure of the height of the standard barrel, the tonel. This meant that along each rumo of keel of any vessel, one could store a number of barrels that only depended on the breath and depth in hold. It is generally believed that in Portugal the hull's capacity would be established after completion by a commission of experts with a set of arcs with the diameters of a tonel, a pipa and a quarto, who would determine how many tonéis, pipas and quartos would fit in each rumo of length of the vessel. Tables of equivalence were used for heavier merchandise or materials that could not be stored in containers. In the early 16th century, 1 tonelada was the equivalent of 750 roof tiles, 500 sugar formas, 14 quintais of metal, or half of an animal and its food. A.1

There is an indication that estimated tonnage could be obtained by multiplying the number of rumos of a keel by the number of tonéis that could be stored on the rumo situated on the midship section, and by a coefficient, but as it is explained by Father Oliveira it remains clear that he did not understand it fully. A.2

In Spain, where commerce with the world was based on a system of freights of private ships, the use of formulas was already common in the early 16th century, and in 1570s England, Matthew Baker presented a formula that remained in use until the 1620s. A.3 Despite the void in our knowledge of tonnage calculations, we have good estimates on the value of most units of measure used in Portuguese shipyards in the late 16th and early 17th centuries.
Measuring Systems and Units

Weights and measures were always a royal matter, generally delegated to the municipalities and checked by civil officials elected by the citizens, as was established by a law of King Afonso III dated from December 26, 1253. The consolidation of the state's power entailed a standardization of the weights and measures used throughout the country. This decision was first expressed in 1361, at the legislative state assembly of the three classes (clergy, nobility and common) – the Cortes – which took place in Elvas.

In 1488, during the reign of João II, a law of October 14 established the Köln mark as the standard weight unit in Portugal. In 1499 King Manuel I placed new standards in the city halls, copied from the royal ones deposited in the king's palace. In the mean time, the privilege of supervision and calibration of all the weights and scales in the city of Lisbon rested upon the Brotherhood of S. Eloy, from its appointment in August 7, 1460 to the adoption of the metric system in 1814.

King Sebastian decreed another reform of the system of weights and measures in 1575, in the Edict of Almeirim, establishing a system of measures for dry products and a separate one for liquids. This law also defined the jurisdictions of the inspectors. Its success was overwhelming as all municipalities received a full set of standards copied from the royal ones. After the adoption of a decimal system based on the meter in France in 1791, Portugal decided to adopt it in 1814 as part of a profound agricultural reform decreed by King João VI. A

In the shipyards, the most important unit was undoubtedly the tonelada, the measure of capacity of every ship on which taxes and freight prices were fixed and charged. The word tonelada derives from tonel, the standard barrel with 6 palmos de goa, or 1 rumo (1.54 m) in height, and 4 palmos de goa (1.027 m) of párea, the designation in use for its maximum diameter. Each tonel contained two pipas, and each pipa two quartos. The volume occupied by each tonel would vary between the space taken by the cylinder obtained by the expression:

\[ 0.513^2 \times \pi \times 1.54 = 1.275 \text{ m}^3 \]
and the prism obtained by the expression:

\[ 1.027^2 \times 1.54 = 1.624 \, \text{m}^3 \]

The basic unit in use in the Portuguese shipyards was the *palmo de goa* (1 pg = 25.67 cm), which contained 7 *polegadas* (1 pol = 3.67 cm) and 14 dedos (1 d = 1.83 cm). The height of a barrel – 6 *palmos de goa* – was called *rumo* (1 r = 1.54 m), and half a *rumo* was called *goa* (1 g = 77 cm). There were also *palmos de vara* (1 pv = 22 cm) which contained each 6 *polegadas* and 12 *dedos*, and *varas* (1 v = 1.10 m), containing 5 *palmos de vara* each.

There were many other units in use as well in Portugal in the late 16th and early 17th centuries, designating lengths, surfaces, volumes of solids, volumes of liquids, and weights. These all varied somewhat in time and space in spite of the reforms mentioned above, and sometimes there is no accurate way to determine exact values – as likely often happened to the people who handled them – and estimates must be relied on.

In his comments on Lavanha's *Livro Primeiro de Arquitectura Naval*, Pimentel Barata presents a table with the measures of the units in use in the late 16th century Portuguese shipyards based on a fairly accurate measure of the *vara*, a value of length that he relates afterwards to the other units mentioned in the contemporary literature. A.5

An early 19th century study presented by a commission from the Portuguese *Academia Real das Sciencias* on the introduction of the metric system in Portugal shows how the best preserved unit template in the country was the *vara* given by King Sebastian to the village of Tomar, and that this standard gauge measured exactly 110 cm. Based on this value, Pimentel Barata related the *vara* with the other units in use in Portugal, as they were described in the literature in relation to each other. A.6 Barata's values are presented in the tables below, together with other values not necessarily related to shipbuilding, but thought useful to the understanding of the late 16th and early 17th centuries' texts.
### Table A.1

Units in use in Portugal in the 16th and 17th centuries: Length

<table>
<thead>
<tr>
<th>Unit</th>
<th>16th / 17th c. Equivalents</th>
<th>Metric Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vara</td>
<td>5 palmos de vara</td>
<td>110 cm</td>
</tr>
<tr>
<td>Palmo de vara</td>
<td>1/5 of a vara</td>
<td>22 cm</td>
</tr>
<tr>
<td>Rumo</td>
<td>7 palmos de vara;</td>
<td>154 cm</td>
</tr>
<tr>
<td></td>
<td>6 palmos de goa</td>
<td></td>
</tr>
<tr>
<td>Palmo de goa</td>
<td>1/6 of a rumo</td>
<td>25.67 cm</td>
</tr>
<tr>
<td>Goa</td>
<td>3 palmos de goa</td>
<td>77 cm</td>
</tr>
<tr>
<td>Côvado real</td>
<td>1 goa</td>
<td>77 cm</td>
</tr>
<tr>
<td>Braça comum</td>
<td>10 palmos de vara</td>
<td>220 cm</td>
</tr>
<tr>
<td>Braça maritima</td>
<td>8 palmos de goa</td>
<td>204.8 cm</td>
</tr>
<tr>
<td>Polegada comum</td>
<td>1/8 of a palmo de vara</td>
<td>2.75 cm</td>
</tr>
<tr>
<td>Polegada de goa</td>
<td>1/7 of a palmo de vara</td>
<td>3.67 cm</td>
</tr>
<tr>
<td>Ángula</td>
<td>1/10 of a palmo de goa;</td>
<td>2.56 cm</td>
</tr>
<tr>
<td></td>
<td>= Engl. inch</td>
<td></td>
</tr>
<tr>
<td>Dedo</td>
<td>1/2 of a polegada de goa</td>
<td>1.83 cm</td>
</tr>
<tr>
<td>Léguia</td>
<td>3 milhas</td>
<td>5.556 m</td>
</tr>
<tr>
<td>Milha</td>
<td>1/3 of a léguia</td>
<td>1.852 m</td>
</tr>
</tbody>
</table>

(1) Also known as palmo craveiro, palmo comum, palmo ordinário, palmo redondo, or palmo singelo.

### Table A.2

Units in use in Portugal in the 16th and 17th centuries: Area

<table>
<thead>
<tr>
<th>Unit</th>
<th>16th / 17th c. Equivalents</th>
<th>Metric Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alqueire</td>
<td>15.625 square palmos</td>
<td>756.25 m²</td>
</tr>
</tbody>
</table>

These values were by no means precise or constant through time. Neither were they the only values in use contemporaneously around the commercial ports. Many tables of equivalents were in use at the same time, and the conversions were a part of the bargain. Merchants were required to have a quick and well trained mind if they wanted to survive in the diversity of the markets and cultures involved in the India trade of the 16th and 17th centuries, mostly when we consider that even the relation between the prices of gold and silver varied from port to port. The India Route trade depended to a large extent on these merchants whose trained minds could quickly evaluate the quality of a merchandise, determine its value in several distant
ports, add the costs of transport to each of them, and the taxes and fees due in every scale. Only large profits could justify the risks taken on such a long voyage, whose success depended on good seamen, skilled officers, competent soldiers, and astute politicians. If we consider all the problems these people had to solve in their 15 months-long trips, the India Route stands as an enormous exploit.

Table A.3
Units in use in Portugal in the 16th and 17th centuries: Volume

<table>
<thead>
<tr>
<th>Unit</th>
<th>16th/17th c. Equivalents</th>
<th>Metric System Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almude</td>
<td>12 canadas</td>
<td>25 liters</td>
</tr>
<tr>
<td></td>
<td>48 quartilhos</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>4 quartilhos</td>
<td>2.083 liters</td>
</tr>
<tr>
<td>Quartelho</td>
<td>1/4 of 1 canada</td>
<td>1/2 liter</td>
</tr>
<tr>
<td>Moio</td>
<td>60 alqueires</td>
<td>780 liters (cereals)</td>
</tr>
<tr>
<td>Saco</td>
<td>6 alqueires</td>
<td>78 liters (cereals)</td>
</tr>
<tr>
<td>Alqueire</td>
<td>1/60 of 1 moio</td>
<td>8 liters (liquids)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 liters (cereals)</td>
</tr>
<tr>
<td>Moio</td>
<td>60 alqueires</td>
<td>780 liters (cereals)</td>
</tr>
<tr>
<td>Tonel</td>
<td>2 pipas</td>
<td>1050 to 1250 liters</td>
</tr>
<tr>
<td>Pipa</td>
<td>1/2 tonel</td>
<td>525 to 625 liters</td>
</tr>
<tr>
<td></td>
<td>21 to 25 almudes</td>
<td></td>
</tr>
<tr>
<td>Quarto</td>
<td>1/2 pipa</td>
<td>262.53 to 312.5 liters</td>
</tr>
</tbody>
</table>

Table A.4
Units in use in Portugal in the 16th and 17th centuries: Weight

<table>
<thead>
<tr>
<th>Unit</th>
<th>16th/17th c. Equivalents</th>
<th>Metric System Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quintal</td>
<td>4 Arrobas</td>
<td>58,754 kg</td>
</tr>
<tr>
<td>Arroba</td>
<td>1/4 de quintal, 32 arratéis</td>
<td>14,690 kg</td>
</tr>
<tr>
<td>Arratel</td>
<td>16 onças</td>
<td>459 g</td>
</tr>
<tr>
<td>Onça</td>
<td>1/16 de arratél</td>
<td>28.69 g</td>
</tr>
<tr>
<td>Oitava</td>
<td>3 escrúpulos</td>
<td>3.027 g</td>
</tr>
<tr>
<td>Escrúpulo</td>
<td>24 grãos, 1/3 de uma oitava</td>
<td>1.009 g</td>
</tr>
</tbody>
</table>
Table A.5
Units in use in Portugal in the 16th and 17th centuries: Currency

<table>
<thead>
<tr>
<th>Unit</th>
<th>Portuguese Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruzado</td>
<td>400 reis</td>
</tr>
<tr>
<td>Escudo</td>
<td>100 reis</td>
</tr>
<tr>
<td>Xerafim</td>
<td>300 reis</td>
</tr>
<tr>
<td>Ducado</td>
<td>( \approx 345 ) to ( 360 ) reis</td>
</tr>
<tr>
<td>Peso</td>
<td>( \approx 320 ) reis</td>
</tr>
</tbody>
</table>

NOTES

A.1 - Costa, *Naus e Galeões na Ribeira de Lisboa*, 77-78.


A.4 - I retrieved much of this information from the web page of the Instituto Português da Qualidade, the department that regulates all matters concerning weights, measures, and standards in Portugal, and from Thomaz, Luís Filipe F. R. *De Ceuta a Timor* Viseu: Difel, 1998, 323-344; and Felner, Rodrigo José de Lima *Subsídeos para a História da Índia Portuguesa*, Lisboa: Academia Real das Ciências, 1868, which includes the Livro de Pesos Medidas e Moedas por António Nunes, from 1554.


APPENDIX B

BIBLIOGRAPHY OF IBERIAN WRECKS

In the Appendix is presented a basic bibliography of the Iberian and similar wrecks found, excavated, and published or made public in any way.

ANGRA B WRECK


ANGRA D WRECK


BAHIA MUJERES WRECK

Keith, Donald, and Smith, Roger, An Archaeology survey of an early 16th century shipwreck site in Bahia Mujeres, Quintana Roo, Cancun, Mexico, Report in the INA archives, 1984.


CAIO NUEVO WRECK

CAIS DO SODRÉ WRECK


CAPITANA DE IVELLA

CATTEWATER WRECK


CORPO SANTO WRECK

DRY TORTUGAS DEEP WATER WRECK
No information published. Salvaged by a Southern Florida company named Seahawk. This wreck laid around 500 m deep and had extensive hull remains.

EMANUEL POINT WRECK

ESPIRITU SANTO (Texas)

ESPIRITU SANTO (South Africa)
Not yet positively identified.

FUXA WRECK

GREEN CABIN WRECK

HIGHBORN CAY WRECK
Peterson, Mendel “Buried treasure beneath the Spanish main” Unesco Courrier, (1972) 23-27.
INES DE SOTO WRECK


JESÚS M.ª DE LA LIMPIA CONCEPCIÓN

No information published.

A galleon from the Pacific silver route – from Callao, the port of Lima in Peru, to Panama city. Lost in 1654 off Shanduy, Ecuador, and has not yet been excavated.

MOLASSES REEF WRECK


MISTERY WRECK OF MAREX


"A couple of papers privately published" by the company MAREX, Memphis, Tennessee. Personal communication of John de Bry, 1998.

NOSSA SENHORA DA ATALAIA


NOSSA SENHORA DA LUZ


NOSSA SENHORA DOS MÁRTIRES


NUESTRA SEÑORA DE ATOCHA


NUESTRA SEÑORA DE LA CONCEPCIÓN (Guam)


**NUESTRA SEÑORA DE LA CONCEPCIÓN** (Dominican Republic)


**NUESTRA SEÑORA DE LAS MARAVILLAS**


**PONTA DO ALTAR B WRECK**


**RIA DE AVEIRO A WRECK**


**RYE A WRECK**


SAINT JOHN'S BAHAMAS WRECK


SAINT HONORAT I


SAN AGUSTIN


SAN ANTONIO


SAN DIEGO


SAN ESTEBAN


SAN JUAN


SAN PEDRO


SANTA CATARINA DE RIBAMAR


SANTA MARGARITA (Florida)


SANTA MARGARITA (Guam)

No information published. Allegedly a Manila galleon wrecked in the 17th century in the Mariana Islands, this ship is being salvaged since 1998.
SANTA MARIA DE LA ROSA


SANTA MARIA MADRE DE DEUS

Not yet positively identified.

Vernon, Gillian "A Portuguese Shipwreck site at Bonza Bay: is it the Santa Maria Madre de Deus of 1643?" The Coelacanth (June 1994) 32.1:28-33

SANTA MARIA DE YCIAR


SANTIAGO


SANTÍSSIMO SACRAMENTO


SANTÍSSIMO SACRAMENTO B


SANTO ALBERTO

Not yet positively identified.


Vernon, Gillian, "A Portuguese Shipwreck site at Bonza Bay: is it the Santa Maria Madre de Deus of 1643?" The Coelacanth (June 1994) 32.1:28-33

SÃO BENTO


SÃO GONÇALO


SÃO JOÃO


SÃO JOÃO BAPTISTA

Not yet positively identified.


Vernon, Gillian, "A Portuguese Shipwreck site at Bonza Bay: is it the Santa Maria Madre de Deus of 1643?" *The Coelacanth* (June 1994) 32.1:28-33

**SEYCHELLES WRECK**

Presumed to be the wreck of the Portuguese Indiaman *Santo Antônio*, lost in 1589.


**SHOT WRECK**


**SPANISH WRECK**


**STONEWALL WRECK**


**STUDLAND BAY WRECK**


URCA LA VIGA


WESTERN LEDGE REEF WRECK


APPENDIX C

LETTER OF PERMISSION

Mr. Luis Filipe Monteiro Vieira de Castro
3625 Wellborn, Apt. #1313
Bryan, 77801 TEXAS
USA

Subject: Permission to print photographs and drawings.

Our Ref.: CNANS 2001/0181, de 06 de Março.

Dear Mr. Castro,

You have permission to use the illustrations listed below in your dissertation "The Pepper Wreck: A Portuguese Indiaman At The Mouth Of The Tagus River".

FIG V.4 - The bronze gun recuperated by sport divers in 1994
FIG V.5 - The bronze gun retrieved by José Garcia in 1972
FIG V.6 - The bronze gun sold for scrap in the 1980s
FIG V.7 - First map of the SB1 area
FIG V.8 - Second map of the SB1 area
FIG. V.9 - Lead ingots from SB1
FIG. V.10 - Mortars from SB1 recovered by a sport diver in the 1980s
FIG. V.11 - Sets of nested weights from SB1 in the collection of CNANS
FIG. V.12 - Map of the SB2 hull after the 1997 field season
FIG. V.13 - Map of squares Q1 to Q3, from the area excavated in 1996 and 1997
FIG. V.14 - Japanese teabas
FIG. V.15 - The first days of work at São Julião da Barra in 1996
FIG. V.16 - Raising timbers during the 1999 field season
FIG. V.17 - Text incised on the base ring of the bronze culverin
FIG. V.18 - Porcelain dish from SB2
FIG. V.19 - Astrolabe São Julião da Barra III
FIG. V.11 - Chinese stoneware pots from SB2
FIG. V.12 - Chinese glazed green and yellow earthenware pot from SB2
FIG. V.13 - Chinese porcelain from SB2

.../...
FIG. VII.6 - Apron in situ
FIG. VII.10 - Plug under floor C3
FIG. VII.11 - Plug on plank T11E, under floor C4
FIG. VII.12 - Roman numeral "X" on floor C2
FIG. VII.13 - Marks of keel axis and edges on floor C10
FIG. VII.16 - Groove on floor C3
FIG VII.25 - Cast of the spike on floor C6
FIG. VII.26 - Cast of the bolt Q2/T1W(1)
FIG. VII.28 - Oakum inserted into the seams
FIG. IX.1 - Date engraved on the astrolabe São Julião da Barra III

Sincerely,

[Signature]

Francisco J. S. Alves, Director

AC
VITA

Luis Filipe Monteiro Vieira de Castro

Date of Birth: 16 November, 1960.

Address: 3625 Wellborn, Apt. #1313, Bryan, 77801 Texas.

Education:

2001 Ph.D., Anthropology - Nautical Archaeology Program at Texas A&M University (with a scholarship from the Portuguese Ministry of Culture).

1994 MBA, Escola Superior de Ciências Económicas e Empresariais, Universidade Católica Portuguesa, Lisbon, Portugal.

1986 Post-Graduation course on Recuperation of old buildings and monuments, Escola Superior de Belas Artes de Lisboa, Lisbon, Portugal.

1984 B.S. in Civil Engineering, Instituto Superior Técnico, Universidade Técnica de Lisboa, Lisbon, Portugal.

Professional experience:

1998-2001 Director of the Pepper Wreck / Nossa Senhora dos Mártires Project, Instituto Português de Arqueologia / Institute of Nautical Archaeology.

1988-2001 Research Assistant, Nautical Archaeology Program, Texas A&M University. Supervisor Dr. Kevin Crisman.

1996-1998 Co-Director of the Nossa Senhora dos Mártires Project, Instituto Português de Arqueologia, Ministério da Cultura. Assistant to the Director of the Centro Nacional de Arqueologia Náutica e Subaquática within the Instituto Português de Arqueologia, Ministério da Cultura, Lisbon, Portugal.

1993-1996 Director of the Department of Licensing, Instituto do Trabalho Portuário, Ministério do Mar, Lisboa, Portugal.

1984-1993 Civil Engineer. Design and construction of buildings, hydraulics and sanitation projects, Portugal.