STUDYING THE HEARTS OF SHIPS: 16TH-CENTURY MAINMAST STEPS AND BILGE PUMP ASSEMBLIES THROUGH AN ANNALES NAUTICAL ARCHAEOLOGICAL PERSPECTIVE

by

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A thesis submitted to the Department of Anthropology
College of Arts, Social Sciences, and Humanities
The University of West Florida
In partial fulfillment of the requirements for the degree of
Master of Arts

2016
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ACKNOWLEDGMENTS

I am profoundly indebted to the many individuals who have assisted, either directly or indirectly, over the course of this project. First and foremost, without financial support by Dr. Elizabeth Benchley and the UWF Archaeology Institute, along with a grant by Florida's Division of Historical Resources, this project would not have been completed. Along with these groups, Karen Mims was also instrumental in providing logistical support so that I could attend several conferences to disseminate my research.

Over the past four years many staff and students from UWF maritime field schools (2013-2016) took part in the project's fieldwork, I wish to thank each and everyone for helping to uncover an important part of history. Thank you to Austin Burkhard, Nicole Mauro, Caitlin Bronston-Flynn, Emily Youngman, Hunter Whitehead, Ben Wells, Arlice Marionneaux, Chris Dvorscak, Andrew Derlikowski, Matt Newton, and Stew Hood for braving the elements during the last two years to come out everyday and do the archaeology that we love. I also appreciate the many shipbuilding conversations between myself, Stephen Atkinson, and Andrew Willard, which assisted in helping to instill insight in me on all aspects of 16th-century shipwrecks. Lastly, this project would still be ongoing if it was not for the support and drive of our field director, Meghan Mumford, who came out even on her days off to make sure we could uncover the shipwreck in a timely manner. I will always be eternally grateful for her consideration and accommodation of my research goals.

Every member of my thesis committee was influential in guiding me towards becoming a better writer and archaeologist. Dr. John Worth's encouragement was instrumental in instilling a vigorous work ethic that left us both excited for all the discoveries we shared together. His intellectual conversations and kindness continue to inspire me in my future endeavors. I would
not be the writer I am today without Dr. Amy Mitchell-Cook's assistance in providing thorough edits that allowed me to fix my own mistakes and improve over the course of my research. I am also personally grateful to Dr. Greg Cook and Dr. John Bratten for being my underwater archaeology mentors throughout my time at UWF. Both gentlemen provided me with an abundance of insight into how to overcome the many problems that arose during excavation. I will always appreciate the trust that both of them placed upon me to properly excavate and analyze the section of a 16th-century shipwreck.

I could not have reached the end of this journey if it was not for my close friends and family, whom stuck with me throughout this lengthy process. Thank you to Ericha Sappington, Jillian Okray, and Michael Okray for spending countless hours discussing thesis ideas and allowing me to find solace when I needed a break from my research. Finally, I cannot express enough gratitude to my family, Susan Bendig, Charles J. Bendig, and James Bendig for allowing me to pursue my dreams and follow my own path through life; this thesis is dedicated to them.
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ABSTRACT

STUDYING THE HEARTS OF SHIPS: 16TH-CENTURY MAINMAST STEPS AND BILGE PUMP ASSEMBLIES THROUGH AN ANNALES NAUTICAL ARCHAEOLOGICAL PERSPECTIVE

Charles Dillon Bendig

Over the past 30 years numerous archaeological investigations have revealed several 16th-century shipwrecks in various states of preservation. Many of these include evidence for the mainmast step and, occasionally, remaining vestiges of the bilge pump assemblies. Surviving mainmast steps allow archaeologists to create datasets to understand specific timeframes for shipbuilding methodology. Previous research is often focused on frame construction and the features related to regional shipbuilding traditions that led to cross-oceanic travel. Archaeologists need to reevaluate their methodology by applying the French *annales* approach, which attempts to understand the multi-layer trends and fluctuations throughout history, including between the archaeological record and the historical events that encapsulate shipbuilding modifications. This thesis also outlines methodology in conducting in-situ analysis on the central-internal hull of the Emanuel Point II (EP II) shipwreck. Results from this study connect not only to the ill-fated Tristán de Luna y Arellano expedition of 1559, which EP II was once part of, but also trends in technological developments, as revealed in the archaeological record, on central internal hull construction. Nautical archaeologists can benefit using a multi-tiered analysis to reveal shipbuilding trends as concerns mainmast step and bilge pump assembly.
UNDERSTANDING THE "HEART" OF A 16TH-CENTURY SHIP

Introduction

After a nine-week voyage from Veracruz, Mexico, Spanish colonists under the leadership of Tristán de Luna y Arellano arrived at Pensacola Bay in August 1559 (Priestley 1928a:211–213). Many colonists hope to escape past hardships and build new identities on the fringes of the Spanish empire. No matter their expectations, the colonial venture was one of the most well-supplied and organized expeditions to have been undertaken by the Spanish since Christopher Columbus. Six weeks after their arrival a terrible hurricane destroyed the anchored fleet causing the loss of crucial supplies and seven ships (Priestley 1928a:245–247). Survivors salvaged what they could from the wrecks and persevered through two turbulent years until the expedition was labeled a failure and all survivors returned to New Spain without establishing the foothold Spanish officials had originally set out to accomplish. As for the wrecked vessels, these were eventually abandoned and sealed under the accumulation of silt, sand, and clay that comprise the bottom of Pensacola Bay.

Archaeologists, under the Florida Bureau of Archaeological Research, conducted a Pensacola shipwreck survey in the beginning of the 1990s (Smith et al. 1998:1). While surveying near the entrance to Bayou Texar, they identified a magnetic anomaly that was associated with a mound of ballast stones. Subsequent site investigations revealed 16th-century pottery and the remains of a wooden sailing ship. Sizable contextual evidence allowed archaeologists to conclude that the ship, now known as Emanuel Point I (8ES1980), was one of the lost ships from the Luna expedition. University of West Florida (UWF) maritime archaeology field school students, conducting their own target dives on magnetometer anomalies at the end of the 2006 field season, located a previously unknown ballast pile. Researchers held hope that the ship
might be related to the Luna expedition. Subsequent excavations confirmed their theory, as the amount of archaeological material uncovered and construction features indicated the remains of a second 16th-century shipwreck. This new shipwreck (8ES3345), known as Emanuel Point II (EP II), became the second known wreck from the Luna fleet.

Investigations on EP II soon uncovered the bow and stern area with an excavation trench placed across the wreckage, directly forward from amidships (Cook 2009). As a result, the mainmast step and bilge pump assemblies were left unexcavated with a general idea on where these components were located. This situation allowed time to design a complete research plan based on theoretical modeling, excavation, and analysis. Few examples of contemporary mainmast steps have been recorded and even fewer bilge pumps have been found from the same period.

*Research Objectives and Parameters*

Determining protocol for examining the mainmast step and bilge pump assembly on the Emanuel Point II shipwreck began by determining the research objectives. Along with locating, identifying, and analyzing these components, five major research questions became the parameters for fieldwork and subsequent analysis. Each question included synopses on why these specific questions were chosen and their relevance to the current research.

*Research Question 1: Where Is The Mainmast Step And Bilge Pump Located On The EP II Wreck Site?*

Investigations near amidships focused initially on collecting ballast samples without emphasis on hull assembly (Gifford 2008:58–59). Subsequent excavation seasons revealed a forward section of the keelson toward the bow. The award of a special categories grant in 2014 from the Florida Division of Historical Resources allowed fieldwork near the center of the site,
exposing the location of the expanded keelson and mainmast step components. After the end of the UWF 2012 maritime field school, excavations had not revealed the hull or whether excavation units were in the correct position for locating the central hull assembly. The first major endeavor for this research was to locate the mainmast step and associated bilge pump assembly.

**Research Question 2: How Was The Central Hull Configuration Assembled?**

Fastening patterns indicate which timbers were installed first and whether this building methodology was a conscious decision by shipwrights or rather a standard methodology. Modifications, such as cutaways or beveling, also revealed changes that occurred during the assembly process.

**Research Question 3: What Types Of Idiosyncrasies Were Apparent In The Assemblage?**

Once the mainmast step was revealed, several important questions arose regarding the configuration and the unique idiosyncrasies in the assemblage. Previous examples of these components provide archaeologists with general expectations on what should be uncovered, along with possible differences in construction features. These differences are pivotal indicators toward understanding regional influences as they developed throughout the 16th century.

**Research Question 4: Why Did 16th-Century Shipwrights Utilize This Type Of Keelson And Pump Assembly?**

Mainmast steps and pump assemblies from the 16th century are clearly part of a long tradition in shipbuilding. This question is an attempt to understand the origins from which the keelson design and other supporting frames were first utilized and why it became standard on oceanic ships at the time.
Research Question 5: Can The Expanded Keelson And Bilge Pumps On EP II, Along With An Available Database From Contemporary Shipwrecks, Expand Several Characteristics Of The "Atlantic Vessel" Sub-Tradition First Proposed By Thomas Oertling (2001)?

These latter questions do not necessarily focus on EP II; rather they required an in-depth analysis from the archaeological record to understand the origin of the keelson, mast step, and the variable developments over several millennia for bilge pump designs. Scholars have acknowledged that a combination of features from several shipbuilding traditions allowed the creation of trans-oceanic ship typologies based on available post-medieval models (Castro 2008:72–77; Adams 2013:63–72). These analyses, due to a lack of material remains, have focused predominantly on hull construction and technological features that could be seen in contemporary iconography. Therefore, an encompassing historical examination on central features found inside the hull, requires the available archaeological evidence from a considerable number of shipwrecks to provide enough evidence to reach reasonable conclusions on technological development.

Previous Research

Maritime archaeologists, whether analyzing the keelson, mast step, or bilge pump components, have provided initial conclusions on technological development in shipbuilding. Most of these conclusions answered questions pertaining to the micro perspective. Their concern was to establish a precedent from which future researchers could connect various fragments from archaeological sites to known examples. These results established known parameters for the general development of ship construction. Recent nautical archaeological scholarship continues to reiterate known parameters in technological development, while emphasizing a continual lack of understanding gaps in the archaeological record (Castro et al. 2008; Pomey et al. 2012). These
modern efforts follow earlier methodologies by simply understanding the isolated technological developments, such as specified hull construction, sailing configurations, or bilge water removal devices. Rather than attempting to identify long term changes and consistencies in the broader perspective as related to technological changes affecting construction methodology. For example, the introduction of the keelson or the bilge pump consequentially required changes throughout the ship design and application within the hull.

Early research on the development of the mast step and keelson configuration was first conducted by Mark Geannette of Texas A&M University (1983) as part of his master's thesis. Geannette was concerned primarily with understanding the origin of the mast step and its development as part of the keelson until the beginning of the A.D. 11th century. Most of his research was from archaeological publications on known keelsons/mast step assemblies in the Mediterranean and Northern Europe, along with personal communication with principal investigators. In addition, he analyzed contemporary textual references to create a viable dataset (Geannette 1983:4–5). Based on his earliest archaeological evidence at the time, Geannette concluded that the mast step had already become an established part of the Mediterranean shipbuilding tradition by the beginning of the 6th century B.C.

Mast steps from such wrecks as the Bon Porté, Kyrenia, and Cavalière were carved initially from single large pieces of softwood that were never fastened to surrounding framework (Joncheray 1976:31–34; Charlin et al. 1978:74–77; Steffy 1985:86). Notches cut underneath the mast step allowed the timber to sit over frames and was kept from moving by the vertical pressure applied by the mast. According to Geannette, keelons were not apparent on contemporary ships until after the beginning of the first millennium. Over successive centuries, these two components combine and became a single component (Geannette 1983:121–125).
Further discussion by Geannette included an analysis of available mast steps found in the combining of Mediterranean and local Celtic shipbuilding traditions throughout northwestern Europe; an important catalyst in the eventual mainmast step assembly seen centuries later. Geannette concluded his analysis by understanding the early development of sailing craft in Scandinavia based on several examples that were available at the time.

Geannette provided the logical foundation for understanding the development in mast step and keelson design. While an important initial step, the conclusions reached by Geannette on Mediterranean shipbuilding were based on a concise dataset. Many of the theories put forth by Geannette could not be answered until further archaeological excavations were carried out, more precisely, those that included missing components. The main limitations of Geannette's dataset was most available archaeological evidence dated from the 6th century B.C. until the beginning of the new millennium. Only two primary examples with intact keelsons/mast step components were examined after this time frame, providing only a tentative description on keelson/mast step development. Geanette also remarked on a possible connection with Egyptian ship construction seen in ship models that were recovered from tombs, although this connection was based solely on observations rather than any direct association. Discussions on the Romano-Celtic and Scandinavian shipbuilding traditions were also hampered by a lack of available information and the limited time frame Geannette placed upon his analysis. Since Geannette did not pursue his analysis beyond the beginning of the A.D. 11th century, his own remarks on Scandinavian shipbuilding must be seen as only preliminary observations on adaptation in sailing within this region. Discoveries subsequent to Geannette's initial investigation have not added new understandings of the development of the keelson/mast step assemblies.
Maritime archaeologists have preferred to provide data within the confines of a regional shipbuilding tradition from which their vessel belonged. Thomas Oertling's original research into "Iberian-Atlantic" shipbuilding followed these same parameters when he first proposed twelve characteristics that all 16th-century ships from Iberia seem to encapsulate (Oertling 1989a). After a decade of new discoveries, Oertling (2001) was able to provide a larger dataset that affirmed his earlier concept. By incorporating another eight shipwrecks, along with the original seven, Oertling's results expanded the time frame from the mid-15th to the end of the 16th century. Three of the 12 characteristics include the keelson, mainmast step, and bilge pump assembly. Oertling claimed that his "Atlantic Vessel" sub-tradition required the keelson to be notched over the tops of the floor timbers. The mainmast step was created in an expanded section of the keelson with a cut away for the bilge pump, and that lateral supports, in the form of buttresses and bilge stringers, should be present (Oertling 2001:236). Out of the 15 shipwrecks Oertling examined, only eight of these wrecks contained evidence of their mainmast step assemblies. Furthermore, only five vessels of the eight had their mainmast steps in situ. Although Oertling was not attempting to provide an expansive historical analysis on the development of shipbuilding components, his initial investigation provides an important catalyst for the research presented in this thesis.

Bilge pumps in antiquity have often been difficult to interpret in the archaeological record, due in part to the ease of removal in salvage or the deterioration of the assembly from site formation processes. These issues unfortunately left few remains for archaeologists to examine. Only after a complete bilge pump analysis was accomplished by Marie-Brigitte Carre and Marie-Pierre Jézégou (1984) was there an agreement between historians and archaeologists that ships from antiquity were equipped with a previously unknown pump typology. Carre and Jézégou's
analysis focused on understanding the development of the chain pump from the 1st century B.C. until the second half of the A.D. 7th century. Along with providing a new bilge pump from their own excavation (Saint-Gervais 2), Carre and Jézégou scrutinized the available archaeological record to specify that there was in fact a bilge pump assembly present on most ships. Carre and Jézégou were under the same constraints that Geannette faced in his own keelson/mast step analysis, namely, the lack of available archaeological examples. As a result, Carre and Jézégou were only able to conclude that a type of chain pump was used predominantly throughout antiquity, but could not provide specifics on when the bilge pump was first introduced or when it fell out of use. Due to this lack of evidence, Carre and Jézégou did not try to understand the development for each individual component and the reasons for any differences between them.

Oertling also provided the most thorough research to date on bilge pump technology from the beginning of the 16th century to the end of the 19th century (1984; 1996). He researched the development of the bilge pump, as well as the effort it took for earlier pump makers to create pump tubes by drilling through the heartwood of large trees. Based on historical accounts, diagrams, and available archaeological evidence, Oertling concluded that the 16th century was the first time shipbuilders were able to choose between three bilge pump typologies. Technological differences in the designs between the burr pump, common pump, and chain pump allowed Oertling to envisage when the different pump styles were embraced by shipbuilding communities. Many scholars rely upon Oertling's analysis as the primary source for understanding bilge pump development, especially due to the scarcity of other 16th-century examples since his publication. Oertling provides analyses on the origins for different bilge pumps or reconstructions based on archaeological evidence and available historical research.
Nautical Archaeology as the Annales Approach

The primary focus for many nautical archaeologists has been to analyze, critique, and summarize the basis for technological development through the archaeological record. These efforts have provided modern researchers with a verifiable foundation from which further insight into understanding shipbuilding changes might continue. This type of dialogue is also particularistic by focusing on identifying specific characteristics in shipbuilding based on regional areas. The traditional research approach impedes discussing a macro perspective concerning larger developments in shipbuilding, whether on general shipbuilding design preferences or technological developments of specific ship components across broad areas. The aforementioned issues notwithstanding, the importance in idiosyncrasies between ships allows archaeologists to set precedence for recurring traits across shorter durations. Different levels of perspective promote parallel archaeological analyses between the long-term tendencies and their short-lived idiosyncratic counterparts.

Results from these paradoxes require an appropriate approach that combines layers of analysis into a coherent structure. The French annales approach fulfills requirements set forth to establish a principal example for further research. Originally championed by pioneers such as Marc Bloch and Lucien Febvre, the annales approach gained notoriety under Fernand Braudel to understanding social history through a combined analysis of the inherent layers of historical change. Braudel was concerned with understanding the social structure or architectural constraints that were built over generations as fixtures that either became stalwart elements within society or eventually succumbed to societal changes (Braudel and Wallerstein 2009:178).
Examining historical changes at this level is considered the *longue durée* or long duration, which has been utilized when describing mental frameworks or geographical constraints (Braudel 1980:31).

For this thesis, the author applied the *longue durée* in the third and fourth chapters to reconstruct technological development in mainmast step and bilge pump designs throughout the historical record until the end of the 16th century. As a generally conservative methodology, shipbuilding easily provides the structure necessary to follow general trends. Since wooden vessels remained paramount into the 19th century, archaeologists can note gradual development in ship designs without concern for sudden disappearances. Bilge pumps, however, appear sporadically in the archaeological record. These concerns, as addressed in the fourth chapter, focus on the lack of evidence available due to gaps in the archaeological record rather than complete technological abandonment.

Ships can be seen as extensions of societal constructs, which requires analyzing the diverse fluctuations of human existence and the rhythms of material life by understanding the *conjuncture*, or middle range (Braudel 1995:892). Braudel introduced conjuncture as part of the *Annales*’ approach to understand medium-term trends that often coalesce together through different continuous cycles throughout history. For example, the conjuncture has been utilized as an ideal paradigm for historians when understanding the nuances between economic recessions or expansion over several centuries (Braudel 1995:899). Braudel reminds us that similar inclinations are seen from different rates of industrialization, which fluctuate based on general economic trends. Supplemental evidence in the fifth chapter describes the ship typologies and archaeological evidence available from this period to understand shipbuilding conjunctures between the 15th and 16th centuries. This analysis also provides archaeologists with an
understanding of the subtle differences between regions and shipyards in their mainmast step and bilge pump components.

Previous UWF theses on the Luna expedition sought to provide historical chapters manifested in the *histoire événementielle* or traditional episodic history. Many authors relied upon the translations provided by Herbert Ingram Priestley, whose immense work in the two volume set *The Luna Papers, 1559-1561* (1928a,b) has been the basis for several generations of research. Priestley's subsequent publication, *Tristán de Luna, Conquistador of the Old South* (1936), relies on his earlier archival work to narrate the major affairs that occurred across the entire expedition. Braudel and the *annales* approach are wary of eventful narrations, such as the ones Priestley provided (Braudel and Wallerstein 2009:174–175). Nonetheless, rather than considering the events that unfolded according to Priestley's translations, this thesis has endeavored to understand the short-term developments that led to organizing, planning, and embarking the Luna expedition from New Spain. Along with several letters in *The Luna Papers*, additional materials from accounting records, independent letters, and several other sources were consulted. Chapter six examines the individuals and materials that were brought from New Spain for the Luna expedition, as well as building a new shipyard infrastructure, issues with fleet construction, the embargoing of available ships, and a description of these vessels. In this regard, the reader becomes familiar not only to the general events that led to the Luna expedition, but the vestiges that have often been less emphasized. Understanding the preceding elements prior to the Luna fleet's departure allows a ship identity to be proposed in this thesis for referencing EP II against other similar ship typologies.

Since no intention was ever made to systematically remove hull structure from the site, evidence in the seventh chapter discusses the in situ analysis and post-fieldwork descriptions for
all important components uncovered during excavation. The conclusion is a comprehensive discussion on mainmast step and bilge pump assemblies prior to the 17th century. After providing this new dataset, the conclusion also outlines the similarities and differences seen on EP II when compared with other contemporary 16th-century shipwrecks. Further discussion on Thomas Oertling's "Atlantic Vessel" sub-tradition is addressed and reviewed for expanding previous characteristics. Lastly, the thesis explains the need for new research and publications on mainmast steps and bilge pump assemblies to fully understand these components.

Over the course of the last century, nautical archaeologists have made significant strides in understanding the development of shipbuilding practices. These initiatives laid the groundwork by collecting available archaeological examples and finding general similarities between shipwrecks. This thesis develops the next step forward by incorporating the *annales* approach to understand the human element within shipbuilding traditions. Rather than rely solely on other scholarly work, new research into the Luna expedition and central hull components from the EP II shipwreck establish a framework for a multi-layered research design.
ARCHIVAL AND ARCHAEOLOGICAL METHODOLOGY ON EMANUEL POINT II

The initial questions for this thesis required a thorough analysis of a variety of formats. These efforts included not only obtaining datasets from archaeological publications, but reviewing archival work and translating primary documents. Limitations in locating the mainmast step and bilge pump assembly also required the creation of a predictive model based on the available data from other contemporary trans-oceanic shipwrecks. Fieldwork was organized around this model, while excavation parameters followed standard methodologies utilized during excavation on the Emanuel Point II (EPII) shipwreck. Timber removal and the collection of photographic data allowed greater precision in recording artifacts and hull remains. Surviving sections from the pump well were rebuilt using 3-D modeling software to minimize damage to the archaeological record. Modeling software not only provided important data on EP II, but has also offered a new avenue for collecting accurate measurements while limiting damage to the shipwreck itself.

Archival Research

The historical component of this thesis required a thorough analysis of primary documents from the Archivo General de Indias (General Archive of the Indies or AGI). Copies of these documents were provided on microfilm by Dr. John Worth, along with English translations by Wayne Childers completed in the late 1990s. Childers’ translations assisted in understanding the bulk of primary documents; however, several errors required retranslation by the author. The documents were comprised mainly from a royal audit of the account records for the Luna expedition, which included expenses for food, transport, naval purchases, and labor. Personal letters were also reviewed for their discussion on the private equity in organizing the expedition. These accounts and testimonies provided the basis not only for the historical
chapters, but also highlighted details on the identities and construction of the vessels from the original colonizing expedition.

Raw accounting data recovered from primary documents were transferred into Microsoft Excel and then organized for categorical analysis. Categories were assigned based on whether purchases were for materials, labor, or food and subsequently organized as to whether or not these resources were for colonists or shipyard applications. Organizing the accounting record in spreadsheets produced an accurate timeline of events for naval production and drew attention to the limitations on supply purchases made by the royal treasury.

*Mainmast Step Predictive Modeling*

Principal investigators were aware of the mainmast step assemblies' general location, but refrained from excavating the area due to a lack of available funding. When the University of West Florida received a Special Categories Grant in 2014 from Florida's Division of Historical Resources, excavations in amidships resumed and expanded beyond established units in the belief that uncovered hull structure would eventually dictate where further dredging should take place. This initiative was repeatedly inhibited due to exposing various disarticulated timbers from the pump well or digging isolated units beyond a meter into the sediment, which limited access for reaching hull structure. Based on these observations, the author created a predictive model for locating where the mainmast step should be located on EP II. Data accumulated from all available ships described in Chapter 4 were analyzed and averaged to build the internal hull structure for a typical "Trans-Oceanic Vessel" (TOV). Only the Newport shipwreck has been excluded from this analysis because the ship's features followed the Scandinavian tradition rather than a true oceanic example.
According to this model, the typical TOV keelson measured 16.4 m long and was 30 cm sided by 26 cm molded. There was an expanded section 1.67 m in length that increased the sided (45 cm) and molded (37 cm) dimensions respectfully. Toward the forward end of the mainmast step was the mainmast mortise (65 cm in length by 21 cm wide and 15 cm deep), indicating that the mainmast was positioned further forward (7.11 m) than aft (9.29 m). Shipbuilders, in this scenario, chose to modify the keelson directly behind the expanded section to accommodate two pump sumps 30 cm in diameter (or 25 cm by 22 cm if square cut) to receive either burr or common pumps. Four pairs of buttresses, on average 69 cm long and 20 cm sided, were positioned over accompanying floor timbers to provide lateral support. Each buttress was a triangular knee and their inboard molded dimensions began at 22 cm and decreased down to 12 cm at the foot wales. Stringers varied in length (9-15 cm); however, the TOV foot wales were 20 cm sided by 13 cm molded throughout. The TOV pump well planking, 1.1-1.25 m long and 25-26 wide, had a standard thickness around 4 cm. Each pump well plank was attached in an irregular fashion to stanchions (7 cm by 10 cm) surrounding the mainmast step and bilge pump assemblies.

The TOV model was superimposed on the EP II site plan, shown on Figure 1 in Appendix A with all other figures (Appendix B includes copyright permission for several figures) to locate the probable area for the mainmast step assembly. Positioning for the TOV keelson was based on available comparisons from Emanuel Point I, Angra D, the San Juan, and the Mary Rose (Smith et al. 1995:37; Garcia and Monteiro 2001:440; Marsden 2003:244; Bernier and Grenier 2007:240). Each of these keelsons terminates prior to the beginning of the Y-timbers and the rise in deadwood. Angle for the TOV keelson on Figure 1 was determined from data collected during the 2009 field season that located a component of the keelson towards the bow.
As seen on Figure 1, earlier units were installed in the area with the highest probable location for the mainmast step. Subsequent excavations confirmed that the 16th-century trans-oceanic shipwreck model could provide substantial assistance when locating specific hull components.

**Excavation and Recording Procedures**

Personnel utilized a 24 x 36 ft. double pontoon barge; anchored adjacent to the site for diving operations. Accurate placement of a 1 x 1 m grid system involved a permanent 19 m baseline offset from the shipwreck on a north-south axis. Grid units were made from square aluminum tubing painted incrementally black and yellow every 20 centimeters. Each unit was anchored into the bay through the use of four vertical posts driven into the bottom sediment. Tags were attached to the northeast vertical post with northern and eastern coordinates in relation to offsite datum points. Personnel began and concluded each excavation dive by obtaining depth measurements from all four corners and the center of a unit. Each measurement was obtained using a string and line level attached to the northeast corner. Excavators used a water induction dredge to remove sediment with hand fanning. Any small artifacts missed by personnel were caught in a double mesh bag attached on the exhaust and later examined on a 1/8 in. standard mesh screen. Levels were recorded as overburden, ballast, and hull structure, which supplemented the depths divers obtained on each dive.

Artifacts discovered in situ were triangulated to the nearest two walls and given a depth measurement. Provenience was written on slates with mylar attached that contained preprinted blank unit information to be filled out by excavators. Mapping the hull structure also relied on triangulation and compiling scantling information for specific features. Due to the depth in the amidships area (90-130 cmbs), a metal dowel rod was zip tied to a folding ruler and two disk
bubble levels to achieve accurate points for mapping (Figure 2). Ballast was removed strategically and carried to an offsite pile established previously by earlier fieldwork.

Excavations in amidships began during the 2010 field season by opening 91N 492E to answer research questions pertaining to the ballast (Gifford 2008:58–59). Subsequent excavations the following year required opening 91N 493E as part of the on-going investigation for 91N 492E. Since neither of these units entirely reached hull structure, succeeding field seasons involved revisiting the units to continue dredging operations. By 2013, units 92N 492E and 92N 493E were installed to widen the excavation as deeper depth was required. These issues were resolved in the fall of 2014 by opening 92N 494E as part of a new initiative to remove artifacts and reveal hull structure. Over the course of 2015, archaeologists consecutively installed 93N 493E, 93N 492E, 93N 491E, 92N 491E, 91N 491E, 91N 494E, and reinstalled 91N 490E because of a plank that extended into 91N 491E. By the end of the year, all units were excavated fully, except 91N 494E and 91N 490E, although both reached hull structure. The following year both units were excavated fully and mapped. Throughout fall 2015 and spring 2016 the author focused on mapping exposed hull structure and obtaining scantling measurements for all exposed components.

Photograph and Laboratory Methodology

Photographic field data was also obtained when the clarity of the water column made it possible. All photographs and video were taken using GoPro Heroes 3 and 4. Imagery collected from this equipment was given file names based on the site number, name of the site, unit(s) recorded, and a brief description. High quality photographs and video stills were then assembled inside Agisoft's PhotoScan to create a three-dimensional map of the mainmast step and bilge pump area. These images provided appropriate figures for showcasing the midships assembly
while keeping the hull intact. PhotoScan was also used for collecting scantling data to complement traditional field methods and vice versa.

Any wood uncovered and not connected to the hull was treated as separate artifacts and later reburied on site. Each timber was given a provenience number and the specific unit where the majority of the artifact originated. Labels were printed from a DYMO Express Pro Handheld Embosser and attached using Monell staples to the northeastern corner in relation to where each timber was found in situ. Further information was collected in a timber removal log that included basic measurements, the units where the wood originated, and the final destination where the artifacts would be reinterred. All timbers were recorded on specific mylar forms in the same manner as artifacts prior to their removal and subsequently photographed before attaching labels. Larger wooden planks that were too long to be carefully brought to shore were recorded in the field and reburied. Disarticulated timber brought back from the field underwent physical cleaning and was photographed using a Nikon D3200 with an AF-S Nikkor 35mm 1:1.8G lens (Figure 3). Subsequent laboratory recording obtained accurate scantling measurements and noted the number, size, and angle of fastener holes.

Approximately 400-900 pictures were taken of each timber using a lazy susan, mylar backdrop, and three LimoStudio 2400 watt soft boxes. Post-processing of each picture was completed in Pixanode Inc.’s Phoduit using operations in the following order: white balance, demosaic, lens correction, median, curves, color profile, levels, histogram, curves, exposure, background mask, gaussian blur, levels, firefly removal mask, dilate, split RGBA channels, invert, join channels, and render, which provided better image quality and produced alpha channel masks. Pictures from each timber were then processed in PhotoScan to create highly detailed 3-D representations. Orthographic images from each angle of every timber were also
exported from Photoscan into Phoduit to create highly accurate scale drawings of all components. All 3-D models, including the amidships area, were imported into the Blender Foundation's Blender software to reassemble the pump well area. Once data collection was complete most timbers were wrapped individually in landscaping cloth with zip ties and reburied on site by using landscaping cloth and concrete weights.
MAINMAST STEPS

An analysis of the mainmast step assembly from a typical 16th-century shipwreck should recognize the *longue durée* that led to the development of this component as a part of a trans-oceanic typology. This thesis defines a shipbuilding tradition as a specific regional shipbuilding methodology that changes over time and can become an entirely new entity when older sets of practices are combined with newer innovations. Analysis began with iconographic sources that allude to the appearance of the mast step in the Mediterranean. Several factors, as described below, eventually transformed the central mast step to become a crucial component of the keelson. This transformation, along with the transition from reliance on the outer hull strakes to provide structural reinforcement to an internal frame network, provides contextual evidence on changing patterns in the mast and sailing configurations.

Early sailing traits stemming from the Mediterranean, and spreading throughout northwest Europe, provided the foundation for the first hybrid shipbuilding tradition. Roman shipbuilding methodology fused with local Celtic building practices to create the Romano-Celtic tradition. Diffusion from northwest Europe led to the incorporation of sail technology into Scandinavia. Eventually, the combination of Scandinavian mast step design in Romano-Celtic hull design produced a Northern European ship typology that created the mast step seen in succeeding centuries. By examining the available archaeological examples from these three shipbuilding traditions (Mediterranean, Romano-Celtic, and Scandinavian), key components of the 16th-century mainmast step become apparent.
Mediterranean Tradition

Early Mainmast Steps and Supports

Known shipbuilding in the Mediterranean originated with the first civilizations to develop in the Near East. Early iconographic examples of sailing ships include a stone censer in Egyptian Nubia at Qustul (Figure 4) (Williams 1989:143, figure 56). The image illustrates a long hull with a single square sail toward the bow that has been dated to the Naqada-Dynasty zero era (3200-3000 B.C.). Although this representation includes a single mast, ancient Egyptians experimented originally during the Old Kingdom (2770-2270 B.C.) with a bipod system. The ship model CM 4882, recovered from a tomb dating to the reign of Pepi II (ca. 2278-ca. 2184 B.C.), includes a bipod mast made from composite materials (Reisner 1913:53-54, figures 190-193). Bipod masts were joined near the mast head with crossing laths on the upper third for reinforcement. Most iconographic examples include a cross-piece on the lower half where quadruple trusses were attached on either side. Trusses were probably connected to fasteners within the hull to provide lateral support to the mast.

Archaeologists lack any physical evidence for mast steps from this period; nevertheless, scholars claim that the bipod mast was probably set into heavy cleats and lashed to a large cross-beam (Landström 1970:46). Throughout this early period in shipbuilding history, mast steps were simple components between frames. Most depictions indicate support for the mast originated at deck level from vertical supports and appropriate stays. Several reliefs depict ships with a forestay and multiple backstays that provided additional longitudinal support to keep the mast upright. Examples of oceanic vessels portrayed in King Sahure's and King Unas' burial temples represent the typical Nile vessels on larger scales, including a tripod rather than a bipod mast (Figure 5) (Borchardt 1913:12-13, plate 12, 13; Landström 1970:64, figure 192).
Egyptians by the sixth dynasty (2420-2270 B.C.) were beginning to embrace the single mast on smaller vessels, although the bipod (or tripod) mast was still present on many larger ships (Landström 1970:47). The lateral support trusses, seen so often in earlier iconography, were replaced with new vertical poles (probably heavy knees fastened to the deck) that the mast was lashed onto when upright. Movement along the Nile relied on oar and sail propulsion depending on the destination, and wind direction. Masts were not positioned permanently as seen in much later vessels, but were unstepped readily when a ship was paddling against the wind. Several depictions from the tomb of Rahenem-Asa in Deir el Gebrawi include a possible tabernacle system that is described with horizontal planking on the front for lateral support between uprights (Figure 6) (Davies 1902:71-72, plates 19,20; Landström 1970:48). After examining these murals closely, it appears that the tabernacle knees were hollowed out to accept the mast and locked in place by inserting two wooden pegs along the backside. The concept of locking the mast in place with pins would eventually dominate deck-level support in later mast collar components.

Other depictions in the tomb of Rahenem-Asa include a ship with a tripod mast and two additional vessels with only single masts (Figure 7) (Davies 1902:59, plate 7). Each of these masts had a large knee on the front side onto which the mast was lashed. Sixth-dynasty shipbuilders also introduced a vertical forked stanchion that replaced the single mast when unstepped and held the entire element above the deck. Another ship model (CM 4918) from the tomb of Prince Mesehti in Asyut during the First Intermediate Period (2270-2040 B.C.) revealed a new technological improvement for positioning and supporting the mast at deck level (Figure 8) (Reisner 1913:75, figures 278-281). As mentioned earlier, after the sixth-dynasty, bipod masts were gradually phased out and replaced with single masts on sailing ships. As a result, the central
longitudinal beam running from bow to stern was broken up into two beam partners at the mast. The first cross-beam positioned directly in front of the mast was often slightly larger than similar beams spaced equally throughout the ship. On top of the larger cross-beam from ship model CM 4918 is a tabernacle knee with two additional knees attached on either side of the main knee running at roughly 45 degree angles. All flanges touching the deck include two wooden treenails fastening them to the cross-beam. The tabernacle knee also includes four pairs of holes on the rear edges and two through the middle (Reisner 1913:75, figures 278-281). Bottom holes are clearly for treenails to secure the angled knees to the main tabernacle. As for the other holes, only the pair in the middle are drilled through to the outside face. Based on earlier imagery, showing tabernacles with dowels holding bipod masts in place, archaeologists assumed that the higher pair of holes indicates a similar element. Holes through the upper middle section of the tabernacle are more perplexing. Two ship models from the eleventh dynasty tomb of Meket-Rē indicate these holes were for holding a pin or for lashing around the tabernacle knees to keep the mast in place (Winlock 1955:62, plate 85).

Prince Mesehti’s model makers were also keen in their efforts to reconstruct accurate details of mast components. Cairo Model 4918 includes a round mast with a square cut foot covered in a bronze cap. Model makers also carved a square vertical stanchion with a curved flange for resting the mast assembly on when not in use. Compared with the bronze cap on the mast, this stanchion has a definitive heel cut near the bottom for the mast step mortise. Hulls on Egyptian models vary, as solid pieces or miniature constructions with internal framing and decks painted on top. On Model 4819, the artisan chose to mimic an actual mast step. The mortise is rectangular with a hollow cone shape on the bottom toward the bow and a shallower cut in the middle. Both the mast and stanchion fit into the former cone shape closest to the tabernacle knee.
There is ample room behind, which implies that Egyptians employed a chock with a small tenon to prevent it from being unseated while holding the mast in place.

Two ship models from the tombs of Karenen and Harshefhotp, dated toward the end of the First Intermediate Period and into the Middle Kingdom (2040-1780 B.C.), reveal that two different types of mast collars with locking pins were also in use (Quibell 1908:137, plate 26; Schäfer 1909:72, figure 113). Both mast partners were incorporated into the shipbuilding tradition and would continue to be used on ships centuries later. Contemporary iconography suggests that smaller vessels at this time relied on the tabernacle knee, while larger ships with deeper holds utilized the mast collar (Landström 1970:87). This period also saw the invention of the halyard beam, often located on the following cross-beam behind the mast to secure running rigging.

Another peculiar difference in ship depictions at this stage includes the shift of unstepped masts from partially resting on the rudder stanchion to resting mainly forward of the central forked stanchion. Shifting the mast by the twelfth dynasty (2000-1780 B.C.) resulted in creating a new and shorter forked-stanchion, along with a stepped triangular mast rest near the bow. Introduction of cleats behind the mast to compensate the halyard beam or to replace it on other vessels allowed easier maneuverability with the running rigging. Most depictions from the New Kingdom (1567-1080 B.C.) position the deck house (formerly toward the stern of the vessel) in the central position on top of the mast, preventing any imagery at deck level or in the hull of the mast configuration. Only three ships sketched in red ochre from a tomb near Thebes reveal a long support (possibly a tabernacle knee) lashed behind rather than in front of the mast (Landström 1970:138).
Oceanic travel orchestrated by Queen Hatshepsut (1479-1458 B.C.) to Punt includes reliefs depicting the successful voyage in her burial temple at Deir el Bahari. These ships did not include deck housing, allowing details of a large truss seen wrapping around the mast and obscuring any other mast components. Scholars originally believed that this large truss wrapped around both the mast and a hogging truss held up by forked stanchions along the length of each ship (Faulkner 1941:8; Landström 1970:122–127). Others have dismissed this argument and instead believe the wrapped truss is actually a remnant from the lateral trusses utilized by Old Kingdom shipbuilders on bipod and tripod masts. The latter scenario is based on the belief that the wrapped truss did not go around the hogging truss since sculptors did not carve a bend in the hogging truss. Depictions of Syro-Canaanite ships from the tomb of Kenamun (1427-1400 B.C.) supposedly include wrapped trusses around the masts without any apparatus in the ships for hogging trusses (Wachsmann 2009:248–251).

These conclusions do not acknowledge the eight centuries of naval innovations in the form of the triple tabernacle knee or the mast collar at deck level. Either of these two components could provide the lateral reinforcement for Hatshepsut's ships rather than the wrapped trusses. Although mural reliefs do not give a standard scale, the images suggest that the hogging truss was probably massive and that the wrapped truss was not tight enough to require the artist to depict a bend in the iconography (Wachsmann 2009:250). Furthermore, the argument that Syro-Canaanite ships had a similar wrapped truss on the mast is based on a single depiction. Other ships from the same relief do not indicate the same lines that were described as a wrapped truss. Where the mast is depicted, there are several horizontal bands that mimic lashing with lines running down from the lower yard to the mast. Cairo Museum model 4841 from the Middle Kingdom includes a sailing rig with running rigging tied off and lashed around the mast below
the lower yard (Reisner 1913:29, figures 116,117). Reexamining the Syro-Canaanite ships shows that the lines originating from the lower yard terminate exactly where the horizontal bands are on the mast. Foreign vessels had not by this time embraced the halyard beam or cleat to tie off running rigging while sailing. It also disproves the notion that the wrapped truss was a lateral support for the mast and emphasizes its use in correlation with the hogging truss.

Around the end of the late Bronze Age, other cultures across the Levant began to embrace the sail. Archaeologists working in Cyprus discovered three terra-cotta ship models all dating to the Late Cypriot I-II period (1600-1200 B.C.). The first model (Figure 9), from Tomb 2B at Kazaphani Ayios Andronikos, includes a rounded hull with a circular mast step in the center (Nicolaou and Nicolaou 1989:52, figure 14, plate 34). On either side of the mast step are cleats protruding inward from the outer hull. Excavations at Site A Maroni Zarukas uncovered ship models A-49 and A-50 from Tombs 1 and 7 respectfully (Merrillees 1968:188, plate 37). Model A-49 has a similar construction as the model from Kazaphani, with a round mast step at the center and four vertical holes equal distance from each other piercing the hull near the turn of the bilge. Model A-50's bottom unfortunately was lost, leaving only two protrusions inside the hull near the center. These protrusions are in a similar position as the Kazaphani model, but with vertical holes present. A Cypriot cylinder seal dating to the end of the Late Cypriot period (1200-1050 B.C.) depicts a ship with two forestays and backstays (Westerberg 1983:18, figure 16). As discussed earlier, Egyptians relied on a single forestay and several backstays to prevent longitudinal movement of the mast. Positioning of the protrusions on the Kazaphani and A-50 models likely indicates where running rigging would be tied off. The apparent use of more than one stay on these ships shows that the protrusions on A-49 were used either for additional lines to secure the mast longitudinally or for running rigging.
Iconographic evidence from Cyprus, the Minoan culture on Crete, and drawings of Mycenaean/Achaean ships all share common traits. Friezes from the Minoan culture in the "West House" at Akrotiri provide the most detailed evidence. Along the West House's southern wall is a miniature frieze depicting various ships from a waterborne procession, including one vessel under full sail (Marinatos 1974:47–52, color plate 9,104; Morgan 1988:124, figures 70,71). Earlier Minoan seals (Figure 10) depict similar sailing configurations; however, most seals do not include yard or sail and have the bare mast attached with two to four stays connecting the stem and sternposts (Evans 1964:239,244, figures 136,141; Casson 1995:32–35 figures 34-41,47,48). Paintings on ceramic sherds from Pyrgos Livonaton and a stirrup jar from Skyros provide contemporaneous illustrations of Mycenaean ships (Hencken 1968:537, figure 486; Dakorania 1990:117–120, figure 2). Although these cultures had differences in hull design, their reliance on a single vertical mast configuration was universal. No matter the medium, almost all artisans chose to depict the mast, a forestay, two backstays, and occasionally, the mast head. Other aspects included intermittently are the sail, yards, and the halyard lattices or sheaves seen near the top of the mast on either side. This mast configuration originates as far back as the Middle Kingdom in Egypt, leading the author to believe sailing technology was first copied by the surrounding cultures before diverging in later centuries.

Mast steps from this period are rarely portrayed, but two ships on a Late Helladic IIIB (1312-1190 B.C.) krater from Enkomi exhibit the masts as stepped into triangular bases (Sjöqvist 1940:figure 20:3). One terra-cotta ship model from Argos, also dating to the Late Helladic, includes a triangular base for a now missing mast in the middle of the hull (Palaiologou 1989:221, figures 1-5). Clearly these depictions do not represent accurate models, as seen in earlier Egyptian equivalents. If the upper mast assembly remained the same throughout the
eastern Mediterranean, it would beg the question whether or not the mast step would hold equivalent similarities? Three Cyprus jugs from the 7th century B.C. also have iconography representing the mast step as a triangular apparatus (Karageorghis and des Gagniers 1974:122–123). The triangular shape infers that the mast was held in place without being unstepped easily and that it was further supported at deck level. A key issue with this scenario is a heavy merchant galley model (BM A 202) (Figure 11) recovered in Cyprus dating to the 8th century B.C. (Casson 1995:65–66, figures 86, 87). The model relies on intrinsic details portraying the holes for the oars, a raised stern castle with prominent side towers for the quarter rudders, and internal cross-beams. Again, as in most other models, the mast is missing, but the model maker was apparently aware of the mast step apparatus by sculpting in several minute details. The merchant galley mast step assembly is similar, if not exact, to the mast step configurations found on Egyptian ship models centuries earlier. Archaeological evidence for mast steps (described below) follows morphology from this mast step assembly rather than the triangular base mentioned above.

Scholars could argue that the triangular mast step was a result of the abstract nature of the iconography. Another equally probable answer is the introduction of a foreign shipbuilding tradition. Ships with triangular mast steps have similar hull designs and the Enkomi depictions included warriors on the upper deck and larger warriors between each ship. On two of the Cyprus jugs the end of the stems are drawn with the head of a bird looking aft. Bird imagery is associated with the Sea Peoples, whose ships are represented on the relief from Ramesses III's mortuary temple at Medinet Habu (Breasted 1930:74, plate 37). If the triangular masts were from the migratory Sea Peoples, then the mast step design originated from another previously unknown shipbuilding tradition. None of the Sea People's ships at Medinet Habut include
evidence for oar propulsion, although the Enkomi depictions contain men within the hold possibly for this purpose. Either several artists from different cultures and regions chose not to show oars on these ships, or sailing was the primary propulsion for these vessels. Triangular mast steps are certainly a more stable platform for ships with single propulsion in mind. For example, earlier Egyptian masts were held in place with cleats relying on support structure at deck level, whereas the triangular mast would place the support in the hold and prevent the heel of the mast from moving. The only other available mast imagery from this period is an archaic galley depiction (ca. 700-650 B.C.) prominently displaying a narrow ram style bow with a single mast amidships (Morrison and Williams 1968:77, plate 8d). Near the base, the artist chose to draw some form of a mast partner assembly behind the mast, probably to provide lateral support. This support knee is indicative of the tabernacle knee seen on earlier sailing ships handed down through the centuries.

Mast Steps In The Archaeological Record

Physical examples of ancient mast steps do not appear until the 6th century B.C., providing evidence that earlier iconography supports a rather conservative morphology (Figure 12) (Joncheray 1976:31–34). Tables 1 and 2 provide an overview for available Mediterranean shipwrecks with surviving mast steps. Until the new millennium, mast steps shared similar characteristics as massive timbers (Figure 13) that did not span the length of the ship, but were located near the central hull (Dumas 1964:120–127; Swiny and Katzev 1973:349; Charlin et al. 1978:74–77; Pomey 1978:83–96; Geannette 1983:11–14; Steffy 1985:86). Most mast steps show no signs of being fastened, instead their own weight and the vertical pressure from the mast kept them in place. Only the contemporary Titan wreck demonstrated an early attempt at fastening
### TABLE 1
SHIPWRECKS FROM THE MEDITERRANEAN TRADITION

<table>
<thead>
<tr>
<th>Number</th>
<th>Site</th>
<th>Date</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Mast Inserted Into</th>
<th>Carved From</th>
<th>Probable Sail Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bon Porté&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6th c. B.C.</td>
<td>10</td>
<td>c. 6</td>
<td>Mast Step</td>
<td>Pine</td>
<td>Square</td>
</tr>
<tr>
<td>2</td>
<td>Ship 17&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5th-4th c. B.C.</td>
<td>28</td>
<td>c. 5</td>
<td>Keel</td>
<td>Acacia</td>
<td>Square</td>
</tr>
<tr>
<td>3</td>
<td>Kyrenia&lt;sup&gt;d&lt;/sup&gt;</td>
<td>375- 400 B.C.</td>
<td>14.7</td>
<td>4.9</td>
<td>Mast Step</td>
<td>Pine</td>
<td>Square</td>
</tr>
<tr>
<td>4</td>
<td>Cavalière&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1st c. B.C.</td>
<td>13</td>
<td>4.6</td>
<td>Mast Step</td>
<td>Bosnian Pine</td>
<td>Square</td>
</tr>
<tr>
<td>5</td>
<td>Chrétienne A&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1st c. B.C.</td>
<td>24-32</td>
<td>8</td>
<td>Mast Step</td>
<td>probably Pine</td>
<td>Square</td>
</tr>
<tr>
<td>6</td>
<td>Madrague de Giens&lt;sup&gt;g&lt;/sup&gt;</td>
<td>50 B.C.</td>
<td>43</td>
<td>9</td>
<td>Mast Step</td>
<td>Oak</td>
<td>Square</td>
</tr>
<tr>
<td>7</td>
<td>I'île Plane à Marseille&lt;sup&gt;1b&lt;/sup&gt;</td>
<td>50 B.C.</td>
<td>N/A</td>
<td>N/A</td>
<td>Mast Step</td>
<td>probably Pine</td>
<td>Square</td>
</tr>
<tr>
<td>8</td>
<td>Saint-Gervais 3&lt;sup&gt;i&lt;/sup&gt;</td>
<td>A.D. 150</td>
<td>17</td>
<td>7.5</td>
<td>Mast Step</td>
<td>Fir</td>
<td>Square</td>
</tr>
<tr>
<td>9</td>
<td>Laurons 2&lt;sup&gt;j&lt;/sup&gt;</td>
<td>A.D. 275-300</td>
<td>15</td>
<td>5</td>
<td>Mast Step</td>
<td>probably Pine</td>
<td>Square</td>
</tr>
<tr>
<td>10</td>
<td>Pointe de la Luque B&lt;sup&gt;k&lt;/sup&gt;</td>
<td>A.D. 4th c.</td>
<td>20</td>
<td>6</td>
<td>Keelson</td>
<td>probably Pine</td>
<td>Both</td>
</tr>
<tr>
<td>11</td>
<td>Port-Vendres I&lt;sup&gt;l&lt;/sup&gt;</td>
<td>A.D. 375-500</td>
<td>N/A</td>
<td>N/A</td>
<td>Mast Step</td>
<td>probably Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>12</td>
<td>Parco di Teodorico&lt;sup&gt;m&lt;/sup&gt;</td>
<td>A.D. 5th c.</td>
<td>9</td>
<td>3.1</td>
<td>Mast Step</td>
<td>Larch</td>
<td>Lateen</td>
</tr>
<tr>
<td>13</td>
<td>Dramont E&lt;sup&gt;n&lt;/sup&gt;</td>
<td>A.D. 383-423</td>
<td>15-18</td>
<td>5-6</td>
<td>Mast Step</td>
<td>Larch</td>
<td>Lateen</td>
</tr>
<tr>
<td>14</td>
<td>Dor 2001/1&lt;sup&gt;o&lt;/sup&gt;</td>
<td>A.D. 475-525</td>
<td>16.9</td>
<td>5.4</td>
<td>Mast Step</td>
<td>Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>15</td>
<td>Tantura F&lt;sup&gt;p&lt;/sup&gt;</td>
<td>A.D. 700-725</td>
<td>c. 15</td>
<td>5</td>
<td>Keelson</td>
<td>Turkish Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>16</td>
<td>Tantura B&lt;sup&gt;q&lt;/sup&gt;</td>
<td>A.D. 800-825</td>
<td>18-23</td>
<td>5</td>
<td>Keelson</td>
<td>Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>17</td>
<td>Serçe Limani&lt;sup&gt;r&lt;/sup&gt;</td>
<td>A.D. 1025</td>
<td>15.66</td>
<td>5.2</td>
<td>Keelson</td>
<td>Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>18</td>
<td>Norman Wreck A&lt;sup&gt;s&lt;/sup&gt;</td>
<td>A.D. 1150</td>
<td>18</td>
<td>5.8</td>
<td>Keelson</td>
<td>Poplar</td>
<td>Lateen</td>
</tr>
<tr>
<td>19</td>
<td>Culip VI&lt;sup&gt;t&lt;/sup&gt;</td>
<td>A.D. 1300</td>
<td>16.35</td>
<td>4.11</td>
<td>Keelson</td>
<td>probably Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>20</td>
<td>Contarina I&lt;sup&gt;u&lt;/sup&gt;</td>
<td>A.D. 1300</td>
<td>20.98</td>
<td>5.2</td>
<td>Keelson</td>
<td>Larch</td>
<td>Lateen</td>
</tr>
<tr>
<td>21</td>
<td>Les Sorres X&lt;sup&gt;v&lt;/sup&gt;</td>
<td>A.D. 1350</td>
<td>10</td>
<td>5</td>
<td>Mast Step</td>
<td>Pine</td>
<td>Lateen</td>
</tr>
<tr>
<td>22</td>
<td>Logonovo&lt;sup&gt;w&lt;/sup&gt;</td>
<td>A.D. 1400</td>
<td>10.05</td>
<td>2.55</td>
<td>Keelson</td>
<td>Oak</td>
<td>Lateen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Mast Step / Keelson</th>
<th>Mast Mortise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (m)</td>
<td>Sided (cm)</td>
<td>Molded (cm)</td>
</tr>
<tr>
<td>Bon Porté</td>
<td>6th c. B.C.</td>
<td>1</td>
<td>8-19</td>
</tr>
<tr>
<td>Ship 17</td>
<td>5th-4th c. B.C.</td>
<td>2.588</td>
<td>35.7-36.1</td>
</tr>
<tr>
<td>Kyrenia</td>
<td>375- 400 B.C.</td>
<td>1.2</td>
<td>24</td>
</tr>
<tr>
<td>Cavalière</td>
<td>1st c. B.C.</td>
<td>7.5</td>
<td>18-26</td>
</tr>
<tr>
<td>Chrétienne A</td>
<td>1st c. B.C.</td>
<td>5</td>
<td>22-48</td>
</tr>
<tr>
<td>Madrague de Giens</td>
<td>50 B.C.</td>
<td>4</td>
<td>55</td>
</tr>
<tr>
<td>I'île Plane à Marseille 1</td>
<td>50 B.C.</td>
<td>4.2</td>
<td>14-30</td>
</tr>
<tr>
<td>Saint-Gervais 3</td>
<td>A.D. 150</td>
<td>4.8</td>
<td>38</td>
</tr>
<tr>
<td>Laurons 2</td>
<td>A.D. 175-200</td>
<td>7.75</td>
<td>26-28</td>
</tr>
<tr>
<td>Pointe de la Luque B</td>
<td>A.D. 4th c.</td>
<td>&lt; 2.1</td>
<td>25</td>
</tr>
<tr>
<td>Port-Vendres 1</td>
<td>A.D. 375-500</td>
<td>7.15</td>
<td>29</td>
</tr>
<tr>
<td>Parco di Teodorico</td>
<td>A.D. 5th c.</td>
<td>ca. 4.67</td>
<td>ca. 21</td>
</tr>
<tr>
<td>Dramont E</td>
<td>A.D. 383-423</td>
<td>7.14</td>
<td>20-23.7</td>
</tr>
<tr>
<td>Dor 2001/1</td>
<td>A.D. 475-525</td>
<td>ca. 9.1</td>
<td>ca. 20</td>
</tr>
<tr>
<td>Tantura F</td>
<td>A.D. 700-725</td>
<td>1.45</td>
<td>26</td>
</tr>
<tr>
<td>Tantura B</td>
<td>A.D. 800-825</td>
<td>7.84</td>
<td>20.2-12.2</td>
</tr>
<tr>
<td>Serçe Limani</td>
<td>A.D. 1025</td>
<td>&lt; 2.17</td>
<td>18</td>
</tr>
<tr>
<td>Norman Wreck A</td>
<td>A.D. 1150</td>
<td>--</td>
<td>30</td>
</tr>
<tr>
<td>Culip VI</td>
<td>A.D. 1300</td>
<td>&lt; 7</td>
<td>13-14</td>
</tr>
<tr>
<td>Contarina I</td>
<td>A.D. 1300</td>
<td>ca. 18.4</td>
<td>N/A</td>
</tr>
<tr>
<td>Les Sorres X</td>
<td>A.D. 1350</td>
<td>6.4</td>
<td>6</td>
</tr>
<tr>
<td>Logonoovo</td>
<td>A.D. 1400</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

---

the mast step into the floor timbers and partially into the keel (Benoit 1961:139; Basch 1972:29). Early mast steps were also notched over the frames and several included chamfered edges to fit snugly against half-frames. All of the mast steps from this era have a mast cavity with a rising arc, indicating that ships often lowered their masts either in port or when paddling against the wind. Along with the mast mortise, shipbuilders carved recesses for a tabernacle board and mast crutches to guide the mast into place and to keep it from unstepping. Carpenters built tabernacle boards originally with square tenons to fit into corresponding mortises in the mast step. Eventually this system was replaced with the introduction of a reverse arc for the tabernacle board to provide a better method for keeping the component firmly in place. Another possible explanation for the reverse arc mortise could involve the weight of the mast pressing against the tabernacle board and making the square tenons break off easily.

Mast steps in the 1st century B.C. became slimmer with expanded molded sections only for the mast mortise complex and thinner arms running along the longitudinal axis. Only the unusual construction on Ship 17, originally found among the submerged city Thonis-Heracleion in Egypt, provides an alternative method for stepping the mast directly on a proto-keel. Egyptian shipwrights chose to build the ship using a modified mortise and tenon system, whereas the normal frames became internal tenons connecting much of the lower hull assembly together. The shallow mortise for the mast heel and the lack of shipworm or abrasion from landing the craft attest to local construction, while discounting sailing as its primary means of propulsion (Belov 2014:315–320,328).

Keelsons appear initially during the early Imperial Roman period in the form of proto-keelsons and sister-keelsons. Mast steps at this point were stretched out in length and no longer included evidence of an expanded section for the mast step area. Proto-keelsons (Figure 14) first
appear as longitudinal supports only near the bow and stern areas, sometimes resting on sister keelsons while below mast step components (Liou 1974:425; Gassend et al. 1984:100; Liou et al. 1990:234–245; Medas 2003:42, figure 9.2). Shipbuilders relied on a sister keelson system (Figure 15) to provide the missing longitudinal support and to assist in keeping mast steps from moving out of place. As the traditional mortise and tenon edge joinery shrank in size, the keelson grew to cover the entire central axis. The mast step and keelson eventually became a single component. Traditions, such as notching and chamfering the bottom edges of the mast step, were carried over to proto-keelsons. This practice continued intermittently on later keelsons, even when half-frames were no longer in use. Early examples of fastening the keelson to the keel appeared by the A.D. 4th century (Figure 16), but did not become a mainstream pattern until the end of the millennium when frame-first construction was widely accepted (Clerc and Negrel 1973:66–67; Kahanov 2000:151–153; Kahanov et al. 2004:121; Barkai and Kahanov 2007:24–26). Keelsons throughout this period, and into the medieval era, continued to rest on sister keelsons or directly over floor timbers. During this same time, mast mortises began to decrease in depth and morphed from the rising arc to a straight angle, eventually becoming a shallow rectangular socket. As the keelson became slimmer, the mortise complex began to disappear, beginning with the recesses for mast crutches. Rather than removing these components altogether, shipbuilders chose to simply construct thicker mast crutches (Figure 17) with beveled ends resting directly on the sister keelsons.

When Mediterranean ships began to embrace the lateen sail, however, the short and lighter mast required less reinforcement at the heel making most of the complex obsolete. Scholars debate when the lateen sail was first employed, as evidence from iconography includes a depiction of a lateen sail on a A.D. 2nd century stele (Campbell 1995:9; Casson 1995:118).
After the A.D. 6th century, most depictions of square sails disappear and were replaced with the lateen sail. Economic decline also forced many shipyards to produce smaller vessels with shallower holds, thus limiting the need for components to guide the mast into place (Wilson 2011:44). The exponential growth and morphology of the keelson as the central longitudinal stringer (Figure 18) also required the sister keelsons to shrink in size and become less supportive. Although available archaeological evidence is limited after the A.D. 1st millennium, it appears that the sister keelsons began a slow expansion from under the keelson outward after the 12th century (Figure 19).

Several examples from the Medieval period indicate that the keelson continued to have a larger cross-sectional area compared to the keel (Steffy 1982:20; Ferroni and Meucci 1996:302). Connection between both timbers was facilitated using different methods, indicating regional variations from bolts between floor timbers to fasteners driven through frames. Separation of the sister keelson component from the keelson required new naval innovations to provide lateral support in this area. Shipbuilders altered floor timbers that ran beneath the mast step to have natural protrusions (Figure 20) to act as lateral buttresses (Bonino 1978:13).

Northern European shipbuilding traditions after the 12th century began to influence shipyards in the far western Mediterranean. Separate lateral buttresses (Figure 21) appeared on ships and these were often fastened to the floor timbers to support the mast step (Prieto and Raurich 1989:323–326). Smaller boats embraced the traditional keelson, but incorporated an entirely separate massive chock (Figure 22) to act as the mast step (Raurich et al. 1992:38–39). From this evidence (Figure 23) it becomes clear that shipyards along the western coast of the Mediterranean, at least by the 13th century onwards, were beginning to combine the best
technology from several shipbuilding traditions to facilitate trade across Europe and eventually into the Atlantic.

**Romano-Celtic Tradition of Northwestern Europe**

Until the arrival of Romans in northwestern Europe (58 B.C.), evidence for sailing craft is rather limited. Only one ship model, made of gold, from Broighter, Co. Derry, Ireland has been dated tentatively to the 1st century B.C. (McGrail 1998:186–187). The model’s hull is symmetrical in character with a gold line near the probable bow for an anchor. On either side of the boat are seven oars inserted into small rings (oarlocks) along the gunwales. Inside the hull are eight (though fastener holes suggest originally nine) benches fastened to the hull with a mast and yard attached through the central bench. Julius Caesar’s own contemporary memoir from fighting in Gaul mentions a prominent Celtic shipbuilding tradition, utilizing sails made from skins and leather (Caesar 1869:book 3.13). Archaeological examples are only dated to a century later, when Roman and Celtic traditions were combined, creating what scholars now call the Romano-Celtic tradition. The earliest example of this type is a boat from the Bay of Bevaix on Lake Neuchâtel in Switzerland. Similar to the Mediterranean tradition with *carvel*, or flush hull planking, the boat has no keel and relies on four flat central planks (Arnold 1975:123). After the turn of the bilge, the strakes are attached to each other in an overlapping pattern known as lapstrake. Investigators recorded twenty-two pairs of frames with the sixth pairing containing a mast step (Arnold 1974:134). Carpenters carved the mast step section of the frame as an inverted "T" (Figure 24). This raised central area provides strength to the central mast mortise, which has a slight chamfer to the rear. Scholars question the mast frame because of the probable low mast partner for stability and no reinforcing superstructure to share the stress from the mast onto the hull (Geannette 1983:91).
The A.D. 2nd century Blackfriars ship (Figure 25) located near the City of London, along the River Thames, shares some characteristics with the Bevaix boat. The Blackfriars ship has no keel and the *carvel* planking is fastened to the frames with double-clenched iron nails driven through treenails. The mast step mortise is positioned one-third the length of the vessel from the bow and set slightly forward into the seventh frame (Marsden 1967:19). Most of the timber surrounding the mast mortise is left intact. Shipwrights also carved medial ridges along the central longitudinal axis on either side of the mast mortise. Along the aft face of the raised central section is a horizontal notch to allow the forward end of the ceiling planking to be fastened down. On either side of the mast mortise are two square holes, possibly for vertical stanchions to support longitudinal beams at deck level. Investigators also found two fasteners sticking out from the forward side of the frame. Several wooden fragments, 5 cm thick, were found beneath these nails, indicating a board was attached to strengthen the forward wall of the mast mortise.

Another contemporaneous ship, the Bruges boat, located and subsequently destroyed by canal construction crew near Bruges, Belgium, is unique by having the actual mast (broken into six pieces) preserved (Marsden 1976:24). Originally estimated at 9.3 m in length, the mast near the heel is rectangular in form until deck level where it became circular and tapered throughout the remainder. Near the top of the mast is a rectangular slot and several meters down is a pair of slots that archaeologists assume were for the stay and halyard (Marsden 1976:41). As with other examples, the Bruges boat is made from oak and includes a mast step-frame similar in construction to the Blackfriars ship. Another timber that survived destruction is a large deck-level cross-beam with a notch of similar dimensions as the mast mortise (Figure 26).
Investigators mention that this timber was crafted originally as the mast step-frame for a larger vessel due to the presence of medial ridges partially crafted on either side of the central notch (Marsden 1976:32).

Excavations near Zwammerdam in the Netherlands on the Roman fort *Nigrum Pullum* during the first half of the 1970s uncovered several dugouts and barges dated to the 2nd and 3rd centuries (A.D. 150-225). Investigators have attributed the turbulent events along the Roman frontier at this time for the construction of these vessels to transport building materials for fortifications (de Weerd 1978:16). Out of the three dugouts, only Zwammerdam 3 includes a small mast step-frame that is believed to be for a towing post rather than a mast due to the size and location (riverine versus oceanic) (Marsden 1976:46). All three barges uncovered during the excavations also include mast steps; however, Zwammerdam 2's mast step cavity is also too small for a sailing configuration, alluding to another vessel with a towing post (de Weerd 1978:17). Both barges Zwammerdam 4’s and 6’s mast step-frames follow similar patterns described above for the Blackfriars and Bruges vessels (de Weerd 1978:17). Each mast step-frame has an inverted "T" shape with a square socket that investigators conclude could hold a mast with sail, although the prospect that this may have simply been a larger tow post is still possible. Zwammerdam 4 includes a surviving double cross-beam with a notch on the aft section to accept the forward half of the mast (McGrail 1998:229, figure 12.20). The mast was prevented from unstepping or falling backward through the use of two metal flanges on either side allowing a dowel to be slid between them.

Two ships from later periods represent a partial continuation of the Romano-Celtic tradition after the collapse of the Roman Empire. Originally discovered during the widening of a drainage channel in Graveney Marshes, England, the Graveney boat (Figure 27) was radiocarbon
dated to the second half of the A.D. 9th century. What makes this vessel unique in this discussion are the three rabbets along the central frames, which investigators suggest for a missing mast step and/or keelson complex (Fenwick 1972:128). The central frame modifications allude to the vessel originally having a purpose in cross-channel trade before the central component was removed and covered with available scrap timber. Whereas the Graveney boat displays consistencies with the earlier Blackfriars ship, the slightly later Utrecht I ship (Figure 28) shows remarkable similarities to Zwammerdam expanded dugouts. Radiocarbon dating from the hull timbers indicate Utrecht I was built around the turn of the new millennium (A.D. 997) (Van de Moortel 2003:183). Although many of Utrecht I's construction features share traits that fall under the Romano-Celtic tradition, the reliance on a single tree trunk to form the central bottom of the hull contrasts against the multi-plank bottom seen on the Blackfriars or Graveney ships. As with earlier dugouts, this boat has a central socket in the eleventh frame slightly aft from the bow that some scholars argue points towards the Romano-Celtic shipbuilding tradition for a tow post rather than a mast (Crumlin-Pedersen 1972:186; Vlek 1987:127).

Fragments from the Queenhithe ship indicate that a tow post may not necessarily be the case, rather that ships built in the Utrecht manner could have relied on sailing propulsion, although the absence of a keel would have made the ship prone to lateral drift (Van de Moortel 2009:323,326). Investigators also emphasize that Utrecht I and similar examples were possibly early versions of the late-medieval hulk that would eventually supersede the cog in maritime traffic during the 15th century.

Scholars agree that a third shipbuilding tradition combined certain aspects of the Mediterranean and Scandinavian traditions, while remaining unique with a basis on local Celtic shipbuilding knowledge. As seen in Table 3, the various scantling dimensions vary across the
### TABLE 3

**ROMANO-CELTIC SHIP AND MAST FRAME DIMENSIONS**

<table>
<thead>
<tr>
<th>Number</th>
<th>Site</th>
<th>Date</th>
<th>Ship Scantling</th>
<th>Mast Step Frame</th>
<th>Mast Mortise</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Length (m)</td>
<td>Beam (m)</td>
<td>Length (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sided (cm)</td>
<td>Molded (cm)</td>
<td>Length (cm)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Width (cm)</td>
<td>Depth (cm)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bevaix</td>
<td>A.D. 0-100</td>
<td>19.4</td>
<td>2.9</td>
<td>2.275</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>42.5</td>
<td>7-18</td>
<td>13</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Blackfriar</td>
<td>A.D. 175-200</td>
<td>15.24-16.76</td>
<td>6.71</td>
<td>3.81</td>
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<td>22-30</td>
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<tr>
<td>3</td>
<td>Bruges</td>
<td>A.D. 175-225</td>
<td>--</td>
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<td></td>
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<td>46</td>
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<td>14.5</td>
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</tr>
<tr>
<td>4</td>
<td>Zwammerdam 3e</td>
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<td>10.4</td>
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</tr>
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</tr>
<tr>
<td>5</td>
<td>Zwammerdam 2c</td>
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<td>22.75</td>
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<td>N/A</td>
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<td>N/A</td>
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<td>6</td>
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<td>A.D. 150-225</td>
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<td>4.40</td>
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<td>N/A</td>
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<tr>
<td>8</td>
<td>Graveney</td>
<td>A.D. 850-900</td>
<td>14</td>
<td>3</td>
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<tr>
<td>9</td>
<td>Utrecht I</td>
<td>A.D. 1000-1025</td>
<td>17.45</td>
<td>3.84</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>9</td>
<td>6</td>
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</tr>
</tbody>
</table>

centuries. Except for the Blackfriars ship and Bruges boat, the remaining examples from the Romano-Celtic tradition are primarily coastal or riverine traffic that relied on oar propulsion or towing from shore. For those ships that did travel in open seas, the construction of the mast step was apparently either a Mediterranean influence or a poorly understood concept by local shipwrights. Placing the step within a transverse frame did not divide the stressful load from the mast into the hull as seen in earlier Mediterranean examples. Local shipwrights instead followed a tradition of cutting the mast mortise slightly forward in a mast step-frame to provide aft support against the mast heel. Shipbuilders occasionally nailed wooden boards on the front face to add additional thickness (Marsden 1967:19). Surrounding wood near the mast cavity was also kept intact, while medial ridges carved on either side of this area acted as transverse support components. The lack of any evidence from the mast step-frame for a mortise complex must imply that additional support originated at deck level. Only the double cross-beam mast partner complex found on the Zwammerdam 4 is the best evidence to what this support entailed.

**Scandinavian Tradition**

There is ample reason to assume that the clinker shipbuilding tradition of Scandinavia also relied on sailing. As described above, contemporary sources mentioned the use of a leather sail for Celtic ships along the Atlantic coast. The earliest evidence for sails in Scandinavia, however, originated with the much later iconographic Gotland stones (Crumlin-Pedersen 1965:126). Gotland stones were originally a mixture of human and animal figurines surrounding geometric art. After the A.D. 6th century these depictions amplified in detail to represent possible events in mythology and carvings of sailing craft (Figure 29). Most vessels are depicted with a single mast and a rectangular brailed sail attached just below the mast head. Several images also included a single fore and aft stay running slightly above the top yard of the sail.
Clearly these representations indicate an established sailing tradition with enough understanding to wield a relatively large sail.

Scholars argue that the appearance of the sail in iconography coincided with the Viking expansion outside Scandinavia (Christensen 1972:165). Several reasons for the absence of an earlier sailing configuration include reliance on the central keel-plank within early Scandinavian ship construction and the light weight lapstrake hull design. Downward pressure from the mast inhibited utilizing this configuration, along with the preference for oar propulsion when navigating known current patterns along traditional coastal waterways. Evidence from Romano-Celtic shipbuilding reveals that local shipbuilders overcame these obstacles by installing the mast into a lateral frame. Until further archaeological examples are discovered, this thesis proposes that the full sail evident in the Blackfriars ship and Bruges boat was diffusion from northwestern Europe to Scandinavia. Through trade and interaction with coastal settlements, Scandinavian shipwrights began to incorporate the mast step within their own traditions.

Clinker shipbuilding consists of a staggered overlapping system of edge-joined planks to form the hull (Steffy 2012:100). Similar to the earlier Mediterranean mortise and tenon tradition, the frames were only installed as a compliment structure to maintain the shape of the hull. Preferences for light weight vessels did not allow for broad lateral frames, as seen in Romano-Celtic shipbuilding. Scandinavian shipbuilders instead followed similar methods for stepping the mast, similarly seen over millennia earlier by their Mediterranean counterparts.

Available archaeological evidence supports the rather late incorporation of sail technology into the Scandinavian tradition (Table 4). Shipbuilders had to learn through trial and error how to incorporate this new propulsion mechanism into an already established building method that emphasized a lightweight and flexible design. Early mast steps were often short.
# TABLE 4

**SCANDINAVIAN TRADITION SHIPS AND MAST STEP MEASUREMENTS**

<table>
<thead>
<tr>
<th>Number</th>
<th>Site</th>
<th>Date Constructed</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Keelson / Mast Step (crone)</th>
<th>Mast Mortise</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length (m)</td>
<td>Sided (cm)</td>
</tr>
<tr>
<td>10</td>
<td>Oseberg</td>
<td>A.D. ca. 820</td>
<td>21.6</td>
<td>5.1</td>
<td>1.65</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>Gokstad</td>
<td>A.D. ca. 895</td>
<td>24.2</td>
<td>5.1</td>
<td>3.60</td>
<td>18-30</td>
</tr>
<tr>
<td>12</td>
<td>Hedeb 1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>A.D. 985</td>
<td>30.9</td>
<td>2.7</td>
<td>--</td>
<td>6.5-?</td>
</tr>
<tr>
<td>13</td>
<td>Hedeb 2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>A.D. ca. 965</td>
<td>9-12</td>
<td>--</td>
<td>&lt; 1.33</td>
<td>4-14</td>
</tr>
<tr>
<td>14</td>
<td>Hedeb 3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>A.D. 1025</td>
<td>22.08</td>
<td>6.20</td>
<td>&lt; 5.40</td>
<td>10-46</td>
</tr>
<tr>
<td>15</td>
<td>Skuldelev 1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>A.D. 1025</td>
<td>16.1-16.5</td>
<td>4.4-4.8</td>
<td>5</td>
<td>18-36</td>
</tr>
<tr>
<td>16</td>
<td>Skuldelev 5&lt;sup&gt;e&lt;/sup&gt;</td>
<td>A.D. 1030-1040</td>
<td>18</td>
<td>2.57</td>
<td>3.7</td>
<td>12-26</td>
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<tr>
<td>17</td>
<td>Skuldelev 6&lt;sup&gt;e&lt;/sup&gt;</td>
<td>A.D. 1026</td>
<td>ca. 12</td>
<td>2.31-2.5</td>
<td>1.32</td>
<td>5-17</td>
</tr>
<tr>
<td>18</td>
<td>Skuldelev 3&lt;sup&gt;e&lt;/sup&gt;</td>
<td>A.D. ca. 1030</td>
<td>13.5</td>
<td>3.2</td>
<td>ca. 3.50</td>
<td>14-24</td>
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<tr>
<td>19</td>
<td>Skuldelev 2&lt;sup&gt;e&lt;/sup&gt;</td>
<td>A.D. 1042</td>
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<td>4.5</td>
<td>13.3</td>
<td>11-38</td>
</tr>
<tr>
<td>20</td>
<td>Schleswig&lt;sup&gt;f&lt;/sup&gt;</td>
<td>A.D. 1100</td>
<td>--</td>
<td>--</td>
<td>2.73</td>
<td>30</td>
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<tr>
<td>21</td>
<td>Bergen&lt;sup&gt;f&lt;/sup&gt;</td>
<td>A.D. 1188</td>
<td>ca. 30</td>
<td>9-10</td>
<td>12.5</td>
<td>18.75-50</td>
</tr>
</tbody>
</table>

<sup>a</sup>Numbers correspond with those seen in Figure 35. <sup>b</sup>Brøgger et al. (1917). <sup>c</sup>Nicolyasen (1882). <sup>d</sup>Crumlin-Pedersen (1997). <sup>e</sup>Crumlin-Pedersen (1967). <sup>f</sup>Christensen (1985).
rectangular blocks that notched over a few frames and sat directly on the keel. This relatively simple design, although indicating that the sail was being incorporated into a local shipbuilding tradition, was still misunderstood and overtly complex in character. The mast step on the Oseberg ship (Figure 30) is reminiscent of earlier mast components found in the Mediterranean during antiquity, where the focus was on the deck-level mast partner rather than the mast heel (Brøgger et al. 1917:300–302). Clearly Scandinavian shipbuilders in their isolated situation found novel solutions for incorporating the mast into the hull. Most Scandinavian mast steps are made from a compass timber with a naturally grown knee to act as a tabernacle, stanchion, and the forward half of the mast mortise (Nicolyasen 1882:82, plate 2; Brøgger et al. 1917:300–302; Olsen and Crumlin-Pedersen 1967:106,115-116,128-129,142,151; Christensen 1985:178–179; Crumlin-Pedersen 1997:241–242,261). Scalloped recesses and chamfered edging reduce weight, as a solid mast step would be one of the heavier components on the vessel.

Ships with larger dimensions and higher decks utilize a mast partner that is often massive in size. Carpenters responded to the bulky size of mast partners by carving recesses to reduce weight and to streamline it with the rest of the craft. Later versions, such as on the Gokstad ship (Figure 31), indicate large oceanic vessels relied on longer mast steps with larger mast partners to support a taller and wider mast (Nicolyasen 1882:82, plate 2). One important technological feature incorporated into this area was the use of lateral knees for the mast step and the mast partner. Another feature that was found on many succeeding mast steps was to forgo the scalloped recess on the space just aft from the mast mortise. The aft area received direct vertical pressure from the upright mast, which allowed the timber to sit directly on the keel and therefore exerted and spread this stress throughout the rest of the vessel.
By end of the A.D. 11th century, mast steps became streamlined and show indications of rapid change from a long rectangular block to a slender longitudinal timber. Most representations include slim arms extending over numerous frames, while the mast mortise is in an expanded section (Olsen and Crumlin-Pedersen 1967:106,142,151; Crumlin-Pedersen 1997:241,236). Vertical knees, horizontal knees, and the incorporation of *snelles* (the combination of two knees as one piece, usually described as "axe shaped") kept the mast step from moving and transformed this timber into a true keelson. Unusual components, such as the lack of scalloped recesses between frames on Skuldelev 3 (Figure 32) and the Schleswig keelson, or the half-frame knees supporting the Hedeby 3 keelson, should be interpreted as part of the intended purpose for the ship (Olsen and Crumlin-Pedersen 1967:128–129; Crumlin-Pedersen 1997:242,261). All three vessels are described as cargo carriers; their larger scantling dimensions attest to hauling cargo, as well as the need for additional support against vertical pressure from the mast. Many of the later ships in this study, excluding Skuldelev 2, are believed to have utilized a cross-beam to support the mast at deck level rather than a mast partner (Olsen and Crumlin-Pedersen 1967:106,115-116,128-129,142,151; Christensen 1985:178–179; Crumlin-Pedersen 1997:241–242,261). A lack of deck planking near the central area and the lowered deck level would not provide adequate space to support the mast with a traditional mast partner.

Differences in the purposes for ships also are reflected in the mast mortise itself, as commercial ships have deeper sockets due to relying on the sail rather than warships using oar propulsion. Only the Bergen ship provides evidence of a technological revolution, probably in response to increasing maritime trade that required larger ships with wider beams compared to earlier vessels. Rather than rely on compass timbers with naturally grown branches or connecting the keelson to the frame, shipbuilders sought to install additional lateral support in the form of
bitis (cross-beams) (Christensen 1985:178–179). The two cross-beams sitting directly over the
Bergen ship's mast step (Figure 33) act as an extended mast mortise and provide similar depth as
seen on other mast mortises found on earlier cargo traders. These beams also diffused pressure
from the mast into the surrounding frame network instead of the keelson. It is interesting to note
that these two different iterations of the Scandinavian tradition eventually influenced the later
medieval cog by combining components from both mast step complexes (see discussion on
medieval cogs below for examples).

Smaller ships, such as Skuldelev 6, also show similar mast step construction with shorter
arms that do not span multiple frames. Scandinavian boats on the other hand were equipped with
small square or rectangular mast steps that would sit laterally against a frame timber near
amidships (Crumlin-Pedersen 1997:120). Investigations into a Slavic/Wendish shipbuilding
tradition along the southern Baltic indicate small and large vessels alike utilized either a mast
step in a transverse frame or a separate timber lashed to an accompanying frame near amidships
(Indruszewski 1996:118–123). While the outward general appearance of these vessels portrays a
shared clinker construction methodology, the difference for incorporating the mast step into the
vessel shows a close diffusion from Romano-Celtic shipbuilding practices. Differences for
placing the mast into different components in the southern Baltic only reaffirms the original
invention in a longitudinal mast step within Scandinavian ships rather than a complete borrowing
from the Romano-Celtic tradition to utilize the sail.

Mast Steps and Medieval Cogs

Northwest European shipbuilding continued to develop during the rise of Scandinavian
expeditions outside their home territory. Scandinavian shipwrights probably obtained knowledge
of the sailing apparatus from northwestern Europe, improved the design, and brought a new
version of the mast step back west. Examples of this diffusion stem from the traditional medieval cog; archaeologists working 400 m inland along the northwestern coast of Jutland, near Kollerup, uncovered a medieval shipwreck with an unusual building pattern. Rather than a keel as with other Scandinavian vessels, the ship had a keel plank and was flush along the bottom, although after the chine, planks were fastened together in an overlapping fashion (Jeppesen 1979:68). This construction is reminiscent of the earlier Romano-Celtic tradition and is acknowledged as the probable manner for most cog construction (Weski 1999:371). Practically all cog-like ships are built under the Romano-Celtic tradition; variations include the presence of a keel in strictly Scandinavian clinker construction and the later fully flush carvel hull that originated from the Mediterranean. Just as with regional differences in hull construction, the mast steps from the cog typology also vary between ships. Compared to later cog-like examples, the mast mortise on the Kollerup cog is set into a lateral floor timber towards the bow rather than near amidships. As seen with earlier Romano-Celtic mast steps, the Kollerup mast-step frame includes a raised central section with the new feature of having a wide vertical notch on the aft end to allow easier seating of the mast heel (Figure 34).

Over the span of four centuries, shipbuilders refined the medieval cog design. Although regional differences in caulking materials, sealant methodology, and fasteners varied, almost all of these vessels relied on sailing as their primary propulsion. The mast step became an important component that required prominence and consideration by shipwrights during construction. By examining the considerable archaeological examples of cogs and cog-like vessels, several observations can be made. Essentially, the two northern shipbuilding traditions, Romano-Celtic and Scandinavian, blended several traits to produce an early version of a ship typology that could
handle rough seas. The Romano-Celtic building method of a flush bottom hull with overlapping strakes along the sides was widely accepted across northern Europe.

Regional differences existed as to how the mast step was to be incorporated into the hull. For ships built east of Bremen, Germany the traditional keelson, as seen in Skuldelev 2 and the Bergen ship, were simply modified and transferred into this new vessel (Figure 35) (Reinders 1982:19–20, figure 5; Oosting 1987:57–59; Cederlund 1990:215, figure 6; Adams 1995:61, figure 7; Hocker 2000:51; Adams and Rönnby 2002:174–176; Vermeersch and Haneca 2015:11–12). Cogs discovered near Amsterdam in Ijsselmeerpolders (Figure 36) and the surrounding area (excluding A 57 and OZ 43 as their full keelsons and associated artifacts implicate these vessels as originating from the Baltic) indicate a rapid evolution across the 14th century to compete in a larger market (Reinders et al. 1980:11; Luns 1985:13). Shipbuilders from this region must have seen the futility of the mast mortise set into a lateral frame and sought to insert a new timber along the longitudinal axis. This new keelson, seen in NZ 42 and possibly in Q 75, is a massive chock that represents the novelty carpenters were experiencing by adding a new and unfamiliar component to the Dutch cog design (Reinders 1985:19–21). By the end of the 14th century, Dutch shipbuilders began to mimic Baltic cog construction by creating small refined mast steps, as seen in Almere Wijk 13, with short arms, although lateral reinforcement remained absent (Hocker and Vlierman 1996:30–31).

Archaeologists also found several cog examples that do not fit the above narrative. For example, the Kollerup cog from southern Jutland dated to the middle of the 12th century (Bartholin and Englert 2000:48). Even though all other cogs found from this vicinity or origin have traditional Scandinavian keelsons, shipbuilders during this century chose to follow the traditional Romano-Celtic tradition of installing the mast mortise into a lateral frame. The early
date of the vessel and the beginning for cog design diffusion into the Baltic might account for this discrepancy. As for the long square socket from the portside of NZ 43, the only conclusion stems from earlier analyses stating that this cog may have been purpose built for the peat trade (Van de Moortel 1987:223). Peat required flat cargo space and the use of a central mast step diminished the amount that could be carried. Another concern for shipbuilders was the possibility that a central mast step would be damaged by the accumulated weight from improper peat loading. A seal from Kuinre dating to A.D. 1399 depicts a cog-like vessel with a bipod mast emphasizing that this type of mast arrangement did exist at the time and therefore supports the original purpose of the NZ 43 cog.

Based on available evidence of mast step components, it is apparent that the cog was the quintessential combination of both Northern European shipbuilding traditions. Observations by other scholars have deduced similar conclusions when looking at the overall hull construction (Crumlin-Pedersen 2000:241). Mast steps, originally short components toward the central position in the Scandinavian ship, were stretched out to become full longitudinal stringers. Traditions, such as scalloped recesses and chamfered edges between notches for the floor timbers, were passed on to this new ship typology. Rather than attaching the keelson to the keel, cog builders continued the practice of connecting the timber to the frames by using treenails and iron fasteners. As with the Scandinavian examples, the mast step on the Baltic cog was always in an expanded section with a larger width and height than the rest of the keelson. The most important contribution was the addition of lateral buttresses to prevent the mast heel from breaking free from the mast mortise. New additions to this convention were the installation of boards along the sides of the mast step to add greater thickness between the mast mortise and the edge of the timber. Only the Bremen cog includes a mortise for a tabernacle board (Figure 37) to
<table>
<thead>
<tr>
<th>Number</th>
<th>Site</th>
<th>Date Constructed</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Mast Step Typology</th>
<th>Mast Step / Keelson</th>
<th>Mast Mortise</th>
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<tr>
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<tr>
<td>22</td>
<td>Kollerupb</td>
<td>A.D. 1150</td>
<td>20.25</td>
<td>4.5</td>
<td>Frame</td>
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<td>N/A</td>
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<td>23</td>
<td>Koldinge</td>
<td>A.D. 1189</td>
<td>ca. 19</td>
<td>N/A</td>
<td>Keelson</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>24</td>
<td>Kuggmaren f</td>
<td>After A.D. 1186</td>
<td>ca. 18.3</td>
<td>ca. 6.84</td>
<td>Keelson</td>
<td>&lt; 5.23</td>
<td>10.3 - 24</td>
</tr>
<tr>
<td>25</td>
<td>Bossholmeng</td>
<td>A.D. 1250</td>
<td>12.5</td>
<td>3.55</td>
<td>Keelson</td>
<td>1.08</td>
<td>4.7 - 12</td>
</tr>
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<td>26</td>
<td>Flevol. OZ 43f</td>
<td>A.D. 1275-1300</td>
<td>16.4</td>
<td>6</td>
<td>Keelson</td>
<td>9.43</td>
<td>12.5 - 35</td>
</tr>
<tr>
<td>27</td>
<td>NOP A 57 Ruttenf</td>
<td>A.D. 1275-1300</td>
<td>15.9</td>
<td>4.6</td>
<td>Keelson</td>
<td>7.08</td>
<td>12.5 - 35</td>
</tr>
<tr>
<td>28</td>
<td>Flevol. NZ 43h</td>
<td>A.D. ca. 1300</td>
<td>12</td>
<td>4</td>
<td>Chock</td>
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<td>--</td>
</tr>
<tr>
<td>29</td>
<td>NOP Q 75i</td>
<td>A.D. 1300-1325</td>
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<td>Chock</td>
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<tr>
<td>30</td>
<td>Doel 1j</td>
<td>A.D. 1325</td>
<td>ca. 21</td>
<td>ca. 7</td>
<td>Keelson</td>
<td>10</td>
<td>30 - 23</td>
</tr>
<tr>
<td>31</td>
<td>Flevol. N 5k</td>
<td>A.D. 1325-1350</td>
<td>12.5</td>
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<td>Frame</td>
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<td>30 - 23</td>
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<tr>
<td>32</td>
<td>Flevol. OZ 36l</td>
<td>A.D. 1336</td>
<td>ca. 11</td>
<td>4-5</td>
<td>Keelson</td>
<td>9.12</td>
<td>16-38 - 12-24</td>
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<tr>
<td>33</td>
<td>Vejbym</td>
<td>A.D. 1372</td>
<td>16-18</td>
<td>5-6</td>
<td>Keelson</td>
<td>10</td>
<td>30 - 23</td>
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<td>34</td>
<td>Bremen a</td>
<td>A.D. 1380</td>
<td>23.27</td>
<td>7.62</td>
<td>Keelson</td>
<td>14.41</td>
<td>15 - 40</td>
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<tr>
<td>35</td>
<td>Flevol. NZ 42i</td>
<td>A.D. 1350-1400</td>
<td>ca. 12.3</td>
<td>2.8</td>
<td>Chock</td>
<td>2.21</td>
<td>41-62 - N/A</td>
</tr>
<tr>
<td>36</td>
<td>NOP M 107j</td>
<td>A.D. 1375-1400</td>
<td>15.8</td>
<td>4.5</td>
<td>Mast Step</td>
<td>1.8</td>
<td>18-41 - N/A</td>
</tr>
<tr>
<td>37</td>
<td>Almere Wijk 13°</td>
<td>A.D. 1410-25</td>
<td>15.95</td>
<td>3.96-4.20</td>
<td>Mast Step</td>
<td>1.77</td>
<td>34 - 23</td>
</tr>
</tbody>
</table>

guide the mast heel into place (Lahn 1992:plate 19). This novel feature must be considered a result of the increasing size of the cog by this point in time. As seen in Table 5, the cog and cog-like vessels indicate similar scantling dimensions with various differences in mast step designs. All Northern European shipwrecks are mapped in Figure 38 and can be referenced with corresponding tables by site number.

Although the position of the mast step within the hull is discussed elsewhere by several authors in varying amounts of detail, some basic elements are provided (Crumlin-Pedersen 1979:30; Reinders 1985:24). Romano-Celtic shipbuilders kept the mast step approximately one third aft from the bow. Many of the ships from Ijsselmeerpolders follow this procedure, inferring that these smaller cogs relied on a sprit-sail and mainly operated in intertidal waterways. The larger Baltic cogs show a progression of repositioning the mast step incrementally farther aft until reaching approximately a meter forward from the central position on the ship. Since these larger vessels were clearly meant to traverse the dangerous North Sea, their sails followed the more traditional square sail that also grew in dimensions. This expansion in canvas eventually led to the abandonment of the single square sail and the adoption of multiple smaller sails across several masts.

*Sailing and Mast Steps Across Europe*

The introduction of sail propulsion required naval innovation in the form of the mast step. Except for the Romano-Celtic tradition, early mast steps were often fashioned from massive timbers with notches along the underside to lock it into place. Chamfered edging in the Mediterranean was originally intended for compensating half-frames and continued intermittently throughout succeeding centuries. Scandinavian mast steps, in a separate technological modification, also had chamfered edges between notches as a result of the
scalloped recesses to reduce weight. Later Northern European keelsons continued this tradition even when weight was no longer a major factor. Almost all mast mortises contain a hole to remove water that accumulated around the mast heel. When ships were built with deeper holds or multiple decks, as was seen early on in the Mediterranean and later in Northern Europe, tabernacle boards were crafted to guide the mast into place. Both traditions indicate early shipbuilders were more concerned with providing deck-level support, due to the shorter height from the bottom of the ship to the deck. Only after the mast step became commonplace and part of the traditional construction design, was support transferred to the mast heel. Gradual increases in the depth of the hold and the number of decks also prompted changing the support for the mast. Northwestern-European shipbuilding was unique among known mast step construction; this tradition modified an existing structural framework to include the mast mortise rather than devise a new component. This decision had ramifications for later ship design by Dutch shipbuilders when economic demands required larger seaworthy vessels and, subsequently, larger masts that could not be secured with traditional mast step frames.

Since the mast step and keelson share the same central longitudinal axis, it is no surprise that these two components would amalgamate into a single timber. The innate decision by shipbuilders to combine two separate ship components varied between the Mediterranean and Scandinavian traditions. Mediterranean shipbuilders incorporated the mast step and the keelson as separate components. Only after the transition from hull strakes to frames as the primary support structure took effect did these timbers combine into a single unit. Shipbuilding counterparts in Scandinavia already utilized the mast step as a multipurpose component and simply expanded the arms to develop a true keelson. Whereas the Mediterranean keelsons, after the frame-first transition began, were straight with occasional raised inclines near the mast step,
Scandinavian keelsons were narrow and only expanded at the mast mortise. The decision to have a long slender keelson with an expanded area for the mast step had wide ramification for subsequent ship typologies, since this style of keelson became standard for trans-oceanic ship typologies.

By placing the mast step into a heavy lateral frame, Romano-Celtic shipbuilders weakened the structural support to bear immense pressure caused by a vertical mast. Lateral support from the frame and the carving of medial ridges only prevented the mast heel from breaking out of the mortise in this direction. As for the keelson, Mediterranean and Scandinavian shipbuilders preferred different methods to support the mast step. Mediterranean shipyards relied on a system of sister keelsons to keep the keelson/mast step component from moving. Scandinavians on the other hand sought to implement a vertical knee to provide the best lateral resistance.

Shipbuilders also had differences in preference for wood species when building the hull. Mediterranean shipbuilders mainly relied on coniferous trees to supply the wood for internal framing and only in later centuries began using poplar and oak. Northern Europeans in both traditions preferred to use oak when it was readily available for most of the hull construction. Other shipbuilding disparities included fastening the keelson to the frames or keel either with treenails or iron fasteners. Romano-Celtic shipbuilders relied on double-clenching iron nails driven through the outside of the hull into the frames (Marsden 1967:16–17; Fenwick 1972:123; Arnold 1975:123; Vlek 1987:134–137). Scandinavian keelsons are primarily held in place by knees and bites with treenails or iron fasteners driven into the frames from above (Nicolyasen 1882:82, plate 2; Brøgger et al. 1917:300–302; Olsen and Crumlin-Pedersen 1967:106,115-116,128-129,142,151; Crumlin-Pedersen 1997:241–242,261). Mediterranean methods varied,
probably by region as much as over time, since several examples show the keelson fastened with bolts through the frame or between frames to connect it to the keel.

A thorough examination of cog typology emphasizes that the Scandinavian keelson and mast assembly was the preferred system for sail propulsion in Northern Europe. This conclusion is not to say that other versions or the earlier Romano-Celtic examples could not perform similar functions when crossing the English Channel, as the Blackfriars ship and possibly the Graveney boat suggest. Larger cogs were being built in the Baltic, indicating that the Scandinavian keelson was better suited for operations in the North Sea and for longer voyages further from the coast. These features must have resonated with other shipbuilders, as archaeological evidence in the western Mediterranean by the 14th century attests to incorporating several traits from this tradition. By the middle of the 15th century, the principle traits for the trans-oceanic ship were well established. Single square sails were divided onto multiple masts and many Northern shipbuilders began to embrace the more economically viable carvel hull planking. Shipyards along the Atlantic coast were already producing a variety of sailing craft with the cog mast step assembly, although competing shipyards and contemporary exploratory voyages along the African coast eventually developed the proper hull design to implement trans-oceanic travel.
For centuries shipbuilders tried in vain to find ways to reduce the amount of leaking that was inevitable in wooden ships. Regardless of the method used, such as reducing the number of seams or using an abundance of caulking material, the result was a collection of water in the bottom of the vessel's hold. This bilge water was often due to a fault in ship construction and a result of the environment in which the ship operated. The invention of the bilge pump allowed water to be removed in an efficient matter and helped to keep the inside of the hull dry. Previous research by Thomas Oertling (1984, 1996), Marie-Brigitte Carre, and Marie-Pierre Jézégou (1984) have each provided analyses in understanding the development of the bilge pump. Rather than simply describe their research verbatim, this chapter combines the available material into a modern narrative that reveals the understanding of this technology is far from resolved. Archaeological evidence and subsequent publications provide some answers to earlier questions, while at the same time present evidence for new hypotheses. Following the parameters of the previous chapter, the discussion below examines the longue durée of the bilge pump from antiquity until the end of the 16th century.

Compared with other aspects of the ship, the bilge pump was not a component readily included in artistic representations from antiquity. The amount of contemporary written material is also rather limited, with only an occasional reference of the bilge pump but without a description of how this component operated on early vessels. Only a brief mention by Artemidorus of the super freighter built by Hiero II of Syracuse (306-215 B.C.) includes using an Archimedean screw to remove water from the bilge (Casson 1995:176, note 40-41). Whereas Paulinus of Nola claimed that an old man was given the duty of watching the bilge, Lucian described that incompetent men were put in positions of leadership so that the more capable
monitored the hold. Artemidorus also includes in his discussion that the operation of the bilge pump relied on a treadmill system, although neither an Archimedean screw or treadmill system is an efficient device for operations on a rocking ship (Oleson 1984:31,389, 2000:265). Since iconographic examples are unavailable and written sources are scarce, the only option for understanding early bilge pumps lies with archaeological evidence. Figure 39 provides an overview for the locations of all archaeological examples associated with bilge pumps from antiquity.

Archaeological Evidence for Chain Pumps

Bilge pumps are important components because they remove accumulated water within the hold; however this important machinery is consistently overlooked by past writers as the absence of any detailed descriptions has shown. Maritime archaeologists have recreated how the ancient bilge pump operated by documenting numerous shipwrecks with various states of preservation. Evidence suggests that the chain pump dated to at least the beginning of the 3rd century B.C. (Pulak et al. 1987:36). Paternoster chain pumps (Figure 40) rely on a single rope with numerous wooden disks (similar to the rosary prayer beads strung on a string, hence the name) traveling in a continuous circuit through two wooden tubes. As the disks move they lift water from the bilge into a reservoir at deck level. Early paternoster pumps relied on wooden disks strung on a central rope with knots in between to maintain an applicable distance for raising water. Additional guide ropes on either side of the central rope kept the disks inline with the pump apparatus and facilitated disks around the lower guide piece into the subsequent pump tube (Charlin et al. 1978:57; Carre and Jézégou 1984:121; Joncheray and Joncheray 2002:87–90). Since disks relied on a rounded intermediate timber between the pump tubes, an angular shape or bevel on the upper surface for each disk was required. Pump tubes throughout antiquity
were often composed of a tree trunk cut in half lengthwise with a semi-circular cut out also lengthwise through the middle and then reattached together. Paternoster pump equipment was originally attached to upper internal hull structure, such as latitudinal beams, without any form of lower joinery holding the mechanism in place within the bilge (Joncheray 1989:75–78).

Developments in the 1st century B.C. introduced a lower wooden dowel like rod and as a result, the need for a lower pump box (Ucelli 1950:184; Foerster 1979:173, 1980:245; Galli 1996:257–259). Lower rollers removed the unnecessary guide ropes and replaced the intermediate timber between pump tubes. The lower roller assembly allowed disks to easily rotate through the end of the first pump tube and into the second tube. This new lower pump component reduced the need for a deep angular carving on the upper face of the disks, although the bevel did not entirely cease until after pump makers at the beginning of the new millennium traded the dowel rod for a thicker circular cylinder. Due to the nature of the bilge pump operating in salt water conditions, most bearings and bushings were made from bronze with minimal ferrous materials to prevent corrosion (Ucelli 1950:185, figure 200; Foerster 1979:173, 1980:245; Carre and Jézégou 1984:129; Santamaria 1984:50, figure 32; Rule and Monaghan 1993:75, figure 58; Joncheray and Joncheray 2002:87–90). Although researchers do not know entirely the exact mechanism that propelled the disks through the pump tubes, it must have been a toothed wheel strung on a long wooden shaft operated using a crank lever, similar to the archaeological remains recovered from the A.D. 1st century Nemi ships (Ucelli 1950:183, figure 198).

Ships also relied on lead reservoirs to collect bilge water from the hold and discharged the contents through connected pipes, which seems to have been standard, except where wooden hoppers were utilized (Ucelli 1950:185; Tchernia 1969:476–477; Frost et al. 1981:1981; Carre
and Jézégou 1984:140–142; Santamaria 1984:50; Corsi-Sciallano and Liou 1985:60; Pulak et al. 1987:36). By the A.D. 7th century modifications removed the need for ferrous fasteners as part of the lower pump assembly by building this section out of a solid block of wood that was hollowed out (Carre and Jézégou 1984:116–120). Rather than attach the pump tubes with nails, pump builders relied on connecting the pump tube through inserts on the upper section of the lower pump box. Disks were given bronze cotter inserts to negate the need for tying knots to prevent slippage (Bound 1989:331–334; Gibbins and Hurst 1989:68–70; Galli 1996:258, figure 3). Cotters also might have fallen out of favor, as the bronze cotter was replaced with leather material tied into cotter knots. Instead of beveling the edges, later disks had recesses along the side for a leather strip to create a seal inside the pump tube. Recesses were also carved on the upper face of each disk to hold more water during the lift to the reservoir.

Positioning for the bilge pump assembly depends on where the lowest point in the hull is located. Although several ships had the pump near the bow, most low points were found in the aft section near the stern (Liou 1974:423–425). Many bilge pumps have evidence of a pump well surrounding the apparatus. Pump wells were built originally as short wall enclosures (Figure 41) to keep the bilge clear from surrounding cargo or any type of ballast that the ship might be carrying (Joncheray 1989:69–70). Few examples showcase innovations, such as the multipurpose ladder/pump well wall found on the Madrague de Giens shipwreck (Carre and Jézégou 1984:129). Eventually these pump wells were built to create complete box structures that required entry from hatches above. Several examples from the beginning of the new millennium indicate that the pump well grew in dimension and that there was less concern for transverse boards compared to planks connecting the stanchions along the longitudinal axis (Gassend et al. 1984:101–103; Liou et al. 1990:252–258). Stanchions were often square or rectangular and later
shipbuilders chose not to include transverse pump well planking. Later pump wells probably had a ladder lowered from above to gain access to the pump or reach other supplies in the surrounding area. The half-frame assembly provided ample room for shipbuilders to construct bilge pumps. When sister keelsons were installed during the Roman era, shipbuilders carved recesses in these timbers and any neighboring ceiling planking.

Operation of the paternoster pump was facilitated at deck level by the toothed wheel that allowed each disk to rest inside the recess while being guided into the first tube. Evidence from the toothed wheels found at Lake Nemi indicate that the adjacent bronze bearings allowed a crank on either end to operate the device (Ucelli 1950:185, figure 200). Smaller ships operating in calmer areas or, as in the Nemi ships, operated on a closed lake, probably relied on a simple crank mechanism. As for larger ships, Carre and Jézégou use the 4.5 m of clearance between decks on the Madrague Giens shipwreck to suggest that some form of a wooden drum, large enough for someone to walk inside, could be used (Pomey 1982:145–146; Carre and Jézégou 1984:140). Artemidorus' treadmill scenario from the 3rd century B.C. cannot be completely ruled out; nevertheless, the main factor for its operation depended on the size of the ship and depth of the hold (Casson 1995:176, note 41).

Paternoster chain pump technology was also not exclusive to the Mediterranean, as the Romano-Celtic Guernsey shipwreck from the A.D. late-3rd century can attest. Compared with other contemporaneous examples from this region, the Guernsey wreck stands out for its flush hull planking instead of the flush bottom and overlapping strakes along the sides (Rule and Monaghan 1993:13). Although the ship still relies on a plank keel, double clenched nailing pattern, and a mast step-frame, the most unusual component is the double framing pattern towards the aft of the ship that creates a wide gap at the lowest point in the hull. Evidence for
limber holes and the fact that most water would accumulate in this area, along with notches on the forward frame suggested the presence of a bilge pump. Further aft, archaeologists also recovered two almost identical bronze bearings that also show remarkable similarity with bearings recovered from the previous millennium (Rule and Monaghan 1993:75, figure 58). These bearings share similarities with the Chrétienne M and Madrague de Giens examples by combining the fastened wings with the thicker extended body to prevent the component from rotating (Carre and Jézégou 1984:132, figure 13; Joncheray and Joncheray 2002:74). Similar bearing designs indicate these components were part of the assembly that held in place the rod for the lower wooden roller. The facts that investigators believe the ship was probably beached somewhere prior to burning and no other evidence for the pump exists, suggest that the pump was removed prior to ships' destruction (Rule and Monaghan 1993:130).

**Tracking the Paternoster Chain Pump After A.D. 700**

After the A.D. 7th century, information on what happened to the chain pump becomes tentative, as the only physical evidence until the 16th century stems from the A.D. 11th century Serçe Limanı shipwreck. Investigators retrieved the end of a wooden handle that is covered in a spindle shaped iron casing. (Bass and Allan 2004:320, figure 18–10 T43). An iron cap on one end of the handle kept the wood from slipping out. On the opposite end of the iron casing, a nail is driven through the protruding timber. Since the shaft is made from wood rather than iron, archaeologists claim that the handle was probably connected to a wooden disk or arm to be rotated. This postulation suggests that the handle was part of the bilge pump device, due to the size of the ship and that few other pieces of machinery were present on vessels at this time. Other known Mediterranean shipwrecks from the Middle Ages are few in number and those that are show a significant decrease in ship dimensions (Wilson 2011:44). As a result, the depth of hold
was reduced and the bilge pump probably became less practical than bailing on the smaller ships. The Serçe Limanı handle also indicates that the bilge pump did not completely fall out of use. Whether these were paternoster pumps or something entirely different is subject to debate until further examples are discovered.

Earlier chroniclers fail to mention the paternoster pump in their writing, which comes as no surprise that later manuscripts also remain silent. Several authorities suggest the chain pump remained forgotten until it reappeared as a drawing in Book III of *De ingeneis*, written by the Sienese engineer, Mariano di Jacopo detto Taccola around A.D. 1433 (Shapiro 1964:571; Prager and Scaglia 1972:51; Oertling 1984:58). Taccola obtained his information about the device from Bartolommeo Pasquini and described it as a 'Tartar' (Mongol) invention. Unfortunately, no information exists concerning Bartolommeo or how he came across the bilge pump in his travels. One theory, suggests that the reemergence of the chain pump on ships in the latter half of the 16th century was the result of earlier explorers who witnessed a Chinese example and brought back their accounts to Europe (Oertling 1996:56). Simply observing Taccola's drawing disproves the latter notion, as the Asian equivalent required a low angle and an open trough that raised water by pushing it between large flat rectangular boards to a higher elevation. Taccola's chain pump required pump tubes in which he claims, "mushrooms" (these appear to be wooden disks) would rotate over a wheel that was turned at the surface and thus raise the water through a continuous cycle (Prager and Scaglia 1972:77). Reemergence of the paternoster style chain pump implies that while this technology possibly fell out of favor it still survived and became widespread by the end of the 15th century. How this technology survived without vanishing requires a review of archaeological evidence from the previous millennium and to acknowledge the historical changes that occurred in Western Europe at that time.
The remaining vestiges of the Western Roman Empire fell to barbarian invasions at the end of the A.D. 5th century (Sarris 2002:40). At that time many technological innovations were neglected and eventually forgotten due to disuse by local inhabitants. Although Mediterranean ship construction was shifting from mortise and tenon planking to frame-based construction, evidence from the contemporaneous Saint-Gervais 2 paternoster pump signifies no major changes in bilge pump technology. Investigators considered a Merovingian origin for the ship, due to its location in southern France, although the limited number of artifacts recovered indicate an African or eastern Mediterranean source (Jézégou 1985:143, 1998:350). The origins for the Saint-Gervais 2 artifacts suggest that the ship was built by Roman shipbuilders, either as surviving vestiges of the preceding western order or by Byzantine equivalents. Several Byzantine-era shipwrecks from the former Theodosian Harbor on the Sea of Marmara (now known as Yenikapı) share several construction similarities with Saint-Gervais 2, along with an obvious area for a bilge pump assembly. Many Yenikapı examples include floor timbers across the breadth of each ship, except YK 14, 27, 29, 31, and 34, which include a pair of half-frames near either the stern or bow (Kocabaş 2015; Pulak et al. 2015:15-17). Investigators claim that YK 14 and 27 were probably large ships, while the remainder were medium size merchantman. Except for YK 34, which is tentatively dated, based on stratigraphy, to the A.D. 5th century, the remaining ships are thought to be from the A.D. 8th or 9th centuries. The absence of any bilge pump related artifacts would not be uncommon, as most of these wrecks sank in relatively shallow areas that probably facilitated salvage. Along with the Yenikapı examples is the A.D. 11th century Serçe Limanı shipwreck, as described above, due to the numerous amphorae and construction features also indicating Byzantine origin (Bass and Allan 2004:4).
Historical events at the beginning of the A.D. 11th century allowed a brief surge in Byzantine expansion that eventually fell victim to the disastrous result of the Fourth Crusade in A.D. 1204 (Magadalino 2002:180; Reinert 2002:254). After these events there is still uncertainty on the existence of the paternoster chain pump. Another avenue to investigate what happened at this time is the source for Taccola's drawing, the mysterious Bartolommeo Pasquini and his claim for a Tartar derivation. If Pasquini was the eyewitness who actually saw the chain pump in operation, then he must have traversed across the eastern Mediterranean, where he stumbled upon the device. Italian merchant enclaves were an essential economic component in Constantinople, as the rise in demand for luxuries from the East grew throughout Western Europe. The Venetians held paramount control until A.D. 1204, later on the Genoese supported the return of the capitol into Greek hands and began monopolistic control in the Black Sea (Scammell 1981:160). Taccola worked previously on Genoa's harbor and dedicated De ingeneis to Sigismund of Luxemburg, who was embroiled in a prolonged conflict against Venice at this time and therefore it is likely that Pasquini was a Genoese citizen (Prager and Scaglia 1972:39; Fine 1987:490–491; O'Connell 2009:30–31).

If Pasquini traveled east in the first quarter of the 15th century, only the thriving Genoese colony in Crimea would have afforded him direct connection with Mongol innovations (Scammell 1981:185). At the same time, internal strife within the Byzantine domain allowed territorial encroachment from all directions and Genoa was not alone in claiming numerous islands across the Aegean for itself. Any local shipbuilding tradition in this region may have afforded the outlet in which Pasquini first witnessed the chain pump in operation. Scholars also suggest that the Byzantine mining industry across Greece and Anatolia continued to rely on Roman technology in comparison with the shallower mines being dug across western Europe,
which provides another outlet that the chain pump might have been at work (Vryonis 1962:17). Only after the device was featured in *De ingeneis* and subsequently copied by contemporaneous plagiarists, did it find suitable application in the German mining sphere. Eventually, the chain pump was reinstalled in late-16th century warships, due in part to the rise in maritime commerce, deeper holds, and the additional manpower available to operate the machinery. Rather than utilize the earlier rope and wooden disk system, these later pumps relied on chains or 'S' shaped metal components connected together with leather or wooden burrs to operate, hence the 'chain' in the chain pump terminology (Oertling 1996:59).

**Cultural and Technological Decisions for Chain Pumps in Antiquity**

Introduction of the bilge pump allowed larger ships to operate on a much wider scale across the Mediterranean. Although the paternoster pump was efficient at removing bilge water, the output still required an excessive amount of manual labor to rotate the upper disk for the rope to circulate. As many historians who study antiquity can attest, the investment in technological development did not coincide with reduced labor costs. Instead, increasing the commodity while keeping the necessities of required manual labor in *status quo* prevented social upheaval (Green 1990:469). This cultural dynamic kept manual labor cheap and allowed additional crewmen to operate the bilge pump only when required. After the new millennium, the preference for Mediterranean ships to rely on lateen sails required additional crew (Campbell 1995:19). As a result, the available manpower to operate the chain pump allowed this pump technology to continue well after the 11th century.

Force pumps were also at use at the same time as paternoster chain pumps. Four bronze force pumps were recovered from the A.D. mid-1st century Dramont D shipwreck. None of the pumps were found along the central axis or in the stern where the lowest point of the hold would
accumulate bilge water. Since additional parts for operation were not found on board, it is believed that these pumps were part of the cargo rather than for pumping out the bilge (Rouanet 1974:65). Furthermore, each pump has a 1.5 cm square water inlet positioned on the side rather than the bottom, which would leave a minimum of 1.55 cm of standing water in the hold (Rouanet 1974:51, plate 2). Force pumps require a piston to be driven through a tube, creating suction when the piston rises, which also opens a lower valve to let water into the cavity. Once the piston is on its downward stroke, the water would flow through a side valve. Most force pumps include two or more pistons interchangeably pumping water into a central reservoir that would then be forced through a narrow tube and expelled under pressure from a nozzle to fight fires or simply raised to a higher level, such as the examples found at the bottom of ancient wells (Stein 2004:224–226). Early force pumps do not work well on a ship. Although the force pump provides adequate suction for moving water, it is not air tight. True suction pumps were not invented until the 15th century (Shapiro 1964:571). This lack of a proper seal meant that the force pump had to be fully submerged in the water, otherwise air could enter above the piston and the pump would not provide an efficient stroke (Stein 2004:242–243). Most force pumps, whether predominantly made from bronze or wood, include multiple materials (wood, iron, and leather) that would survive better submerged rather than being intermittently wet. These important points made the force pump less than ideal for operation on a ship, and allowed the paternoster pump to remain prominent throughout this period rather than being replaced by another pump typology.

Finding the Burr Pump in Northern Europe

The reduced amount of maritime traffic after the 11th century, evident from historical testimonial and archaeological evidence, has already been described as a probable reason why
shipbuilders began to omit the bilge pump throughout the following centuries. Although evidence suggests the paternoster chain pump was known in the Romano-Celtic shipbuilding tradition, most ships built after the new millennium and until the late Middle Ages shared a similar reduced size as seen in the Mediterranean. Scandinavian vessels, with their long narrow design and a single deck, relied on bailing rather than trying to implement a bilge pump system. Archaeological evidence suggests a bilge pump did appear on the late-medieval cog by the beginning of the 14th century. Several examples, such as Figure 42, demonstrate absent floor timbers in the framing pattern, indicating the location for missing bilge pumps (Crumlin-Pedersen 1979:32, figure 2.13; Bonde and Jensen 1995:105, figure 2; Hocker and Vlierman 1996:29, illustration 2; Vermeersch and Haneca 2015:18).

Further evidence is also seen with the absence of frames 9 and 34 on the Bremen cog (Figure 43), as only half-frames are present in these areas (Lahn 1992:plate 8,11). Along with the half-frames, investigators uncovered two separate draining components, a draining board and a draining box, that would discharge water outside the hull. The presence inside an opposite portside cabin for the draining box is described as part of the bilge pump assembly that was not installed prior to the wrecking event (Lahn 1992:162–163). There is ample information in the reconstructions to indicate that the portside draining box is not part of the bilge pump assembly, especially since the windlass drum sits directly over the central axis at the lowest point in the hull. The half-frames directly below this position, along with the space made between a transverse board and cross-beam, strongly suggest a bilge pump would be installed in this area (Lahn 1992:plate 9). Shipbuilders were intent on this construction, as there is a square hole below the deck on the starboard side for an absent cross-beam dale. As for the half-frame assembly near the bow, there is unfortunately no further evidence to support a bilge pump
installed in this area. Since the Bremen cog was lost prior to the installation of this important equipment, knowledge on the type of the bilge pump in operation at the time is still unclear. Only prior knowledge of the force pump throughout continental Europe predisposed modification for an appropriate use on northern ships.

Oertling cites the monumental work *De re metallica* by Georg Agricola, originally published in 1556, as providing an accurate description of what is now known as the burr pump (Agricola 1950:176–178; Oertling 1996:16–17). The pump was composed of two parts (Figure 44) with the first being a long tree trunk having a straight hole drilled through the center. Each pump tube was connected to a foot valve that was carved to fit inside the lower end of the upper tube. Foot valves had holes or recesses cut on the bottom half for water intake, while the upper section included a metallic or leather claque valve to control the flow of water through the pump. The claque valve worked in tandem with a wooden spear, which included a leather cone fastened on the lower end. When the pump operator lifted the spear, the leather cone expanded to match the pump tube diameter and lifted the water upward exiting through a spout near the top. This lift also created some suction allowing the lower foot valve to open to permit more water into the tube. On the downward stroke, the leather cone collapsed around the spear and the process would repeat. Agricola also mentioned that a wooden or metal disk with five or six holes would operate far better than relying on the leather cone (Agricola 1950:177). These disks were either screwed onto the lower end of the spear or held in place using a cotter pin. Burr disks operated under the same principle as the leather cone; the disks were sealed with a separate leather piece that covered the holes during the upward stroke and allowed water through during downward movement. Pump operators either relied on a cross-bar attached on the top of the spear or a lever positioned on a separate fulcrum to operate the pump.
Discovery of a mid-15th century shipwreck in 2002 along the River Usk in Newport, Wales provides archaeologists with the earliest physical remains for the burr pump to date (Nayling and Jones 2014b:24–25). Four pump sumps (see Chapter 4 for further discussion about these locations) were located along the central axis of the ship. Assembly for the lower section of the bilge pump was retrieved from the stern pump sump (Figure 45). Poor preservation eventually led to the lower elm pump tube breaking into three pieces. Reconstruction indicates only 84.06 cm in height is left from this component with an outer diameter 25.12 cm near the bottom and increasing to 26.87 cm (Nayling and Jones 2014a:2). Internal tool marks from the central bore indicate that two different boring bits with different diameters were drilled through the center, as the bottom is 15.86 cm compared with the upper section at 11.48 cm. Ferrous staining near the base suggests that an iron band was once present to prevent the pump tube from splitting. Along with the pump tube, investigators also recovered several fragments from the foot valve, the male section was originally found still inside the lower pump tube.

The extent of the fragments indicate the foot valve is 30.5 cm tall and has a slightly smaller diameter than the pump tube, although investigators suggest this might be due to damage or erosion (Nayling and Jones 2014a:4). There is evidence for a single horizontal bore through the side of the lower fragment, several centimeters off the bottom. When the male end from the foot valve was recovered from inside the pump tube, archaeologists also recovered a 10.3 cm diameter leather disk and two fragments from a semi-hemispherical wooden valve weight. Three rows of holes throughout the leather disk indicate where nails fastened this piece onto the flat underside of the valve weight. There is no evidence for fastener holes on the side of the neck on the foot valve, although there are fastener holes on the 5.3 cm wide tongue of the leather disk and additional evidence for iron staining around the foot valve neck (Nayling and Jones 2014a:4–5).
Several fragments from the upper burr valve were also found with this lower pump assembly. Evidence suggests that this burr valve was composed of several leather panels made from calfskin around 2 mm thick and were stitched together to create two cones; one wrapped around the other and attached at the end of a wooden spear (Nayling and Jones 2014a:7–8). Leather strap fragments indicate that these were stitched to the top of the inside lip on the outer cone and then nailed slightly above onto the wooden spear. Impressions on the straps also show that a thick thread or cord was wrapped around the nails. The leather straps were probably supportive during the opening of the valve on the upward stroke from the wooden spear. Two panels that comprised the inner cone were stitched together and were then further stitched to the inside bottom end of the outer cone. Several leather panels were also used for creating the outer cone, along with a thin leather bead strip along the seams to protect these areas from abrasion. Only the outer cone was fastened with iron nails to the bottom of the wooden spear (Nayling and Jones 2014a:6).

Separated from any other pump assembly was another burr valve (Figure 46) located toward the front of the ship. As with the stern burr valve, two leather cones were attached to an approximately 66.6 cm by 4 cm fragment of the lower wooden spear. The outer sleeve, 21 cm by 14 cm and over 2 mm thick was fastened to the lower end of the spear with two tiers of iron nails. Impressions on the leather indicated a cord was once wrapped around four times over the higher tier of nails. The inner sleeve, measuring 16.7 cm long and twice (4.86 mm) as thick as the outer sleeve, was attached to the wooden spear only by the second tier of nails (Nayling and Jones 2014a:6–7). There is some damage to the inner sleeve, as a large slash is cut almost through the entire component that investigators believe was from an attempt to remove debris fouling the valve. Two leather beads were also found, providing protection for the seams against
friction incurred by the inner walls of the pump tube. Leather straps attached on the upper lip of the outer sleeve were nailed on the opposite end higher up along the wooden spear. Six other leather panels were also recovered, each having some conical shape suggesting other pieces for additional burr valves.

Other components uncovered on the Newport wreck include several hemispherical wooden valve weights, including one found near the starboard pump sump at amidships. This valve weight is 10 cm in diameter and 3 cm thick, found broken into two separate pieces. On the bottom flat surface are seven small fastener holes, along with two additional nail holes along the side of the smaller broken piece. Investigators believe that this location is where the hinge was attached (Nayling and Jones 2014a:4). Another valve weight was located in the vicinity further outward. This valve weight, possibly made from elm, is 11.4 cm in diameter. There is a 7 cm long and 3.8 cm deep bevel along one side. Along the flat underside is a leather disk attached using a single nail in the center and additional nails employed outward and along the edge. Rather than cut the leather disk to include a tongue, a second rectangular piece of leather (7 cm wide and 4 mm thick) is also attached underneath the leather disk. The other half of this leather tongue and a corresponding section from the leather disk are torn away at the section where the bevel was on the valve weight. Another valve weight 12.2 cm in diameter and 4.5 cm thick was found near the edge of the remaining portside further aft from midship (Nayling and Jones 2014a:5). No evidence of fastener holes suggests that this valve weight may have been a spare part. After the hull was systemically removed from site, another valve weight 6.9 cm in diameter was uncovered that appears to have been crudely made with only a single nail hole on the bottom flat face and two nails on a beveled edge for a missing hinge. There is evidence of charring, but this damage must not have been an issue as marks from later operation appear over this area.
The presence of blue-gray clay on site, which filled many of the cavities, including the pump sumps, provided an anaerobic environment from which many organic remains were preserved (Nayling and Jones 2014b:10). This environment allowed wicker basketry at the bottom of two pump sumps to be found in situ. These strum boxes provide an additional filter to keep out debris from the intake holes toward the bottom of the foot valve. One complete willow strum box (Figure 47), approximately 20-25 cm in diameter and 20-22 cm deep, was found in the starboard pump sump cut just aft from the mainmast mortise (Nayling and Jones 2014a:13). Fragmentary remains for a second strum box made from alder and willow were found in the area around the stern pump sump. Fortunately, enough fragments remained for investigators to conclude that the aft strum box was probably square or rectangular in shape. There were also fragments for a third strum box in the aft area, possibly made from a Prunus species or wild cherry with a different weaving pattern compared to the other strum boxes. Investigators also found a 62 cm long by 4 cm in diameter timber that is attributed as the pump handle for the burr valve found isolated toward the bow (Nayling and Jones 2014a:45). Two nails are still embedded in one end of the handle, while there are approximately nine other fastener holes present. Bilge pumps on the Newport shipwreck operated under the same principles written by Agricola a century later, which included a foot valve working in tandem with a spear or plunger to raise water. Only the presence of the strum boxes and wooden valve weights for the lower claque valve were unknown components not observed on later examples.

An important discovery located along the southeastern coast of Sweden near Kalmar Castle, also provides evidence supporting an established burr pump tradition in northern Europe. The gradual accumulation of silt into the surrounding harbor prompted local officials during the 1930s to clear the area by dredging. Operations eventually uncovered approximately 20 different
ships and boats in varying degrees of preservation. While working in the vicinity of a rampart built for the castle in the 1570s, investigators uncovered most of the lower section of a ship that was constructed originally around the turn of the 16th century (Åkerlund 1951:79). Several timbers uncovered suggest a bilge pump system was located near the stern of the ship. Cross-beams were located throughout the hull with carving on the ends indicating these were originally exposed outside the ship. Near the aft end, one of these cross-beams was modified by having a 5 cm square trough cut through the central upper face (Åkerlund 1951:74). The channel became a circular bore that allowed personnel to discharge contents outside the ship. Along with this cross-beam dale, investigators recovered a burnt oak pump tube that was originally positioned directly behind the aft end of the keelson. This area also produced a clump of coarse cloth surrounding an object with a non-through hole in the center. Inside the hole is a round bar 4 cm in diameter, which investigators deduced as part of a gasket that was tied to the lower end of the missing piston (Åkerlund 1951:74).

Evidence from the 9 cm diameter central bore for the pump tube indicates a controlled burning and drilling process. Most of the original tree that made the pump tube is left intact, except for the sapwood and a slight inward angle around the base. As ships grew in size, shipbuilders by the 13th century began to install dales for the bilge water to be poured into and gradually emptied over the side (Åkerlund 1951:76). When it came time to reconstruct the bilge pump assembly on Find V, investigators reconstructed this component as a unique force pump (Figure 48) (Åkerlund 1951:176, plate 16). Based on the fragment of lower pump tube and the gasket component, it was assumed that the tube was connected to a lower pump box with a claque valve on the bottom. When the piston was pushed down in the pump tube, water was
forced through a separate pump tube next to the first, which eventually discharged the water into the cross-beam dale.

Investigators believed that the ship only had partial decks at the bow and stern. Partial decks insinuate that an abundant amount of water was always present in the hold and the reconstructed pump would require an ample amount of water to operate. The Find V reconstruction centers the lower pump valve box on short legs raising it slightly above the hull, which would also require a substantial amount of water to collect in the hold to operate the pump. Turning the pump box so it ran parallel with the keel would reduce the distance from the lower claque valve and the bottom of the hold, but the ship would still retain several centimeters of water. Rather than a force pump, all of the evidence described strongly indicates Find V was installed with a burr pump.

Several 16th-century examples indicate that the burr pump was still in use even after the true suction pump became more widespread. Investigators working on an early-16th century shipwreck on the Molasses Reef in the Turks and Caicos Islands, British West Indies uncovered a lead disk that was probably once attached to a wooden piston (Oertling 1989c:585). The disk (Figure 49) is 12.5 cm in diameter with seven small holes along the outside and a single large hole in the center. Although the lead disk is 1 cm-1.5 cm thick, the 4.8 cm height is attributed to the tall collar surrounding the central hole. Two smaller holes pierce the central collar on either side, indicating the position for a cotter pin. Another identical disk was retrieved by treasure hunters who visited the site prior to the archaeological investigation. This additional disk suggests that the ship had two burr pumps on board, though whether these two pumps were both in use or one was a spare cannot be determined.
Contemporaneous with the Molasses Reef wreck, archaeologists uncovered a similar shipwreck off Poole Harbour in England. Investigators recovered the ship's lower foot valve, along with a leather claque valve (Thomsen 2000:77). The lower foot valve is made of walnut, carved into a circular form 20 cm in diameter with a 7.3 cm central bore. The flapper is made out of seven or eight pieces of leather, 10 cm in diameter and stitched together. Underneath the foot valve is a curved notch directly through the middle to allow the movement of bilge water. Another such foot valve (Figure 50) was also found on the Red Bay, Labrador vessel 24M, believed to be the 1565 galleon San Juan (Waddell 1985:243). This foot valve, made from birch, is carved into a stepped cylinder with an 11 cm diameter neck for the 12 cm bore from the upper pump tube to slide over the top. The central bore between the pump tube and foot valve is 6.5 cm in diameter. Along the side of the foot valve neck is a recess carved to accommodate the tail from a leather flapper. Several fastener holes are still visible inside the recess, indicating where the flapper was held in place. Craftsmen also carved four semicircular notches along the underside of the foot valve to allow the flow of bilge water into the pump (Waddell 1985:243–244).

The claque flapper is composed of six layers of leather 10 cm in diameter. Two layers have tails to attach the flapper on the neck of the foot valve. Investigators also uncovered a single piece to a separate leather flapper with the same diameter, although the length of the tail and fastening pattern is different. Along with the foot valve, archaeologists recovered a 2.39 m long section of associated pump tube (Waddell 1985:246–249). Analysis of the pump tube indicated it is made from beech and is almost 26 cm square with beveled edges, except for the foot, which has angular straight edges for the tube to fit properly between floor timbers. Evidence for a metal reinforcing band is found near the heel of the tube, probably to prevent splintering or
fragmentation. Inside the pump tube, investigators were able to recover two sections of the plunger that were once scarphed and fastened together. On the bottom end of the lower section are 21 leather disks perforated in the center by the actual wooden spear. The first 11 disks are the same diameter as the pump tube, while the remainder varies in diameter decreasing toward the tip. Combined, these disks are 8 cm thick and are kept from sliding off the plunger by an iron pin driven through the spear 2.5 cm above the end. Along with the pin, craftsmen also carved a recess to wrap with string or twine to keep the pin and disks in place, as well as preventing the plunger from splitting. Rather than utilize the leather cone or perforated disk as Agricola had described, the pump builders for the San Juan decided to utilize a number of disks that guided water past this section on the down stroke and sealed the pump tube upon the return.

Appearance of the Common Pump (A True Suction Pump)

Although the burr pump was an adequate device for raising water, it did not provide complete suction. Not until the beginning of the 15th century does evidence appear for an efficient suction pump that relied on barometric pressure rather than simply submerged movement by a piston. The earliest example for such a device was drawn around 1433 by Mariano Taccola (Shapiro 1964:571, figure 4; Prager and Scaglia 1972:44, figure 15). Although Taccola did not include a description or label the components for this suction pump, there are clear differences from the earlier burr pump. Instead of the leather cone or disk, this suction pump relies on a valve piston attached to a compound crank at the top of the pump tube. Later examples were also found in Francesco di Giorgio Martini’s Tratato di Architectura, which was originally written around 1475 and indicate gradual advancement in suction pump technology (Reti and Martini 1963:290). Martini’s suction pump designs always include two valves located within the pump tube. The lower valve is located near the intake, often in a similar position as
the foot valve would be for the burr pump. Lower valves are stationary, compared to the higher valve, which is often connected to different mechanisms from above that facilitated moving the valve through the water column within the tube. All of these pumps required water to be poured above the upper valve to create a seal cutting air off from the compartment below. Once the pump operator began to move the piston, air was removed and created suction for water to enter the chamber through the lower valve.

True suction pumps are governed by barometric pressure, meaning that for every foot that the water column rises, it must equate to an inch of mercury expressed as barometric pressure (Oertling 1996:23). Most late-15th-century suction pumps indicate only a few meters distance between valves, when theoretically it is possible to increase this distance to around 9 m. This observation is interpreted as an imperfect understanding of this new pump design. Available evidence suggests that the suction pump was invented originally in Italy, although no contemporaneous physical evidence for this device has been found in the region (Shapiro 1964:574). Suction pumps were embraced eventually by German mining enterprises at the beginning of the 16th century and became standard equipment for most operations after 1550. Scholarly understanding for early suction pump typology is based on the original eyewitness accounts, such as Agricola, who visited the mines and described their operation (Agricola 1950:vi–vii). The true suction pump became so widespread that by the end of the century it simply became known as the 'common' pump by succeeding generations. Original operators saw the early common pumps as inadequate and continued to rely on the burr pump until technological adaptation allowed the common pump to become the preferred choice. For example, issues with the foot valve on the burr pump made removing the entire pump from the
hold inadvisable during turbulent weather. Servicing the common pump was easier, as lowering a pole with a hook could pull up the valves for inspection (Oertling 1996:21).

One of the first archaeological examples for the common pump does not originate from a mining operation but from the English warship, Mary Rose. Originally built in 1510, the Mary Rose sank at the beginning of a naval engagement with the French outside Portsmouth on 19 July 1545 (Marsden 2003:2,18). Subsequent salvage in the second quarter of the 19th century included removing the main bilge pump, which was at sold at auction. Fortunately, archaeologists at the end of the following century found a spare pump tube (Figure 51) on the Orlop deck (Marsden 2009:289–290). The spare tube is 8.22 m long and 32.6 cm in diameter, with a 15.3 cm central bore. Along the bottom is an 8.7 cm tall lip and evidence that an iron band was in place to prevent the tube from splitting. Similar to notches found on the bottom of contemporaneous foot valves, this pump tube has several notches dividing the foot into quarters. Each notch is 4.2 cm tall and 3.8-6.6 cm wide, which facilitated water through the lower valve while preventing larger debris from fouling the pump (Marsden 2009:289).

An interesting addition to this pump was the presence of an inspection hatch located approximately two-thirds from the bottom. Both hatch components are made from oak; while the inner cover is 82.8 cm, the longer outer cover is 1.074 m. The inner cover is carved to be part of the central bore and encompassed entirely on the outside by the second, longer and wider, cover. Horsehair caulking was recovered between the two covers and fourteen fastener holes provide evidence for iron nails that were once driven between covers. There is also a rebate to allow the outer cover to be removed when maintenance was required. Archaeologists also recovered three leather disks for the pump valves, including one found inside the pump tube. All of the disks are made from three pieces of leather originally cut into a figure '8' and folded over to make six
layers (Marsden 2009:290–292). The top leather disk is folded over a tail to fasten the entire component to the pump. Each flapper is stitched together in a spiral pattern beginning in the middle and moving outward. Diameters for each disk vary, as the one found inside the pump tube is 11.2 cm, while the other two found elsewhere in the ship are 12.8 cm and 17 cm respectfully. Most contemporaneous flappers are layers of leather stitched together. The *Mary Rose*'s smaller leather disks share this same standard, while the largest disk includes pieces of wool between each layer. Several cross-beam dales were also found in situ; the midship dale, which crossed the breadth of the ship for the main pump, is located beneath the weather deck.

Investigators are not explicit as to whether or not the spare tube is a burr or common pump. Evidence strongly suggests the latter, as the notches along the bottom for water intake and the presence of the lower valve inside the tube correspond with earlier diagrams. Along with the inspection hatch described above, another rectangular hatch is located near the foot to provide access to the lower valve. Although these two hatches are not seen in earlier designs, the amount of effort to maintain an air tight seal suggests a common pump typology. Furthermore, none of the leather disks have a central hole to be strung on a piston, as seen on the *San Juan*, or for covering an upper valve disk as on the Molasses Reef wreck. These disks are ideal as valve covers, and the number recovered suggests several valves were present. Common pumps on the *Mary Rose* are not out of place, as this thesis has shown, the date of construction and sinking were contemporaneous with the adoption of this technology throughout Europe.

*Understanding the Bilge Pump Through History*

Toward the beginning of the 3rd century B.C. or perhaps earlier, there was a general change in the size and number of ships sailing across the Mediterranean. As dimensions grew, so did the depth of the hold, requiring an innovative device for removing accumulated water.
Shipbuilders chose to incorporate a novel pumping system that seems to have gone unnoticed by writers in antiquity. Early paternoster chain pumps relied on wooden disks strung on a central rope rotating between two wooden tubes lifting water from the bilge rather than creating any form of suction. Guide ropes allowed the disks to pass over a wooden intermediate piece that was later phased out to accommodate an actual roller. Based on available archaeological evidence, it appears the paternoster pump technology was never replaced and pump makers simply altered components from the original design. For example, pump makers replaced ferrous fasteners with bronze bushings and combined the lower pump assembly into a single carved timber to ease removal and servicing (Carre and Jézégou 1984:116–118).

Bilge pumps in antiquity were often placed near the stern, at the lowest point in the hull, although several ships had the paternoster pump assembly at the bow. Shipbuilders must have seen the need to protect the bilge pump assembly from shifting cargo, as the pump well appears at approximately the same time as the pump itself (Joncheray 1989:69–70). Originally, these pump wells were simply used to prevent debris from fouling the pump, however over time, the pump wells were built to cut off this area from the surrounding cargo hold. Only after the new millennium was there a general modification in pump well design, which involved increasing the size of the pump well area and included only longitudinal walls to protect the pump. Shipbuilders were also concerned with the pump location, as almost all archaeological finds show the pump positioned between the half-frame assemblies. When sister keelsons appeared, these timbers were modified to accommodate the already established pump tradition.

Besides evidence for a possible crank shaft from the 11th-century Serçe Limanı shipwreck, recent analysis from Yenikapi suggests that the paternoster pump typology continued in the eastern Mediterranean even after it fell out of use throughout Western Europe. Once Italian
republics began to grow based on maritime commerce through the Near East and in the Black Sea region, this technology was rediscovered and brought back to Italy. Adoption in European mining industries saw the paternoster chain pump spread throughout Europe and eventually reappear on late-16th-century warships due to larger ships being built and their growing crew sizes (Oertling 1996:58).

The force pump was known throughout northern continental Europe under Roman occupation, but the decline in maritime commerce that corresponded with much of the Middle Ages, reduced the size of ships and limited the need for bilge pumps. As a result, investigators, until recently, were unaware of the available evidence in the archaeological record for bilge pumps in late-medieval cogs. As seen in the previous chapter, the cog was in use continually through a number of subsequent centuries. Only at the beginning of the 13th century was there an intentional modification in the framing pattern by removing a floor timber for half-frames or purposely shifting the framing pattern to provide space for bilge pump assemblies (Vermeersch and Haneca 2015:18).

Bilge pumps in Northern European ships were not an introduction from an outside source, but an intended consequence from creating a ship typology with flat bottoms and high sides that also increased the depth of the hold. Cogs had angular deck planking, meaning that ocean spray drained into the hold and created a lower center of gravity rather than spilling through scuppers back into the surrounding ocean (Gardiner 1994:41). The hold required constant bailing, which necessitated the need for novel technology to remove water from inside the ship. Most ships were purposely built with limber holes to allow bilge water to move freely, while also guiding water to the lowest section in the hull where a bilge pump was located. Bilge water was free to collect either directly behind the stem or in front of the sternpost on 14th-
15th-century cogs. Other evidence includes the square hole cut into the side of the Bremen cog toward the stern, this placement would be ideal for installing a dale directly in front of the half-frames where the bilge pump would be located.

There are additional observations concerning bilge pumps on cogs and similar vessels. None of the ships described here include evidence that pump wells were constructed in the areas where the supposed bilge pumps are located. This absence does not explicitly exclude bilge pumps from the construction, rather it may highlight a difference in ballast or cargoes that would not directly interfere with bilge pump operations. Except for the early-15th century Almere cog, all ships with evidence of bilge pumps were built east of the Rhine (Hocker and Vlierman 1996:75). The mast step analysis for the Almere cog, emphasized that cog construction already blended features and traits by this point in time.

Although slightly later chronologically, evidence from the Newport shipwreck indicates that the bilge pump was present in shipbuilding by the mid-15th century and that this pump technology had become complex enough to signify a well-established tradition. Preservation from the local clay deposits along the banks of the River Usk also revealed important components, such as the strum boxes and valve weights that had not been recorded on other burr pump examples. Since the common pump did not spread into northern Europe until the end of the 15th century, it is possible that the burr pump was installed in northern cogs at least by the beginning of the 13th century. This observation further insinuates that pump technology was already widespread and must have been in operation earlier than scholars have predicted previously.

When investigators found Find V near Kalmar Castle, it was clear that several components were part of the bilge pump assembly. As concluded earlier, Find V further supports
that the burr pump was already in use throughout Northern Europe. Available evidence from much earlier Scandinavian cargo carriers includes the installation of cross-beam dales to work in tandem with traditional bailing. Based on the later cog and Find V examples, these examples seem to support a continual development until the burr pump technology was incorporated.

Examples from 16th-century Iberian ship construction indicate that the burr pump by this point was widely known. Although archaeologists cannot differentiate whether a ship carried a burr or common pump typology based on the pump sump alone, most Iberian pump evidence includes foot valves or other assemblies associated only with burr pumps. This evidence suggests that the burr pump tradition was well established in the Iberian Peninsula and shipwrights did not adopt the common pump as readily as their English neighbors. Preferences in ballast must have shifted to a reliance on stone rather than sand (Ansorge et al. 2011:163) or a less hard material by the 16th century, as evidence for pump wells are present on most shipwrecks from this period (see Chapter 4 for further discussion on pump wells). As seen on several northern shipwrecks, vessels might have had two bilge pumps located on either end of the ship. Find V provides evidence for only a single pump located in the stern. Other 16th-century examples indicate a dramatic shift in pump locations. Investigations on the Mary Rose reveal that there was once a second pump in the aft near the stern, along with evidence for the main bilge pump at midship (Marsden 2009:289). Presence of cross-beam dales at both positions also supports the idea that the ship once held two pumps. Evidence for two pumps infers that English shipbuilders were still constructing ships based on earlier techniques when it came to installing dales and pumps. In fact, evidence from the earlier English warships Grace Dieu (1418) and Regent (1498) indicate that two bilge pumps was relatively consistent in Northern European shipbuilding or at least on
larger vessels (Howard 1979:25). Once the common pump became widespread, it eventually superseded the burr pump for ship operations.

Many 16th-century shipwrecks also provide a consistent position for the bilge pump near the mainmast step. Often this pump sump was cut into the expanded keelson to allow the pump to sit on a portion of the keel to support the weight of the assembly and the water column. Previous investigations assumed this positioning was a crudely done modification and as an afterthought due to the paradoxical nature of cutting into the expanded keelson (Waddell 1985:257). The need to have the pump situated so its weight rests on the keel rather than the garboard are reasonable, but the position for the pump and the crude manner it was installed is testament of the earlier Northern European shipbuilding tradition. All cog examples discussed in this research and Find V indicate that the pump was situated along the central axis on keel-planks or on the true keel; either in front or directly behind the keelson. By the 15th century, with a blending between Northern European and Mediterranean traditions, the keelson was extended to cover the entire central axis. This keelson extension became an issue between important framing installation and bilge pump configurations, along with the fact that the lowest point in the hold shifted from the stern and/or bow to near amidships due to the gradual curvature in the hull that developed at this time. As a result, shipbuilders who before installed bilge pump assemblies in other areas had to abruptly change the position and sacrifice the expanded portion of the mainmast step in the process. After the burr pump was phased out and the common or chain pump became standard, modifications in later 16th-century ship construction allowed the incorporation of the new bilge pump position into the trans-oceanic shipbuilding tradition without sacrificing internal strength within the hold.
Shipwrights clearly understood that the environment in which their wooden vessels operated ultimately produced leaks and accumulated water in the hold. Early civilizations in the Mediterranean often relied on bailing by hand. Once economies grew and larger ships were built to accommodate more mercantile traffic, a need for new technology to discharge bilge water was required. Once the bilge pump became part of the standard shipbuilding traditions within the Mediterranean and Northern Europe, ships could survive longer and sail further while maintaining dry holds. The development of an oceanic shipbuilding tradition along the Atlantic coast included the installation of bilge pumps within new ship designs. These new ships required moving the bilge pump locations and modifying other internal frames to accommodate these devices. As shown in the next chapter, ships built throughout the 16th century reveal shipwrights embraced the new bilge pump location, and allow archaeologists to categorize these pump sumps as a signature trait for oceanic ship construction.
SHIP TYPOLOGIES AND CONTEMPORARY CASE STUDIES

Ships were often purpose built, usually for inter-trade between European regions. Even after Europeans sailed into the Atlantic, ship typologies remained consistent, as contemporary chroniclers never deviated in their descriptions of the types of oceanic ships from the late-15th century until the end of the 16th century. In addition, archaeological examples indicate ship construction remained similar across Atlantic shipyards. Yet, alterations did occur, as will be highlighted below. As a result, the "idiosyncrasies" located on Emanuel Point II become readily understandable in their context of 16th-century shipbuilding.

Ship Typologies (1400-1600)

Exploration near the African coast and across the Atlantic required the Iberian powers to develop ships that could tackle such ventures. During the 14th century, ships from northern Europe followed the longboat tradition inherited from Scandinavia and remnants from the Celtic-Romano tradition. In contrast, Mediterranean ships inherited building methods from Roman antiquity, with sleek thin vessels for ramming or large cargo transports. Many southern European ships relied on large oars on either side of the stern quarter, whereas northern Europeans invented the stern rudder (Mott 1991:83–84,111). By combining naval technology from across Europe, new ships were able to travel in high seas and undertake voyages further afield.

Beginning in the 15th century, Portuguese explorers relied on barcas and barinels. These small vessels operated with one or two masts with square sails, although oar propulsion remained the predominant form of propulsion due to strong coastal currents. Shipwrights built barcas frame first, relying on the frame to provide the bulk of support rather than the hull. Early barcas varied between 25 and 70 tons and slowly progressed to larger tonnages throughout the 15th and 16th centuries (Gardiner 1994:92; Unger 1980:212). Barinels were similar to the barcas, except
their construction was shell first, meaning, barinels relied on the strength of the actual hull rather than internal frames. Barinels also grew in size, starting around 60 to 90 tons, and by the middle of the 15th century reached between 110 and 180 tons (Gardiner 1994:92).

Most scholars agree that by the 1440s barcas and barinels were being phased out in favor of the caravel (Duffy 1955:49; Unger 1980:212; Smith 1992:19; Gardiner 1994:93). Caravels appear in texts as far back as the 13th century when authors describe these vessels as small fishing boats. What made caravels superior to previous vessels was the quintessential combination of Mediterranean and northern European naval technology (Gay and Ciano 1996:75–76). Caravels inherited southern Europe’s frame first construction, along with the carvel flush hull planking (Figure 52). Masts were predominantly rigged with the Mediterranean lateen or triangular sail (Campbell 1995:1–2). Compared to the standard square sail, the lateen sail allowed caravels to tack closer to the wind and rely on lighter gusts for momentum. Northern Europe’s preference for slimmer vessels, a high slender bow, the single stern rudder, and a square tuck stern allowed for greater maneuverability compared to previous ship designs.

By the middle of the 15th century, caravels grew to over 50 tons, which allowed for a longer (20-30 m) and 4-5 m wider vessel (Unger 1980:212). These ships were described as having low stern-castles and an absent forecastle. Many caravels were given categorical typology as caravela latina, caravela redonda, or caravela de armada. This typology is based on size and sail configurations to differentiate between vessels. Caravela latina were longer and shallower draft vessels than similar Mediterranean round ships (Custer-Bojakowski 2011:22). Portuguese explorers, after reaching the Guinea coast, found it difficult to use lateen sails for the return trip to Lisbon. Shortening of the foremast allowed for sailors to exchange lateen sails for square ones (Gay and Ciano 1996:81–82). Although the square sail required less manpower, Portuguese
explorers often continued to use full lateen rigs because of their traditionally larger crews (Unger 1980:214–215). *Caravela redondas* increased in size to allow four masts, both the fore- and main masts carried square sails. These ships became more frequent after the 1480s, as longer voyages along the African coast increased (Gardiner 1994:93). Throughout the 16th century, the invention of the *caravela de armada* incorporated, on average, fifteen artillery pieces per vessel (Gardiner 1994:93). These ships increased in size between 140 and 170 tons and had a length-to-beam ratio of 2.9:1. Sailing configuration included two square sails on a raking fore mast while the remaining masts remained in a lateen sail configuration (Gardiner 1994:93).

One disadvantage of caravels was the sacrificing of cargo space in favor of maneuverability. Portuguese and Spanish explorers had to rely on support vessels to carry the supplies needed as they sailed further away from safe harbors (Unger 1980:214). Freight vessels were often carracks (also known as *naos* or *naus*), one of the largest ship types from the 15th and 16th centuries. Although the origin of the carrack denotes a large freight galley of the 13th century, the vessel evolved from a combination of the Mediterranean round ship and the northern European cog (Unger 1980:216; Gay and Ciano 1996:63; Castro 2005:3). Carracks were built frame first with *carvel* hull planking and a length-to-beam ratio between 3:1 and 3.5:1. A higher triangular forecastle, compared with a relatively high sterncastle, provided strong evidence of its cog ancestry. In the 15th century, carracks contained one to three full decks with a tonnage greater than 400 (Gardiner 1994:82). These freight carriers included a swept up fore-post, heavy frames, a flat middle hull, sternpost rudder, and a flat wing transom.

Many carracks utilized a square rig configuration with the fore- and mainmast carrying two square sails to the mizzen and bonaventure masts carrying a lateen sail (Unger 1980:228). Divisions between merchant ship and warship did not develop until the late-16th century.
Carracks, because of their heavy frames and wide inward curvature of the hull, or tumblehome, were often installed with heavy artillery (Gay and Ciano 1996:64). This weaponry allowed the ship to operate on longer voyages and to protect it from potential dangers. These heavily armed ships could then be utilized in both commercial and military expeditions (Gardiner 1994:103). Carracks utilized by explorers were usually less than 100 tons. Only the Portuguese-built carracks (Figure 53) exceeded 500 toneladas (or 1,000 ton displacement). Spanish and Portuguese officials during the 16th century attempted to reduce the size of these vessels to save capital and to reduce losses from pirates or major storms that had become frequent with larger ships (Castro 2005:56–58).

Larger vessels required small tenders to disembark cargo and personnel. Fustas and chalupas were either carried as ship boats or were large enough to operate along coastal waterways and on open sea voyages. Both vessels had similar qualities, as each included one mast (chalupas occasionally having two) and six to eight oars per side (Smith 1992:26). Chalupas were predominantly bigger than fustas and had a closed deck as opposed to the smaller open decked fustas.

Spain and Portugal’s connections with the Low Countries and Hanseatic League in the 16th century introduced the use of urcas (hulks) to transport supplies and bulk goods. Originally a 9th-century small river craft in northern Europe, these early hulks had no keels and relied predominantly on a broad center plank for ease in amphibious landing (Unger 1980:58). Northern shipwrights later incorporated Mediterranean ship technology into a new urca as a large rounded flat-bottomed supply ship. Late medieval urcas were clinker or carvel-built with larger tumblehomes than carracks (Konstam 2008:8; Adams 2013:109). Upper hull structure included a quarter sterncastle and higher forecastle than carracks. Similar to the medieval cog,
urcas had a square sail on the main mast, but also utilized lateen sails on the fore- and mizzenmasts. Although some urcas also had topsails and spritsails for additional speed and maneuverability, their broad hull shape emphasized slow cargo transport. Urcas embargoed for the 1588 Spanish Armada (most from northern Europe) had tonnages varying between 100 and 700 toneles macho (Casado Soto 1988:384).

Naval warfare in the 15th and 16th centuries modified traditional boarding actions to heavy artillery duels. Although carracks remained a reliable warship, their lack of maneuverability required a new vessel. Originally built at the Venetian Arsenal, galleons (Figure 54) were adopted by the Iberian powers in the early 16th century. The term galeón originates from the Venetian word gallioni, used in the 15th century to describe the traditional Mediterranean galley (Gardiner 1994:98). Galleons were constructed frame first with flush hull planking and a high stern castle divided into a half-deck, quarter deck, and poop deck (Unger 1980:256). Compared to the carrack and caravel, the galleon had a low set-back forecastle. Other components included the beak-head below the bowsprit and a square stern (Gardiner 1994:104). Most galleons were constructed with heavier beams, which allowed for two to three decks that contained one or two tiers of artillery. These vessels usually had a length-to-beam ratio of 4:1; with a much narrower tumblehome compared to other full-rigged ships (Unger 1980:256). Early galleons were smaller than most merchantmen with an average tonnage of 350, but increased to 700 by the end of the 16th century.

Philip II in 1593 attempted to control the Manila trade with New Spain by restricting only two galleons, rated less than 300 tons, to travel the circuit (Schurz 1939:193). The legislation on the number and size of the Manila galleons were largely ignored and galleons reached in excess of 1,000 tons by 1614. Galleons quickly replaced the carrack for dangerous voyages because of
their greater maneuverability and larger gun capacity. Spanish galleons escorting the annual Atlantic fleets were usually 500 tons. After four round trips, crown officials often sold these vessels to operate further in a mercantile capacity. By the end of the 16th century, the galleon became the forerunner for the ship-of-the-line, with only minor modifications until the late-18th century (Unger 1980:265).

Spanish colonization missions in the last quarter of the 16th century also began to utilize the fragata as an important fleet component. Fragatas were originally the smallest of Mediterranean galleys, comprising a long undecked longboat with six to twelve pairs of oars (Smith 1992:26). These ships relied mainly on oar propulsion, but were also equipped with two masts in lateen sail configurations that provided additional maneuverability. Galley design included a beak at the bow that contained artillery and an iron ram to smash into enemy hulls. Besides the oars in the central section, galleys also had raised sterncastles to allow a higher platform for navigation and steerage using a stern rudder. Contemporary naval author, Diego Garcia de Palacio, claims that the New World fragata, ideally, did not exceed 50 toneladas (Palacio 1986:116). Most fragatas were used for inter-coastal reconnaissance, relying on larger vessels to tow them in open sea voyages.

Combining northern European and the Mediterranean naval technology allowed ships to sail farther into unknown regions. Portuguese and Spanish explorers took advantage of their geographical position to sail around the Cape of Good Hope and across the Atlantic. These initiatives eventually led to Spanish hegemony dominating the Americas, while colonization efforts relied upon the growing maritime power. As a result, ship typology designs in the 14th and 15th centuries grew exponentially in size and shape. New demands for vessels that could travel longer distances and advances in naval warfare required shipwrights to build ships with
novel classifications. By the end of the 16th century, other European powers were encroaching on Spanish territory in the New World. Competing powers mimicked the naval innovations from their Iberian brethren to compete with, and to surpass, their success in subsequent decades.

*Archaeological Case Studies (1450-1600)*

Ship typology provides one clue to the identity for shipwrecks found in the archaeological record. Scholars have also examined the historical iconography to understand how these ships appeared above the waterline (Custer-Bojakowski 2011). These attempts have not provided an adequate understanding of the lower hull remains. Most archaeological analyses create theoretical models to rebuild the hull, while extrapolating available iconography to suggest a possible typology based on superstructure. The ships discussed here represent the known archaeological case studies available.

**Ria de Aveiro A and Newport**

Portuguese archaeologists working in the Aveiro Ria in 1994, along the west coast of Portugal, revealed the partial remains of a mid-15th century ship along the intertidal zone of the Mira channel (Alves et al. 1998:317). The hull fragment is approximately 10.4 m long and 2.5 m wide, which composes the lower half of the stern and terminates slightly forward of amidships. Several keelson fragments were also found, including a section, 13 cm sided by 12.5 cm molded (Alves et al. 1998:336). Along the underside of the keelson is the characteristic notches, 11.5 cm to 15 cm wide for seating over the floor timbers. Three mortises, 50 cm by 4 cm and sloping to 2.5 cm deep are located along the upper face, which investigators suggest were for stanchions holding upper deck structure.

Another keelson fragment was uncovered, intact, near the stern that retained a scarf on one end. Both keelson sections include iron fasteners that connect the keelson to the floor
timbers near the stern with a single nail long enough to pierce the keel. Two iron bolts (2.5 cm in
diameter) were also found, originally located on either side of the keel scarf. Further excavation
inside the hull revealed the rear keelson, 1.15 m long, and with similar dimensions (12.5 cm wide
and 11.5 cm high) to earlier examples (Alves et al. 1998:338). Preservation amidships was far
worse, as the expanded keelson section did not survive. The presence of three floor timbers with
tooth-like protrusions (Figure 55) for lateral buttressing in this area indicates that the mast step
was 30-32 cm wide and at least 71 cm long. Investigators believe the Ria de Aveiro A shipwreck
was built under Iberian-Atlantic shipbuilding principles. The floor timbers with built in
buttressing for the mast step are thought to be the master frame and subsequent pre-designed
frames from the original construction (Alves et al. 1998:331–333).

Another important example, the Newport shipwreck, was uncovered in 2002 during
construction along the River Usk in Wales. Dendrochronological analysis, along with several
numismatic finds, indicate that the ship operated in the middle of the 15th century (Nayling and
Jones 2014b:3; Nayling and Susperregi 2014:10–12). Compared against the Ria de Aveiro A
remains, most of the lower section from the Newport shipwreck (22.5 m in length by 7.65 m
wide) remains intact, except for damage that occurred during the modern construction project,
which originally discovered it. After removing overburden, investigators uncovered the 9.87 m
keelson (Figure 56) along the central axis with the mainmast step located near amidships
(Nayling and Jones 2014:12, figures 12,18). The first keelson segment is 1.95 m long and 20 cm
sided, increasing to around 76 cm in width at the 3.1 m long mast step. Tapering aft from the
mainmast mortise, the last segment (4.7 m long), reduced the width to 18 cm. Molded
dimensions begin at 15 cm and rise to nearly 38 cm at the mast mortise and decreases (13 cm)
again in the aft sections. Along the underside are notches to situate the keelson for direct contact
with the top of accompanying floor timbers, but there is an absence of notches directly aft from the rear keelson scarf. This absence is understandable, because there is a 60 cm by 5 cm mortise for an upper deck stanchion on the top face directly in front of the keelson scarf that required additional support underneath. Beveling along the underside between floor timbers is apparent only in the expanded keelson area. Two oak treenails in a staggered pattern connect each floor timber to the keelson with occasional iron fasteners present. Only the mast mortise (96 cm by 43 cm and 23 cm deep) is found on the upper face of the mainmast step, directly aft is a 31-32 cm diameter pump sump, 56 cm deep, and cut into the starboard side of the mast step.

Since the pump components have already been discussed in Chapter 3, the concern here is the positioning of the pumps and associated artifacts. Evidence reveals four pump sumps throughout the ship, including one at either end and two at amidships (Nayling and Jones 2014b:18). Near the bow, two floor timbers were chiseled away to accommodate the foot valve and lower pump tube. At amidships, evidence for two pump sumps was found on either side of the mast step, although only the starboard pump sump was in operation. The portside pump was not in use because carpenters covered the portside pump sump with ceiling planking and installed one of the pump well stanchions in this area. Several fragments from the lower pump assembly were uncovered in the stern pump sump, indicating that this pump sump was also in operation in tandem with the starboard midship pump sump. Besides providing the earliest physical example for burr pumps on ships, the Newport shipwreck also provides an extensive example of experimentation by shipbuilders in positioning the bilge pump due to the presence of four pump sumps.

Compared with other contemporary examples, the Newport ship was built under the Scandinavian tradition. Although the ship is broader than earlier lapstrake vessels, its underlying
shape necessitated the bilge pump to be located directly on or adjacent to the keel. Historical precedence, as discussed in Chapter 3, indicates that Northern European bilge pumps installed at the bow and stern were not uncommon. Nevertheless, the bow pump position must have been inadequate, and thus required installation in the central area of the hull because the forward position inhibited the collection of water, compared with the central location in the hold. Investigators believe that the portside pump was installed first because it was later covered with ceiling planking (Nayling and Jones 2014b:18). Further evidence to support this observation can be gleaned from the location of the portside pump sump, which allowed the foot valve to rest directly on the strakes rather than the keel. Placing the bilge pump on the strakes focused the stress in a single area and retained more water in the hold compared to the starboard pump sump location. By repositioning the pump onto the keel, carpenters were required to cut a deep notch into the starboard side of the keelson. The new position allowed the stress from the bilge pump to spread out in a greater area and was also more efficient at bilge water removal.

Lateral support for the mast step is evident by the presence of 10 pairs of buttresses fastened to floor timbers on either side of the mainmast step. Just as with the keelson, oak treenails, along with iron spike-nails, connect these components together. Buttresses vary from 40 cm to 78.4 cm in length, with averages 58.3 cm by 20.1 cm and 16.6 cm high on the inboard end, reducing in height outward (Nayling and Jones 2014b:20). Shipbuilders also carved rabbets on the buttresses' upper faces to fit bilge boards between; keeping the bilge clear from any outside debris. Outboard ends for each buttress are set into notches along the first stringers on either side of the hull. Stringers varied considerably in dimension, with the longest at 12.9 m and
the thicknesses range between 4.8 cm to 9.7 cm. These components also vary in width (25.2-37.7 cm), indicating that stringers and buttresses were variably fashioned depending on location within the hull.

The Ria de Aveiro A and Newport shipwrecks are prominent examples for 15th-century development in shipbuilding practices. These wrecks are clearly transitional vestiges of the long independent shipbuilding traditions that began to incorporate different spheres of influence. Original investigators believe the Ria de Aveiro A shares similar construction methodology with later Iberian-Atlantic ships found throughout the 16th century (Alves et al. 1998:320). There are clear indicators that its original builders held onto the Mediterranean tradition, based on the preference for floor timbers with buttress protrusions, the triangular recesses to fasten the frames to the keel, and the assembling of pre-designed frames. Evidence from the keelson, although fragmentary, also shows a preference for slimmer dimensions. Examples from the 14th-century Contarina I and Culip VI discussed in Chapter 2 provide earlier transitions for these traits.

The Newport ship's lapstrake hull is a clear testament to a Scandinavian shipbuilding tradition; however, dendrochronological evidence advocates that the vessel was built originally in the Basque country of northeastern Spain (Nayling and Susperregi 2014:11–12). Most constructional features are straightforward, such as the presence of foot wales, buttresses for supporting the keelson, and an expanded keelson for the mainmast. The number of pump sumps and the abundant number of buttresses suggest that Basque shipbuilders were still experimenting in the application of internal hull components. In fact, the massive mast mortise highlights the enormous size ships in the latter half of the 15th century grew from their earlier counterparts, although this might also be a result of the ship relying on a single mast since no other mast components were found. Pump wells, absent from most of the archaeological record except in
antiquity, make their reappearance on ships based on a fragment from a vertical stanchion near the midship pump sump (Nayling and Jones 2014b:18). The trial and error within the Newport ships’ internal hull design emphasizes a transitional phase, which required carpenters to experiment until standardization took root throughout Atlantic Europe.

**Cais do Sodré**

Scholars attempting to understand the trans-oceanic shipbuilding tradition often cite the Cais do Sodré as an example of oceanic ship typology (Oertling 2001:233–234). Originally found during construction of an underground station near downtown Lisbon, Portugal in 1996, archaeologists were called onto the scene only after construction equipment had already disarticulated most of the central hull frames (Castro et al. 2011:328). Archaeologists recovered four fragments from the keelson, varying between 1 m and 5 m in length. Except for a single fragment that matches the fastening pattern in the area damaged from construction, the other keelson sections were found in situ and all pieces recovered are almost square (27 cm by 26 cm) throughout. Two keelson segments found near the stern are connected together with a horizontal hooked scarf and this same feature is also evident on one end of the central keelson fragment. All keelson pieces have notches underneath to sit snugly on the frames and have approximately 3 cm diameter bolts spaced throughout. Each bolt was driven through the keel and associated floor timbers into the longitudinal keelson (Castro et al. 2011:335–336). Several mortises along the top face, including the lower portion of a stanchion found in situ, indicate that the ship was completely decked. Investigators were unable to find the mainmast step, although a single 1.3 m long buttress was found sitting unfastened on a floor timber toward the stern (Castro et al. 2011:332,340).
While contemporaneous buttresses are carved into triangular wedges or knees, the Cais do Sodré example, as seen in Figure 57, is relatively square (20 cm wide by 18 cm). The location of the buttresses allows it to fit against the first stringer and the absent section of keelson (or mainmast step) in this area. Both the buttress and floor timber underneath include a notch 5 cm deep and 25 cm wide on their aft faces (Castro et al. 2011:340). Similar notching is also seen on the starboard side on the same floor timber. Directly behind the portside notch is a ceiling plank, also with similar notching, that provided a rectangular hole 25 cm by 20 cm. Investigators postulate that the holes were locations for absent bilge pumps (Castro et al. 2011:340). Radiocarbon dating from outer hull planking and floor timbers dates the wreck to the mid-15th to early-16th centuries.

Evidence from the Cais do Sodré wreck has been used by previous authors to attribute this ship as part of the Iberian-Atlantic shipbuilding tradition (Oertling 2001, 2004). This designation is understandable when examining the framing pattern, *carvel* flush hull planking, pre-designed frame features, and the rising of the floor timber toward the bow (Castro et al. 2011:342). When examining the keelson and available mast step assembly, there are obvious attributes, such as the consistently square keelson, that point towards the Mediterranean tradition. This observation is further collaborated by the presence of the possible buttress, as the length, combined with the absent starboard twin, indicates that no expanded keelson was present on this vessel.

The presence of two pump sumps does not automatically insinuate Northern European influence on design, because the bilge pump was already widely known. Positioning is unusual compared with the Newport wreck, as a pump in these locations would cause undesired stress on the strakes rather than the keel. Archaeological evidence from contemporary Mediterranean
vessels Villafranche (*Lomellina*) and Mortella III reveal differences in how the bilge pump was designed in southern Europe (Guérout 2002; de la Roche 2010:46–53). Instead of seating foot valves to rest on the keel or outer hull planking, Mediterranean shipwrights devised the foot valves with extended upper arms that allowed the mechanism to rest on accompanying floor timbers. Pressure from the pump assembly is then distributed into the surrounding frames rather than causing unnecessary stress on the outer hull. According to these Mediterranean examples, the methodology of a separate foot was utilized whether the ship operated with burr (Villafranche) or common (Mortella III) pump typologies. Referring back to the Cais do Sodré shipwreck, the positioning of the pump sumps is congruent with Mediterranean design.

Framing patterns and pre-designed frames also cannot be assigned as an Iberian traditional invention, as this shipbuilding methodology was common throughout the Mediterranean tradition (Castro et al. 2011:333). Pre-designed frames are recorded from earlier vessels, such as the 11th-century Serçe Limam wreck, although the true origin for pre-constructing frames is attributed to the transition from mortise and tenon to skeletal ship construction (Bass and Allan 2004:160).

**Cattewater**

Several other 16th-century shipwrecks have also been identified, including the Cattewater wreck, which was originally located in 1973 during dredging operations at the mouth of the River Plym along the southern coast of Britain. Investigators uncovered the central hull with most artifacts and construction features indicating the first quarter of the 16th century (Redknap 1984:39). Initial examination included the retrieval of several disarticulated frames, two wrought iron guns, and the 4.6 m long keelson/mast step assembly (Figure 58). Both ends of the keelson received damage either from marine organisms or because of earlier dredging on the site.
Investigators observe that the first 70 cm of the keelson is 30 cm sided and 27 cm molded. Evidence from the broken section on the other side of the mast mortise indicates that this portion is similar in dimension. The 1.5 m long mast step expands to 54 cm and includes two rising inclines; the first climbs to 33 cm and then 40 cm around the main mortise. Dredging damage unfortunately prevents an accurate length for the mast mortise, although archaeologists were able to obtain the sided (33 cm) and depth (15 cm) measurements. Estimates place the original mortise at around 76 cm in length and suggest the mast was at least 84 cm in diameter. Shipbuilders carved an elliptical hole 30-34 cm wide through the timber at the level of the first incline; this hole narrows downward and is interpreted as the pump sump. At the beginning of the second incline, between the pump sump and the mast mortise, is a shallow mortise 12.5 cm by 8.7 cm that was probably for an absent deck stanchion. As seen on other keelons, the Cattewater example includes 14 notches underneath and beveling across the bottom faces. Carpenters who installed the bilge pump must have also altered the frames in this area, as the notching pattern conflicts with the elliptical hole. Three iron bolts were also found along the entire length of the keelson, all of them being driven from the underside situated only along one side of the timber.

Investigators do not mention any indentation or fragments that could be attributed to the buttress complex. The absence of buttresses has led to detailed hull reconstructions that suggest an absence of any lateral support for the mast step or adjacent lower hull stringers (Redknap 1984:99, figure 54). Other components from the hull, along with supporting artifacts, suggest an Iberian origin for the ship, but the absence of important lateral mast step assembly could be attributed to the poor preservation environment in which the hull was located or the damage the ship attained from dredging rather than any purposeful absence for these features. The length and
width of the mast step mortise alone provides enough contextual evidence to insist that a lateral support structure was in place, otherwise the mast tenon would have easily broken out of the surrounding timber. No surviving floor timbers or other hull elements that would have been located around the expanded keelson have survived.

**Highborne Cay**

Excavations in 1986 off the coast of Highborne Cay in the Bahamas provided possibly the earliest cohesive example for trans-oceanic mainmast step and bilge pump assemblies. Investigators date the remains to the beginning of the 16th century, based on the wrought-iron artillery and its associated materials, along with a few pieces from earthenware bowls (Smith et al. 1985:64–69). Salvage attempts on the wreck exposed the bow and stern timbers. Dislocated sections were also found in the surrounding vicinity. Fortunately, the ballast mound protected most of the ships' bottom, allowing archaeologists to reveal the mainmast step assembly and associated pumps sumps at midship (Figure 59). Based on available evidence, archaeologists recorded a 8.15 m keelson segment, including the 1.95 m long expanded area (believed to have been 2.25 m overall) for the mainmast step (Oertling 1989b:247). Areas forward and aft of the expanded keelson indicate that the timber varied between 16 cm and 21 cm sided, although it maintained 17 cm molded throughout. As for the mainmast step, this area increases in sided (40 cm) and molded (25 cm) dimensions. In the center of the expanded keelson is the mast mortise, which is approximately 65 cm by 17 cm and 15 cm deep. Investigators also found a chock (30 cm by 15 cm) inside this mortise toward the forward end (Oertling 1989b:247).

Behind the mainmast step, two semicircular notches are cut into the keelson along the portside. Each notch is 27 cm in diameter and an associated shallow mortise on the top face of the keelson is believed to be the location for a pump well stanchion (Oertling 1989b:249,
1996:18). No other evidence for an actual pump assembly was uncovered, thus it is unclear whether two pumps were in operation or that shipbuilders adjusted the position of a single pump. The latter may hold true, as the aft pump sump is cut deeper than the forward example, which if cutting continued, would have threatened the integrity of the mainmast mortise. Shipbuilders carved notches along the underside to allow the keelson to rest over each frame. Four bolts driven inward from the outside were uncovered along the central axis; three passed through floor timbers while the fourth, toward the bow, is between frames. Three pairs of buttresses resting on floor timbers were uncovered on either side of the mast; these are triangular in shape, measuring 64.6 cm in length on average (Oertling 1989b:246). Buttresses on their inboard ends are 13.5 cm sided and 21.9 cm molded, shrinking down at the foot wale to 11.8 cm by 16 cm respectfully. None of the buttresses have evidence for fasteners, indicating that they were held in place by being wedged between the face of the mast step and accompanying notches made into the first stringers. Recesses on the top faces between buttresses indicate that bilge boards were once present to keep out debris.

**Rye Vessel A and Studland Bay**

Along with the intact examples found at Cais do Sodré, Cattewater, and Highborne Cay, two other wrecks (Rye A and Studland Bay) are also representative of this early period. Drainage work at Rye, Britain, in 1963 revealed fragments from two ships that were buried beneath a layer of clay (Lovegrove 1964:115). Neither ship was fully revealed, as only fragments that were in the way of construction were removed and analyzed. Based on these examples, comparisons were made with the mainmast step fragment recovered from Rye A and the Cattewater wreck, attributing the former as either late-15th- or early-16th-century construction (Redknap 1984:95).
Enough similar archaeological examples shown in this chapter could actually place the Rye A mast step anywhere from 1475 to 1550.

Keelson fragments recovered from Rye Vessel A indicate this timber is at least 5.49 m long and 39.37 cm wide on either side of the mainmast step (Lovegrove 1964:116–117). The molded dimension appears to be 30.48 cm, except at the expanded keelson, which rises to 45.72 cm in height. The 1.45 m long mast step also expands to 52.07 cm sided and includes the mast mortise (58.42 cm by 25.4 cm and 17.78 cm deep) located closer to one side (probably toward the bow) than the other. Most other mast mortises have straight walls, but the Rye A example includes a slight angle, that narrows the mortise by 2.54 cm in length. On the opposite face from this angled wall is a 22.86 cm long drainage hole 6.35 cm wide drilled near the bottom of the mortise. Evidence for two treenails were found in the mainmast step fragment, the first is in the bottom of the mast mortise, while other is situated after the keelson reduces in dimensions.

Shipbuilders chose to cut deep bevels along the underside of the timber, indicating a reduction in width from 52.07 cm to 19.05, and 15.24 cm at the mainmast step. Two indentations 18.42 cm by 20.32 cm are present on either side of the expanded keelson above the notches, indicating the presence of buttressing. Aft from the mainmast step is a 6.35 cm square mortise approximately 5 cm deep. This mortise may have been for a pump well stanchion, as the half-circle notch 29.21 cm in diameter for the bilge pump is cut out of the keelson behind the mortise (Lovegrove 1964:117, figure 1).

The keelson and probable mainmast step unfortunately were not preserved from the 21 m long by 7 m Studland Bay wreck, originally discovered by divers in 1984 near Dorset, England (Hutchinson 1991:171). Based on the hull construction and artifacts recovered, investigators dated the ship to the first quarter of the 16th century. This wreck has been informative regarding
the bilge pump apparatus in use at this time, as discussed in Chapter 3. Although important timbers for the current analysis are missing, available evidence still provides some essential information on positioning and fastening patterns for these crucial components. Investigators recovered a heavy mast-partner, which includes two semi-circular notches on either side for the mainmast and bilge pump assembly. According to these measurements, the mast was approximately 42 cm in diameter, while the pump tube for the bilge pump was 30-40 cm in diameter and 12 cm off-center to port (Thomsen 2000:77–78). The notch for the pump tube is also conical in shape, allowing easier removal for maintenance. Four keel bolts and similar holes along the longitudinal axis indicate that the missing keelson was connected to the frames and keel in this manner.

**Mary Rose**

Out of all the ships described here, only the *Mary Rose* was known to have been built outside the Iberian Peninsula. Constructed from 1510 to 1511, the warship was a favorite of the Tudor monarch, Henry VIII, until her sinking in 1545 outside Portsmouth, Britain (Marsden 2003:2,10). The *Mary Rose* is also unique to this study by providing an exact ship typology; the well-known English carrack. Most of the starboard side from the ship was buried and preserved until investigators rediscovered it and raised the hull during the 1980s, although salvage work conducted after the sinking and during the 19th century removed several important components (Marsden 2003:28). Along the central axis is a 20.85 m long keelson (Figure 60) made from three large oak timbers horizontally scarfed together (Marsden 2009:83). Clenched iron bolts connect the keelson with the keel through floor timbers. Measurements from the 8.44 m long forward timber indicates an almost square dimension (25 cm sided by 24 cm molded) that increases to 37.5 cm by 39 cm at the first scarf. Connected to the forward timber is the midship
timber, which is 9.85 m long and 40 cm wide by 45 cm high, increasing further just before the expansion for the mainmast step. Finally, the aft timber is 4.26 m long and tapers from 30 cm square down to 24 cm by 21 cm at the end where it terminates prior to the deadwood. Carpenters beveled the underside of the keelson and cut notches to allow the timber to sit comfortably over consecutive frames. Toward the forward end of the midship timber is an expanded keelson for the mainmast step, which is 2.68 m long and 82.5 cm wide by 59.5 cm tall (Marsden 2009:84).

Shipbuilders positioned the mast mortise (70 cm by 35 cm, and 13 cm deep) near the front end, which includes two drainage holes 5 cm in diameter on the bottom floor near each aft corner. Three mortises, one directly behind the mast mortise and two others further aft along the central axis of the keelson were for holding deck stanchions. After the next consecutive frame behind the mast mortise on the portside is a slight bevel 39 cm in diameter for the main bilge pump. Archaeologists working in this area found the in situ remains for the pump well (84 cm by 102 cm), constructed out of softwoods 28-41 cm wide and 2.6 cm thick. Slightly aft and near the starboard side of the mast step is a 14 cm square mortise for a pump well stanchion. Three buttresses lay on either side of the mainmast step, the starboard group is 50-55 cm long and 15-25 cm sided by 32.5 cm molded on their inboard ends. Portside buttresses are 37.5-42.5 cm in length, 17.5 cm wide, and also 32.5 cm molded near the expanded keelson. Each buttress is triangular in shape; their molded dimensions decrease until they connected with corresponding notches on the foot wales. Rather than cut rabbets into the tops of the buttresses for bilge boards, shipbuilders chose to cut short planks 35-56 cm by 30.7-34.5 cm to act as limber boards (Marsden 2009:94). Two holes are drilled into them, probably for inserting a rope handle for easy removal, as investigators found evidence for fragmentary rope fibers. English shipbuilders
also chose to position rider timbers laterally over the keelson, providing additional hull strength and further preventing the keelson from moving.

**27M**

Survey work by Parks Canada at the beginning of the 1980s revealed three Basque ships at Red Bay, Labrador. Subsequent excavations provided archaeologists with probable dates for a number of the vessels, however, 27M, due to the limited artifacts and burned condition of the ship, has thus far only been dated to the second half of the 16th century (Bernier and Grenier 2007:295,303). Investigators conducted test excavations in 1983, revealing the bow, stern, and midship sections. These excavations indicate 27M has a 13.09 m long keelson that is 37 cm sided by 30 cm molded at the 1.2 m long expanded mainmast step (Ringer 2007:205; Stevens and Waddell 2007:210). Notches along the bottom half of the keelson allow the timber to rest above the floor timbers. Along either side of the mainmast step are three triangular buttresses 43 cm long by 22 cm wide and 17 cm tall on average.

Shipbuilders crafted the buttresses with recess cuts on the bottom to rest over floor timbers and accompanying ceiling planking. None of the buttresses are fastened to the frame and all of their outboard ends fit against the foot wales. Only two bilge boards 44 cm by 28 cm were between buttresses and there was no evidence for cutting rabbets, rather the shipbuilders chose to cut angular faces on the boards to make them rest against the mainmast step to create a smooth angular profile. Toward the front half of the expanded keelson is the mast mortise, with a single draining hole on the bottom face slightly aft from center. On either side of the mast step, directly aft from the third buttresses, are two pump sumps. Investigators describe how shipbuilders took care in building this area, since the mainmast step only received soft beveling to accommodate
absent pump tubes. Accompanying limber boards on either side are cut to provide a 27 cm by 20 cm recess for the pump assembly to reach the bilge (Stevens and Waddell 2007:210).

Evidence for the pump well was also found in situ, including four vertical framing timbers that were mortised into the surrounding ceiling planking (Ringer 2007:206). Planks are made from 6 cm thick hardwoods, which shipbuilders carefully crafted so that these would sit properly over the keelson and surrounding components. Measurements obtained from the pump well vertical stanchion mortises indicate that the box is oblong, as the length for the starboard planking is 77 cm, compared with the portside planking at 85 cm. In comparison, the forward side is 1.31 m, while the aft wall is 4 cm longer. Craftsmen built the pump well so that the pump sumps are positioned against the forward wall, allowing some room just aft on either side of the keelson. Archaeologists were able to find a number of artifacts in this area, including the recovery of basket fragments that may indicate strum boxes were installed in the pump sumps (Ringer 2007:203). If this basketry is remnants of a strum box, then the 27M wreck contains the only 16th-century example.

Emanuel Point I

The first ship of the 1559 Luna fleet, designated Emanuel Point I, was located as part of the 1992 Pensacola Shipwreck Survey conducted by the Florida Bureau of Archaeological Research (Smith et al. 1995:xii). Rather than perform a full-scale excavation of the wreck, investigators chose to follow Parks Canada examples for 27M and 29M by locating key features from the lower hull. In this case, excavation focused on revealing the bow, amidships, stern, and the surrounding debris field behind the ship. Archaeologists revealed the 2.1 m long expanded mainmast step (Figure 61); evidence from this area indicates superior craftsmanship and care was taken in building this component. Limited disturbance allowed most of the top half and the
portside of the keelson to be revealed, demonstrating that the aft section from the keelson is 35 cm wide and expands to 47 cm around the mast mortise (Smith et al. 1995:26–27). Shipbuilders also carved the keelson with a 39 cm tall incline between the beginning of the mainmast step and reduces after the pump sumps. Toward the front of the expanded keelson is the mainmast mortise 94 cm by 22 cm and 20 cm deep. On the bottom face, archaeologists found a 3.5 cm in diameter drainage hole 41.5 cm forward from the aft wall. There is also a carved cross on the bottom near the forward face that archaeologists interpreted as possibly a marker for the master frame located below. Similar markings have been found in earlier Northern European cogs, indicating a possible diffusion of this tradition (Vermeersch et al. 2015:337, figure 13).

Two wooden pieces were also found inside the mast mortise, including a 8 cm long and 23.5 cm molded wooden shim and a 33 cm by 20 cm, and 19 cm tall chock against the aft face. Additional mortises were found on either end of the mast mortise, the forward hole still contains the lower half of the deck stanchion while the 12 cm, 8 cm side, and 4.5 deep mortise found aft of the pump sumps is probably for a pump well stanchion (Smith et al. 1995:28). Notches and beveling along the underside facilitates the keelson resting over the frames. The keelson is fastened to the keel with iron bolts, however only a single bolt was uncovered piercing the center of the aft incline from the mainmast step. Subsequent excavations in the bow revealed further evidence for bolts along the 19.2 m estimated length of keelson (Smith et al. 1998:32).

Four buttresses, 63 cm in length, are found along the portside of the mainmast step, each is 25 cm tall on their inboard ends and decrease to 6.5 cm toward the bilge (Smith et al. 1995:30–31). Each buttress is fastened to the expanded keelson and connected to the floor timber below with iron spikes on the outboard end. Rather than allowing the ends of the buttresses to rest against the foot wale, shipbuilders crafted the bottoms to include a 7.5 cm rabbet to accept the
adjacent ceiling planking. Almost all other 16th-century examples have the buttresses notched into the accompanying foot wale, which makes EP I's configuration unique. Partial excavation allowed investigators to examine the same buttress complex on the starboard side. The first buttresses toward the bow on both sides are 11.5 cm sided, the second pair 12.5 cm, and the last pair at 17 cm.

Grooves 2.5 cm deep and 3-4.5 cm wide are found on the top edges of each buttress, allowing the bilge boards to rest and create a smooth profile. Further evidence for the care taken in building the mainmast step include the rabbets made along the portside edge of the expanded keelson to accept the top edges of the bilge boards. Each board is 2.5 cm thick and the first two are 70 cm by 21 cm. Damage from spilling ballast stone after wrecking broke the third board. Situated 30 cm aft from the mast mortise on either side of the expanded keelson are deep bevels 32 cm in radius cut for the absent bilge pumps (Smith et al. 1995:28–29). Initial salvage must have included removal of the bilge pumps; the only evidence found at the pump sumps was a leather fragment from the flapper valve (Bratten 1995:52) Only a small square board 21 cm by 18.5 cm that is 2 cm thick with a nail in each corner was uncovered at the bottom of the excavated portside pump sump. Several fragments and other sections of the wooden planking for the pump well were found in situ, but the poor preservation of these remains prevented any attempt to recreate dimensions.

San Juan (24M)

A major archaeological excavation was undertaken at Red Bay on 24M, tentatively known as the San Juan, which sank in 1565 (Bernier and Grenier 2007:308). Investigators recovered a 9.97 m long keelson fabricated from a single oak tree with the traditional expanded keelson close to center. Dimensions for the 4.14 m long forward end are 23 cm sided by 19 cm
molded and incrementally increase to 32 cm by 27 cm prior to the mainmast step (Loewen 2007a:153). In comparison, the aft section is 4.25 m long and also tapers from 32 cm wide by 29 cm in height down to 20 cm square. The remaining section, which was the 1.55 m long mainmast step, was expanded to 40 cm in width and 30 cm molded. Shipbuilders beveled the top edges of the keelson, along with the bottom edges between frames. Approximately in the center of the expanded keelson is the 75 cm by 18 cm and 16 cm deep mast mortise with a 2.5 cm drain hole slightly forward from center in the bottom face. Forward in the mortise is a small log 12 cm in diameter and a 28 cm long wooden block fitted against the aft face. These chocks adjusted the mainmast tenon from 37 cm at the top and narrowed down to 33 cm at the bottom. Six 5.5 cm diameter iron bolts were found along the central axis of the keelson, each having a countersunk top for forelock pins (Loewen 2007a:154–155). Four treenails are also driven through the keelson and frames, although these dowels did not penetrate the keel. Along with these fasteners, ship fitters also cut recesses on either side of the keelson to install 13 counter sunk iron nails.

Four pairs of buttresses were located on either side of the mainmast step (Figure 62) over floor timbers and are 39-40 cm in length by 17-21 cm wide. Inboard ends begin at 23 cm and slowly reduced down to 12-15 cm where they are notched 5-7 cm into the adjacent foot wale. Between the buttresses are 50 cm by 20 cm and 2 cm thick bilge boards that are attached using countersunk iron nails. Just aft from the mast mortise craftsmen cut a circular notch approximately 25 cm in diameter out of the portside mast step for the pump sump. Compared with the craftsmanship seen on the 27M and 29M hulls (discussed below), investigators emphasized the crude manner in which this notch was made. The accompanying limber boards, many of which are made from the waste of outer hull planking, were cut away to provide access for the pump tube into the bilge (Loewen 2007a:157).
Western Ledge Reef

Four ships in this analysis have been dated to the last quarter of the 16th century, the oldest, known as the Western Ledge Reef wreck, is located off the southwestern coast of Bermuda. Originally discovered by local divers, the wreck was subsequently salvaged until field school students from East Carolina University (ECU) identified the hull while surveying in the surrounding waters for the Bermuda Maritime Museum in 1988 (Watts 1993a:105). Several of the artifacts recovered by the salvagers were donated to the museum, including two cast iron cannons and two *versos* (anti-personnel cannons). Inscribed slightly forward from the touch-hole on one of the cannons is the date 1577, providing the *terminus post quem* for the site (Watts 1993b:49; Bojakowski 2011:18). Archival research revealed the loss of the *Santa Lucia* (ca. 1584) near Bermuda and is a possible candidate for the identity of the wreck (Watts et al. 1994:61).

Archaeologists from ECU returned to the shipwreck in 1989, conducted full excavations that eventually led to removal of the hull timbers in 1991 and transferred them to the National Museum of Bermuda for further analysis. Most of the bow structure and aft sections from the ship are missing; however, the amidships area and the lower section of the sternpost were recovered. Poor preservation left only a 2.17 m long section of the keelson (Figure 63); 20-21 cm sided by 17-21 molded. The timber retains these dimensions throughout its length without any evidence for tapering (Bojakowski 2011:26). This section of the keelson must have stretched further aft, as there is evidence for a scarf secured by an iron nail. Fasteners present throughout the keelson include round iron bolts 54-55 cm long and 2.3-2.7 cm in diameter, along with several square iron nails.
When ECU archaeologists began excavations, erosion terminated fortunately at the forward end of the mainmast step, which allowed this important section to be retrieved and preserved. The mainmast step comprises 1.15 m of the surviving keelson and it expands to 32 cm sided by 30 cm in height. Slightly forward from center is the mast mortise, measuring 42 cm by 15-17 cm and 14 cm deep (Bojakowski 2011:26–27). Although no chock was found inside the mortise, evidence from wear indicated the presence for a wooden block in the aft section. Lateral support is supplied on either side of the expanded keelson with three triangular shaped buttresses. Most of these buttresses are 51-53 cm by 15-16 cm and 20-22 cm high at their inboard edges, while tapering down to 7-9 cm (Bojakowski 2011:28). Only the third portside buttress is somewhat smaller than the rest. Investigators conclude the reason for this inconsistency was to accommodate the nearby bilge pump.

Each buttress has a 4 cm deep rebate cut on the underside outboard ends, allowing 27-34 cm to rest directly on top of floor timbers. The outer ends of the buttresses butted up against the foot wales, which unfortunately did not survive, although the fastening patterns allowed investigators to discern their original locations. Fasteners connect the buttresses to the mainmast step and to the first ceiling planking underneath, along with evidence for nail holes on the outboard edges for the missing foot wales. Almost all other contemporary ships had bilge boards cut to conform to the space between buttresses, in this case, the shipbuilders chose to cut two boards roughly 74 cm in length that covered all three buttresses and are lightly fastened to ease removal (Bojakowski 2011:28–29). Behind the mast mortise and off the portside is an approximately 3.9 cm notch reducing the remaining width of the expanded keelson to accommodate the absent bilge pump assembly. Investigators claim that this position would have required the bottom of the pump to rest on the garboard, although most site plans suggest enough
clearance made by the notching to allow some weight to rest on the keel. Another pump was possibly installed on the starboard side, as a limber board in this area includes a 19 cm square cutaway providing space to reach the bilge between frames.

29M

The third ship discovered by Parks Canada archaeologists at Red Bay, known simply as 29M, has undergone dendrochronological analysis, indicating that the ship is 13 years younger than 24M (Bernier and Grenier 2007:294). If 24M is indeed the San Juan, as the investigators have argued, then 29M must have been sunk sometime after 1578. Archival documents have not provided an identity to 29M, although scantling dimensions indicate 29M was a much larger ship than the other Red Bay examples. Excavators were able to locate the 12.31 m long keelson, which includes a 7.81 m forward arm and a 2.35 m section behind the 2.15 m mainmast step (Stevens and Waddell 2007:209). Evidence for a scarf on the aft end without any fasteners suggests that the keelson includes an additional section that did not survive. Appearing square throughout, the keelson expands to 38 cm sided by 33 molded at the mainmast step. The mast mortise, 70 cm by 19 cm and 17 cm deep, includes a drain hole in the bottom and a 15 cm wooden chock in the aft section. Another wedge chock is located toward the front half of the mortise, probably to adjust the mast heel once stepped in place. Five truncated wedge buttresses are located on each side of the expanded keelson; these average 81 cm in length by 27 cm wide. Near the mainmast step, each buttress is 18 cm molded and tapered down where the outboard edge abutted against the foot wale. As with the other Red Bay ships, there is no evidence for fastening the buttresses to the floor timbers below or to any other surrounding structure. Some consideration was made for the construction of the mainmast step, as the four bilge boards on either side (82 cm by 27 cm) are only 2 cm thick and sat in rabbets to create a smooth profile.
Aft of the mast mortise, on either side of the keelson where the width begins to reduce, are two pump sumps. Shipbuilders must have chosen this area carefully, as there is no deliberate evidence for cutting away the keelson to accommodate the bilge pumps. Only the 21 cm diameter holes cut in the accompanying limber boards and the 5 cm cut from the sides of the adjoining floor timbers indicate these positions (Stevens and Waddell 2007:210). Surrounding this area is evidence for the pump well, although none of the stanchions survived and only a single plank 1.12 m long by 6 cm thick was recovered. Other unusual features include a single board 95 cm in length, 20 cm wide, and 6 cm thick found lying in between frames directly over the outer hull planking on the bottom of the pump sumps. Archaeologists believe that the board provided elevation so that the foot from the pumps would not rest on the garboard or it may have distributed the weight to the keel and protected the garboard area, due to outer hull planks not fitting into the keel as on earlier examples (Stevens and Waddell 2007:210). Investigators also uncovered a 15.5-16.5 cm in diameter wooden disk, 2.5 cm thick, found inside one of the sumps. Four holes were distributed evenly around the face and were 2 cm from the outer edge (Stevens and Waddell 2007:211).

**Arade 1**

Dredging in 1970 at the mouth of the Arade River in Portugal led to the destruction of several shipwrecks. The subsequent investigation by sport diver groups identified two shipwrecks damaged from these operations (Castro 2006:48). Further dredging and destruction in this area eventually led the Centro Nacional de Arqueologia Náutica e Subaquática (CNANS) to survey the area in 2001 with the assistance of a local group of amateur divers. The remains from one of the earlier damaged vessels, Arade 1, was lost after being identified decades earlier and was only relocated during to the 2001 survey. The following year, local divers and archaeologists
from the University of S. Paulo and Texas A&M University (TAMU) began excavations that revealed other sections (Loureiro and Alves 2008). Earlier investigations uncovered portions of the keelson that were recorded as 5.13 m long and tapered toward the stern (Castro 2006:302). There was shallow notching for the timber to rest above the frames and sketches from the original discovery indicated the mast step was 20 cm square with a mast mortise 40 cm in length, 8 cm wide, and 5 cm deep.

Subsequent field seasons uncovered the keelson once again, although this time archaeologists recorded the timber as 4.4 m long and had the expanded mainmast step as 35 cm sided by 33 cm molded (Loureiro and Alves 2008:278). Two bolt concretions found on the upper face of the keelson indicate the timber was once connected to the keel. Toward the stern of the vessel investigators identified a pump sump carved between frames, creating a hole approximately 20 cm in diameter. Further evidence from Arade 1, relevant to the current discussion, has been lost through dredging and erosion. Forty-two wood samples were collected from the hull to undergo dendrochronological analysis. Results indicate that most of the wood is oak and originated in northwestern France, while a few samples indicate that repairs utilized chestnut (Domínguez-Delmás et al. 2013:131,133). Most of the trees were felled sometime after 1583 and have provided the most accurate dating for the ship thus far. The origin for the ship and where it was built still remain unclear.

Angra D

Portuguese authorities, in co-ordination with the Museum of Angra do Heroísmo, invited personnel from the Institute of Nautical Archaeology (INA) at TAMU to develop a survey project in the Azorean waters. Pre-disturbance archaeological surveys in Angra bay off the southern coast of Terceira Island revealed three historic shipwrecks in the area of future marina
development (Garcia and Monteiro 2001:433–434). Out of these three ships, two were dated to the end of the 16th or beginning of the 17th century; based on the identified ceramic assemblages. Subsequent decisions allowed the older ships to be excavated by CNANS officials with the assistance from several experts from abroad. Excavations were carried out over four months, during which archaeologists recovered all hull timbers and artifacts. Excavators only found a segment of the keelson from Angra C, while evidence from the Angra D included much of the vessel's lower half. Fortunately, in this case, the approximately 23 m long keelson was found mostly intact and still in situ over the central axis (Garcia and Monteiro 2001:442–443).

Angra D's keelson is made from three timbers, as evidenced by two key hook scarfs on either end of the central section. Shipbuilders chose to carve the keelson as a rectangular dimension throughout, maintaining 28 cm sided by 25-32 cm molded (this molded variance is due to the notches on the underside of the timber). Near amidships, the roughly 2.16 m long mainmast step expands to 46 cm and includes a slightly higher incline. Assembly at the expanded keelson required five filling pieces to be inserted between the floor timbers and the keelson. Above and slightly aft in the expanded section is the mainmast mortise (61 cm by 20 cm), which includes a chock near the forward end. Shipbuilders drilled a central hole on the bottom face of the mortise to facilitate draining water away from the mast heel. Two other mortises, 25 cm by 5 cm, and 4 cm deep, along with a third similar mortise, were also found along the central axis on the forward half of the keelson.

Five pairs of triangular buttresses sitting above accompanying floor timbers on either side of the mainmast step (Figure 64) are 90 cm long and 20 cm square against the keelson, decreasing in height at the outboard end. Several buttresses on the outboard undersides are notched to accommodate adjacent ceiling planking, while all of the buttresses end against the
accompanying foot wales. Four pairs of bilge boards, roughly 2.16 m by 32 cm, lay longitudinally over the buttresses on either side of the mainmast step. Investigators also recovered the lower planks from the pump well (1.8 m long by 1.6 cm wide), which are 2.5 cm thick. Stanchion holes for the pump well include several holes approximately 12 cm by 16 cm cut into the bilge boards. Additional 8 cm square associated stanchions were found in situ attached to the first floor rider forward from the mainmast step.

Positioning of the pump well indicates that two pumps were once behind the expanded keelson. Eight floor riders were also uncovered, spaced roughly 1.5 m apart over the length of the hull and notched along the underside to accommodate several stringers and the keelson (Garcia and Monteiro 2001:441). Investigators were surprised by the presence of the floor riders, since these components have not been found on any other ships from the 16th century, except for the *Mary Rose*. Floor riders became standard sometime in the 17th century, but earlier examples are seen from the Bergen ship (in Chapter 3) or on other large Scandinavian lapstrake cargo vessels. These observations indicate the floor rider as another component from Northern Europe that continued into the oceanic tradition.

**Discussion**

Naval treatises, along with contemporary iconography, have provided scholars with a basic outline for ship typologies between the 15th and 16th centuries. Research has also shown that many of these ships were originally smaller coastal craft that increased in size over time into larger trans-oceanic vessels. Adaptations and the gradual expansion in maritime commerce by the end of the 15th century required Atlantic shipyards to produce ships with larger cargo carrying capacities. Shipbuilders, rather than developing entirely new craft to meet these demands, chose to rely on known typologies to fulfill economic desires. Rather than define ships
by their superstructure alone, officials began to define certain vessels based on modified sailing configurations that were for combating new ocean currents and unknown wind directions. Once solutions for these obstacles were established, ship typologies, based on sailing configurations, laid the groundwork for future developments on changing typological classifications. Shipyard inventions, such as the 16th-century galleon or fragata, indicated a new direction for a familiar theme by combining traits from the Mediterranean galley with lessons learned from the early oceanic ship typologies. The eventual incorporation of naval artillery also saw the invention of the gun port and a dramatic shift in naval warfare. As a result, the need to build multipurpose vessels permeated into 16th-century ship construction, which allowed ships that could operate as armed merchants or in warship capacities.

Although limited amounts of superstructure from 15th and 16th-century shipwrecks has survived in the archaeological record, nautical archaeologists have been fortunate with the amount of lower-hull structure that often persists beneath ballast piles. Analyses from contemporary examples indicate that the trans-oceanic model was beginning to be embraced by Atlantic shipyards by the middle of the 15th century. Table 6 provides overall scantling dimensions for each ship, along with the measurements for their corresponding keelsons (also see Figure 65 for locations of archaeological sites). Examples, such as the Ria de Aveiro A and Newport shipwrecks, have been attributed to the earliest evidence for the "Atlantic-Iberian" shipbuilding tradition. As discussed, this classification is not necessarily a straightforward conclusion, as both ships still retain regional shipbuilding preferences for keelson/mainmast step construction. Evidence from the almost square Ria de Aveiro A keelson and its significantly reduced dimensions insinuate Mediterranean shipbuilding, while the thicker and more robust Newport example, with tapering ends, shows Scandinavian lineage. Furthermore, the Newport
TABLE 6

15TH- AND 16TH-CENTURY SHIP AND KEELSON DIMENSIONS

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Overall Length (m)</th>
<th>Beam (m)</th>
<th>Keelson Length (m)</th>
<th>Sided (cm)</th>
<th>Molded (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Ria de Aveiro A</td>
<td>1450</td>
<td>ca. 13</td>
<td>ca. 5</td>
<td>4.65 (frag.)</td>
<td>12.5-13</td>
<td>11.5-12.5</td>
</tr>
<tr>
<td>(2) Newport</td>
<td>1469</td>
<td>30</td>
<td>10</td>
<td>9.87</td>
<td>18-20</td>
<td>13-15</td>
</tr>
<tr>
<td>(3) Rye A</td>
<td>1475-1550</td>
<td>--</td>
<td>--</td>
<td>5.49 (frag.)</td>
<td>39.37</td>
<td>30.48</td>
</tr>
<tr>
<td>(4) Cais do Sodré</td>
<td>1500</td>
<td>&lt; 24</td>
<td>4.16</td>
<td>12.78 (frag.)</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>(5) Cattewater</td>
<td>1500-1530</td>
<td>27.7</td>
<td>9.7</td>
<td>4.6 (frag.)</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>(6) Highborne Cay</td>
<td>1500-1530</td>
<td>ca. 19</td>
<td>5-5.7</td>
<td>8.15 (frag.)</td>
<td>16-21</td>
<td>17</td>
</tr>
<tr>
<td>(7) Mary Rose</td>
<td>1545</td>
<td>42</td>
<td>14</td>
<td>20.85</td>
<td>24-40</td>
<td>21-45</td>
</tr>
<tr>
<td>(9) Red Bay 27M</td>
<td>1550</td>
<td>N/A</td>
<td>N/A</td>
<td>13.09</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>(10) Emanuel Point I</td>
<td>1559</td>
<td>45.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.2 (est.)</td>
<td>35</td>
<td>N/A</td>
</tr>
<tr>
<td>(11) Emanuel Point II</td>
<td>1559</td>
<td>32.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>(12) Red Bay 24M (San Juan)</td>
<td>1565</td>
<td>22</td>
<td>7.5</td>
<td>9.97</td>
<td>20-23</td>
<td>20-29</td>
</tr>
<tr>
<td>(13) Western Ledge Reef</td>
<td>1577</td>
<td>18.52-23.45</td>
<td>5-6</td>
<td>2.17 (frag.)</td>
<td>20-21</td>
<td>17-21</td>
</tr>
<tr>
<td>(14) Red Bay 29M</td>
<td>1578</td>
<td>24</td>
<td>8</td>
<td>12.31</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>(15) Angra D</td>
<td>1583</td>
<td>&lt; 7</td>
<td>6</td>
<td>5.13 (frag.)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Numbering next to site names corresponds with locations of sites found on Figure 65. <sup>a</sup>Estimated measurements taken from calculations in Chapter 7.
keelson also includes the familiar beveling underneath, as well as the absence of notches in certain sections to fit snugly with floor timbers for deck stanchion support, which is also part of the Scandinavian tradition.

Differences between keelsons are also present when considering examples from the beginning of the 16th century, as the keelson from Cais do Sodré and Rye Vessel A are identical to those described fifty years earlier. Although the mainmast section has been lost on Cais do Sodré, the square keelson and absence of beveling underneath are telling signs for Mediterranean preference. Whether or not archaeologists uncover the rest of Rye Vessel A in the distant future, it can be argued its shipbuilding influence as Northern European, based on the underside beveling and expanded keelson arrangement. Other examples after 1530 began to exhibit only the Northern European preferred method for the keelson/mainmast step design, which became standard across all trans-oceanic ships during the 16th century.

Examining the development of the keelson and expanded mainmast step section throughout the remainder of the 16th century indicates no dramatic changes. Slight modifications did exist, including the reduction on beveling the entire underside of the keelson. Shipbuilders after 1550 cut chevron or scalloped shaped bevels only between notches and proceeded to bevel the entire topside. When full keelsons were uncovered, there was also another obvious correlation, as most examples began and terminated before the rise in deadwood on either end. Major differences in the location for the mainmast (Table 7) appeared to be local in nature, rather than regional, as these varied considerably. Clearly, earlier ships followed the cog example by setting the mast mortise toward the bow, but throughout the first half of the 16th century the
mainmast was set further aft. Most ships after 1550 have this component moved toward the bow again, although San Juan shipbuilders constructed the expanded keelson almost directly in the center.

**TABLE 7**

**DISTANCE FROM CENTER OF MAINMAST MORTISE TO END OF KEELSON**

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Forward from the center of mast mortise (m)</th>
<th>Aft from the center of mast mortise (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport</td>
<td>1469</td>
<td>ca. 3.82a</td>
<td>ca. 6.59a</td>
</tr>
<tr>
<td><em>Mary Rose</em></td>
<td>1545</td>
<td>ca. 10.74</td>
<td>ca. 10.15</td>
</tr>
<tr>
<td>Red Bay 27M</td>
<td>1550</td>
<td>6.65</td>
<td>6.44</td>
</tr>
<tr>
<td>Emanuel Point I</td>
<td>1559</td>
<td>ca. 4.55</td>
<td>ca. 14.64</td>
</tr>
<tr>
<td>Red Bay 24M (San Juan)</td>
<td>1565</td>
<td>4.97</td>
<td>5</td>
</tr>
<tr>
<td>Red Bay 29M</td>
<td>1578</td>
<td>6.7</td>
<td>5.61</td>
</tr>
<tr>
<td>Angra D</td>
<td>1590-1600</td>
<td>ca. 9.08</td>
<td>ca. 13.92</td>
</tr>
</tbody>
</table>


Table 8 provides comparative measurements for the mainmast steps and their corresponding mast mortises. Available examples provide no correlation, suggesting the dimensions for these components were based on the individual dimensions of each ship rather than an agreed upon methodology across all Atlantic shipyards. On the other hand, mainmast step lateral reinforcement buttresses, as seen in Table 8, shows a gradual correlation between time and the number of buttresses. Most of these components seem to have similar square dimensions near the expanded keelson and reduce accordingly, although the molded slope varies considerably. As with the keelson, lateral reinforcement during the mid-15th century underwent several changes. Mediterranean ships, such as Ria de Aveiro A, relied upon modifying accompanying floor timbers to carve built-in buttress arrangements. Comparatively, the Newport example was an outlier in standard buttressing, as the 10 pairs of buttresses is greater than the five pairs seen on late-16th century vessels. This substantial lateral support complex, along with
the massive mast mortise, signifies a rather large mainmast. Earlier cogs often had several massive buttresses that spanned half the length of the flat bottom hull. Introduction of stronger foot wales allowed shorter buttresses to take shape, although concerns for the massive heel still breaking loose must have persisted, requiring further buttressing.

TABLE 8

MAINMAST STEP MEASUREMENTS (1450-1600)

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Mainmast Step</th>
<th>Mainmast Mortise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Length (m)</td>
<td>Sided (cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length (cm)</td>
<td>Width (cm)</td>
</tr>
<tr>
<td>Ria de Aveiro A²</td>
<td>1450</td>
<td>0.71</td>
<td>30-32</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Rye A³</td>
<td>1475-1550</td>
<td>1.45</td>
<td>52.07</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Rye A³</td>
<td>1475-1550</td>
<td>1.45</td>
<td>52.07</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Rye A³</td>
<td>1475-1550</td>
<td>1.45</td>
<td>52.07</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
<tr>
<td>Newportb</td>
<td>1469</td>
<td>3.1</td>
<td>76</td>
</tr>
</tbody>
</table>

Massive mainmasts were resolved by the beginning of the 16th century, as throughout the remainder of this period the mast mortise was significantly reduced. Early examples, such as Rye Vessel A or Highbourne Cay, show a two or three buttress minimum, while larger ships built later on indicate the number of buttresses grew throughout the century (Table 9). Mediterranean shipbuilding designs for lateral reinforcement were also seen on the Cais do Sodré wreck, where a single square buttress was recovered. Most buttresses included rabbets on their top faces, facilitating custom bilge boards cut to rest between them to prevent debris from reaching the
## TABLE 9

**COMPARISON OF REINFORCING BUTTRESSES**

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Pairs</th>
<th>Length (cm)</th>
<th>Sided (cm)</th>
<th>Inboard Height (cm)</th>
<th>Outboard Height (cm)</th>
<th>Rebate Underneath?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport</td>
<td>1469</td>
<td>10</td>
<td>40-78.4</td>
<td>20.1</td>
<td>16.6</td>
<td>5.5</td>
<td>No</td>
</tr>
<tr>
<td>Rye A</td>
<td>1475-1550</td>
<td>2</td>
<td>--</td>
<td>18.42</td>
<td>20.32</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cais do Sodré</td>
<td>1500</td>
<td>&lt; 1</td>
<td>130</td>
<td>20</td>
<td>18</td>
<td>18</td>
<td>No</td>
</tr>
<tr>
<td>Highborne Cay</td>
<td>1500-1530</td>
<td>3</td>
<td>64.6</td>
<td>13.5-11.8</td>
<td>21.9</td>
<td>16</td>
<td>N/A</td>
</tr>
<tr>
<td>Mary Rose</td>
<td>1545</td>
<td>3</td>
<td>37.5-55</td>
<td>15-25</td>
<td>32.5</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td>Red Bay 27M</td>
<td>1550</td>
<td>3</td>
<td>43</td>
<td>22</td>
<td>17</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td>Emanuel Point I</td>
<td>1559</td>
<td>4</td>
<td>63</td>
<td>11.5-17</td>
<td>25</td>
<td>6.5</td>
<td>Yes</td>
</tr>
<tr>
<td>Red Bay 24M (San Juan)</td>
<td>1565</td>
<td>4</td>
<td>41</td>
<td>16-19</td>
<td>24</td>
<td>9</td>
<td>No</td>
</tr>
<tr>
<td>Western Ledge Reef</td>
<td>1577 (1584?)</td>
<td>3</td>
<td>51-53</td>
<td>15-16</td>
<td>20-22</td>
<td>7-9</td>
<td>Yes</td>
</tr>
<tr>
<td>Red Bay 29M</td>
<td>1578</td>
<td>5</td>
<td>81</td>
<td>27</td>
<td>18</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td>Angra D</td>
<td>1590-1600</td>
<td>5</td>
<td>90</td>
<td>20</td>
<td>20</td>
<td>N/A</td>
<td>No</td>
</tr>
</tbody>
</table>

### TABLE 10

MEASUREMENTS OF FOOT WALES (1450-1600)

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Length (m)</th>
<th>Sided (cm)</th>
<th>Molded (cm)</th>
<th>Notches for Buttresses?</th>
<th>Beveling?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ria de Aveiro A&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1450</td>
<td>N/A</td>
<td>24-30</td>
<td>5-6</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Newport&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1469</td>
<td>12.9</td>
<td>25.2-37.7</td>
<td>4.8-9.7</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cais do Sodré&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1500</td>
<td>11.65-16.6</td>
<td>18</td>
<td>17</td>
<td>Yes (Reduction in width)</td>
<td>No</td>
</tr>
<tr>
<td>Highborne Cay&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1500-1530</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Red Bay 27M&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1550</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Emanuel Point I&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1559</td>
<td>N/A</td>
<td>18.5</td>
<td>15-16</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Red Bay 24M (San Juan)&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1565</td>
<td>9.41-9.53</td>
<td>26</td>
<td>10</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Western Ledge Reef&lt;sup&gt;h&lt;/sup&gt;</td>
<td>1577 (1584?)</td>
<td>--</td>
<td>ca. 19</td>
<td>--</td>
<td>Yes</td>
<td>--</td>
</tr>
<tr>
<td>Red Bay 29M&lt;sup&gt;i&lt;/sup&gt;</td>
<td>1578</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Arade 1&lt;sup&gt;k&lt;/sup&gt;</td>
<td>1583</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>--</td>
<td>No?</td>
</tr>
<tr>
<td>Angra D&lt;sup&gt;l&lt;/sup&gt;</td>
<td>1590-1600</td>
<td>ca. 21.32</td>
<td>13</td>
<td>14</td>
<td>Yes (Not all)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

bilge. Modifications of this style included shipbuilders from the *Mary Rose*, who cut the bilge boards to act as shorter limber boards or cut longer planks that laid longitudinally over the buttresses and were fastened in place, as seen on the Western Ledge Reef and Angra D shipwrecks.

Another peculiar difference is the rebate cut on the lower outward edge of buttresses from the Emanuel Point I and Western Ledge Reef examples. Whereas buttresses on Emanuel Point I do not rest against the foot wale, making the rebate an understandable modification, the Western Ledge Reef construction allows the buttress to rebate for the first ceiling planking while resting against the foot wale. Whether or not this feature is unique to these ships or part of a regional shipbuilding modification cannot be determined currently. Except for Emanuel Point I, all other ships from this analysis have buttresses either resting against or notched into the accompanying foot wales. Table 10 provides available information on these components, representing that similar circumstances for stringer dimensions corresponded to the size of the vessel rather than chronologically. Modification for beveling the topside of the stringers also corresponds with the same time that keelsons began to have this trait (post-1550).

Except for the Ria de Aveiro A, all other examples discussed include evidence for bilge pumps, due to shipbuilders creating sumps cut into the keelson, surrounding floor timbers, or ceiling planking. Positioning for the pumps was still variable, as the four pump sumps uncovered on the Newport shipwreck indicate. Prior to the mid-15th century, pumps were installed on either end of the vessel, however, the shift from flat-bottomed ships to curved hulls due to rising deadwood on either end required new pump locations. As shown on Table 11 below, two traditional pumps were maintained on most examples throughout the 16th century. Changes in ship design required these pumps to shift toward the center of the ship, which unfortunately was
already occupied by the presence of the expanded keelson. As a result, earlier examples of pump sumps show crude semi-circular notches cut into the expanded keelson or just aft from this component to facilitate the pump reaching the lowest point in the hold.

TABLE 11
PUMP SUMPS FOUND ON 15TH- AND 16TH-CENTURY VESSELS

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Pump Sumps</th>
<th>Operable Pumps</th>
<th>Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport</td>
<td>1469</td>
<td>4</td>
<td>2</td>
<td>25-32 (square)</td>
</tr>
<tr>
<td>Rye A</td>
<td>1475-1550</td>
<td>1</td>
<td>1</td>
<td>29.21</td>
</tr>
<tr>
<td>Cais do Sodré</td>
<td>1500</td>
<td>2</td>
<td>2</td>
<td>25 x 20</td>
</tr>
<tr>
<td>Studland Bay</td>
<td>ca. 1520</td>
<td>1</td>
<td>1</td>
<td>30-40</td>
</tr>
<tr>
<td>Cattewater</td>
<td>1500-1530</td>
<td>1</td>
<td>1</td>
<td>30-34</td>
</tr>
<tr>
<td>Highborne Cay</td>
<td>1500-1530</td>
<td>2</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Mary Rose</td>
<td>1545</td>
<td>2</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td>Red Bay 27M</td>
<td>1550</td>
<td>2</td>
<td>2</td>
<td>27 x 20</td>
</tr>
<tr>
<td>Emanuel Point I</td>
<td>1559</td>
<td>2</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>Red Bay 24M (San Juan)</td>
<td>1565</td>
<td>1</td>
<td>1</td>
<td>29 x 20</td>
</tr>
<tr>
<td>Western Ledge Reef</td>
<td>1577 (1584?)</td>
<td>2</td>
<td>2</td>
<td>19 x 19</td>
</tr>
<tr>
<td>Red Bay 29M</td>
<td>1578</td>
<td>2</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Arade 1</td>
<td>1583</td>
<td>1</td>
<td>1</td>
<td>ca. 20</td>
</tr>
<tr>
<td>Angra D</td>
<td>1590-1600</td>
<td>2</td>
<td>2</td>
<td>--</td>
</tr>
</tbody>
</table>


Additionally, Table 11 indicates that these pump sumps were not standardized, as several examples show rectangular dimensions, perhaps indicating that the bottom of the pump tube was beveled for insertion between floor timbers. Discrepancies on pump sump locations at the beginning of the 16th century include differences seen on the central bore aft of the Cattewater mast mortise and on the Cais de Sodré, by placing pump sumps relatively further away from the central axis. As the century progressed, the reduction in the expanded keelson and the novel tradition for seating the pump directly aft from the mast mortise became a standard component of the trans-oceanic tradition. Establishing the new pump position allowed shipbuilders by the middle of the century to cut bevels or shallow recesses to allow the pump to reach the bilge.
Pumps became so standardized as to allow shipbuilders working on 29M and Arade 1 to fit the pump tube next to the mainmast step and adjacent floor timbers without sacrificing the integrity of these components. In fact, by the end of the century, as seen on Angra D, modification for the pump sump had disappeared and only the pump well structure confirms the original presence of these devices.

Outliers from this scenario are also present in the archaeological record, such as examples shown in Table 11 that include several pump sumps present, even though archaeological evidence emphasizes only a single pump in operation when the ship sank. The Newport and Mary Rose are key examples, due to former pump sumps being covered over with ceiling planking. Evidence for two pump sumps along the portside keelson on the Highborne Cay wreck could indicate that two pumps were in operation in this area. Although it is far more likely that shipbuilders reseated the pump, realizing that the lowest point was further back than thought originally. Furthermore, ordinances proclaimed by Philip II of Spain in 1552 required all ships to have two pumps on board, whether sailing across the ocean or plying the trade routes along the European-Atlantic coastline (Casado Soto 1991:98–99). Most late-16th century ships that were Iberian in origin include two locations for bilge pumps. Nevertheless, Iberian shipbuilders still chose to construct ships with single pumps as seen on the San Juan and Arade 1.

Pump well enclosures reappeared in the 15th century, as evidence for a single 14 cm by 16 cm stanchion found in the vicinity of the midships pump sump at Newport attests. Table 12 provides scantling and area dimensions for pump wells, when archaeological evidence is available. Observations from this dataset indicate that pump well dimensions shed light on whether ships operated with two pumps or not. Positioning of the pump well inside the hold, either centered over the keelson or off to one side, also supports whether or not a ship had
### TABLE 12

**PUMP WELL PLANKS AND ASSOCIATED STANCHIONS**

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Thickness (cm)</th>
<th>Stanchion (cm)</th>
<th>Base Dimension (cm)</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1469</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>14 x 16</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Rye A&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1475-1550</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>6.35</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cais do Sodré&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1500</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>7-10</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><em>Mary Rose</em>&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1545</td>
<td>84-102</td>
<td>28-41</td>
<td>2.6</td>
<td>6-14</td>
<td>84 x 102</td>
<td>85.68</td>
</tr>
<tr>
<td>Red Bay 27M&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1550</td>
<td>77-135</td>
<td>N/A</td>
<td>6</td>
<td>N/A</td>
<td>81 x 133</td>
<td>107.73</td>
</tr>
<tr>
<td>Emanuel Point I&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1559</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>8 x 12</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Red Bay 24M (<em>San Juan</em>)&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1565</td>
<td>81-95</td>
<td>22-30</td>
<td>2.5</td>
<td>9</td>
<td>85 x 93</td>
<td>79.05</td>
</tr>
<tr>
<td>Red Bay 29M&lt;sup&gt;h&lt;/sup&gt;</td>
<td>1578</td>
<td>112</td>
<td>N/A</td>
<td>6</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Angra D&lt;sup&gt;i&lt;/sup&gt;</td>
<td>1590-1600</td>
<td>160-180</td>
<td>N/A</td>
<td>2.5</td>
<td>8</td>
<td>180 x 160</td>
<td>288</td>
</tr>
</tbody>
</table>

several pumps. Carpenters built these wells with various planks on hand, but there is an unusual standardization for plank thicknesses that might be attributed to the shipyards or regional origins. Stanchions for the pump well provide the most thorough dataset, although the evidence indicates these components were not standard and simply cut as rectangular forms. Depending on the shipyard, pump wells were built with available softwood, as on the San Juan, or in the case of 27M, were built with care to properly seal this area from the surrounding ballast. Shipbuilders also sought to keep the foot of the pump from resting directly on the hull and installed simple boards either to minimize stress by spreading it over a wider area or balancing it between pumps by inserting longer boards beneath the keelson.

Mariners and naval treatises alike during the 16th century described contemporary oceanic ships based on known hull typologies. A vessel's size and scantlings were described as the only major changes these ships underwent during the period. Through this comparative archaeological study, the author discerned that other modifications were taking place. Trial and error between northern and southern European shipwrights eventually found common ground in implementing features from mainmast steps and bilge pump assemblies that were structurally sound. By implementing a novel system at amidships, shipbuilders provided sailing craft that could travel further and safer across the high seas. These accomplishments allowed Europeans to explore, colonize the Atlantic, and subsequently established maritime empires.
THE LUNA EXPEDITION

Across the Caribbean, Central America, and South America, conquistadors were successful in subduing indigenous peoples and colonizing in the name of Spain. La Florida, which encompassed Florida and a large section of the southeastern United States, remained an exception to the rule, as numerous expeditions were routinely met with disaster (Irving 1851:56; Weddle 1985:48; Adorno et al. 1999:77). Explorers and colonists who voluntarily went to Florida often found hostile Indians and an unforgiving landscape. Other groups, shipwrecked along the peninsula, struggled to survive or perished altogether. These failures revealed the need for a larger and better funded expedition to colonize the Floridian coast successfully. The response was met by organizing a new expedition under the tutelage of Tristán de Luna y Arellano. Rather than provide a traditional historical narrative to the Luna expedition and the trials that happened on land (Priestley 1936; Weddle 1985:251–284; Hudson et al. 1989), this chapter examines the preparations of the expedition up to the hurricane disaster on 19 September 1559. The modern Gregorian calendar was not enacted until 1582 and all dates are ten days behind the modern calendar (Gingerich 1983:265; Ziggelaar 1983:223).

Purpose for Expedition

Petitions for a new conquest of Florida by religious officials and layperson alike cited the need to create a secure base from hostile natives. Between the disaster of the Hernando de Soto expedition (1539-1543), which traveled throughout the modern southeastern United States and the Luna expedition, several major wrecking events evoked public scrutiny due to the need to protect Spanish individuals. For example, in 1551 the vessel San Juan was shipwrecked, leaving 21 people to be marooned and/or killed by hostile Indians (Weddle 1985:251). Similar events transpired with the 1553 and 1554 fleets. The following year, Archbishop of Mexico, Alonso de
Montúfar y Bravo de Lagunas, began sending petitions to Philip II of Spain for native conversion in Florida (Priestley 1936:55). Other religious members followed suit, such as Fray Diego Sarmiento, bishop of Cuba, who requested the import of native Florida women to support the island's dwindling indigenous population (Weddle 1985:252).

Father Andrés de Olmos, a prominent Franciscan missionary along the northern fringe of New Spain, wished for a broader missionary network to include Rio de Palmas (Soto la Marina), Rio Bravo (Rio Grande), and Ochuse (Pensacola) (Priestley 1928a:265; Weddle 1985:254). The Alcalde mayor (mayor) of Panuco, Rodrigo Rangel and vicar Pedro Rodriguez Canillas supported Father Olmos’s proposal. Rangel, a former member of the Soto expedition, stressed the importance of colonizing Ochuse. Although the full Soto expedition never visited Ochuse, pilot Francisco Maldonado discovered the bay and returned to Soto's army in the Tallahassee area with an Indian chief from Pensacola (Hudson et al. 1989:31). Several Soto survivors also wanted to see an interior settlement at the Indian town of Coosa, due to the abundance of resources they witnessed. New Spain’s Viceroy, Luís de Velasco (1550-1564), also wrote in support of sending missionaries to Florida (Priestley 1936:56). Secular arguments to settle Florida included a letter written on 3 January 1557 by Doctor Pedro de Santander, Royal Overseer at Veracruz. Santander’s plans involved construction of a five vessel fleet to patrol the coastline, a settlement at Miruelo Bay (vicinity of Apalache Bay), and pacification of the natives by force (Weddle 1985:256).

King Philip II responded to these petitions on 29 December 1557, ordering Velasco to appoint a new governor for Florida. Velasco was in charge of assembling an expedition to settle the Punta de Santa Elena (modern day Parris Island, South Carolina) and another site of his choosing (Priestley 1936:56). The reversal by Philip II on the prohibition to colonize Florida,
which was established after the failure of the Soto expedition, did not stem from ecclesiastical concern or shipwreck survivors. European encroachment on Spanish America had been on the rise through piracy, illegal trading, and colonization in the New World. French colonists were already in Newfoundland and had made seasonal voyages south to trade with natives in Florida. Santa Elena, due to a previous voyage of discovery by Lucas Vázquez de Allyón (1526), was reported as a hospitable area for cultivation (Lyon 1981:279). Rumors of potential French settlement prompted the Spanish to begin colonization along their northern border.

Velasco quickly went into action, writing the following year on a plan to colonize the Gulf coast and march overland to Santa Elena (Priestley 1928a:259). The size of the North and South American continents was not understood clearly and the Spanish thought the distance between the proposed colonization sites was much shorter. Final plans involved three settlements; one would be along the Gulf of Mexico, another at Coosa, and the remainder of the expedition would march east to Santa Elena. These colonies would allow for conversion of the natives and enrich a new generation of conquistadors.

Experienced Leader

On 1 November 1558, Tristán de Luna y Arellano took the oath to become governor of Florida (Priestley 1928:36). Velasco’s decision to appoint Luna included a mixture of merit and cronyism. Emigration records indicate Luna was born around 1514, migrated to the New World, and became a citizen of Mexico City by 1537 (Boyd-Bowman 1968:318). Luna was born into a wealthy aristocratic family from Borobia, Spain, but because he was the younger of two sons, he had to seek his fortune elsewhere due to primogeniture. Luna followed in the footsteps of the conquistadors that preceded him by volunteering to assist Francisco Vázquez de Coronado y Luján in searching for the fabled city of Cibola reputed to be located in the modern US.
southwest. Muster roll records denote Luna as originally a captain of the cavalry, who rose to maestre de campo, and eventually lieutenant-general of the expedition (Flint and Flint 2005:331,392).

Coronado returned to New Spain in failure, but the capabilities Luna displayed in management and in engaging hostile Indians successfully were not overlooked. In 1545, he married the twice widowed Doña Isabel de Rojas, whose rich encomienda (an allocation of forced native labor and tribute) holdings brought him a small fortune (Priestley 1936:65). Luna also relied on family ties to become close with his cousin, New Spain’s first Viceroy Antonio de Mendoza y Pacheco (1535-1550). Mendoza sent Luna at his own expense in 1548 to pacify an uprising in Tetiequipa and Coatlán near Oaxaca (Priestley 1928a:199–205; Weddle 1985:265). Luna’s success in crushing this revolt was rewarded by an appointment as administrator of Marquesado del Valle de Oaxaca’s holdings in 1551. The 1550 replacement of Viceroy Mendoza with Velasco had no apparent ramifications for Luna, as he also became a close friend and confidant to the new arrival. Due to his noble status, previous success in the New World, and his close relationship with men in power, Luna appeared to be a capable choice for the Florida expedition (Priestley 1936:63).

Previous Experience

Luna’s decision to settle Ochuse relied on earlier efforts, such as accounts by Narváez expedition survivors, and the account by Soto’s pilot, Francisco Maldonado (Weddle 1985:193; Hudson et al. 1989:31). Velasco also understood the importance of scouting ahead when he sent an exploratory mission under Guido de la Vaçares to locate a safe port. Vaçares’ three ships, a chalupa, a barca, and a fusta, departed San Juan de Ulúa on 3 September 1558 (Priestley 1928a:333). Once Vaçares caught sight of land, he sailed east and located a large bay he named
Bahia Filipina (modern Mobile Bay). Bahia Filipina was described as auspicious with a variety of wildlife, including local Indian villages near the water, which contained fields of corn, beans, and pumpkins (Priestley 1928a:335).

After visiting Bahia Filipina, Vaçares attempted to sail further east, but inclement weather in late fall prevented additional exploration. The small exploratory mission departed Bahia Filipina 3 December and arrived at San Juan de Ulúa eleven days later. Previous research concerning the Luna expedition has also discussed a direct mention by pilot Gonzalo Gayón about an exploration mission sent in late December under Juan de Rentería (Weddle 1985:259–260). Under this mission, a single vessel departed San Juan de Ulúa and traveled to Havana, from there the ship sailed a counter-clockwise circuit of the gulf. Gayón’s probanza from 1564 claimed the pilot found Ochuse, along with several other natural harbors (Gayón 1564). Available royal account records include details on payment for the Vaçares’ expedition, but no information on a second exploratory voyage.

Many members of Luna's expedition were accustomed to exploration or colonization in the New World. Both Luna and Juan Xaramillo were members of Coronado’s journey into the American southwest. Luis Daça, Alvaro Nieto, Rodrigo Vázquez, Juan de Vargas, and several others all were part of the previous Soto expedition (Weddle 1985:266). Maestre de campo, Jorge Cerón Saavedra, sailed under Hernán Cortes along the Baja California coast, and Mateo del Sauz had fought in Peru. Even Bernaldo Peloso, a Soto veteran and one of Vaçares’s pilots, also went and probably guided the fleet towards Bahia Filipina. Four Florida Indians (taken during the Soto expedition) who had been living in Mexico City were brought along to act as interpreters (Priestley 1936:50; Yugoyen 1569:folio 461). Experience was an essential ingredient to any successful colony, as veterans knew to respect the unforgiving landscape and hostile
native populations. By having so many veterans on the Luna expedition, Velasco and other
officials expected the venture to succeed where so many had failed before.

Soldiers and Colonists

Contemporary accounts claim 500–550 soldiers were brought on the Luna expedition,
including seventeen military officers. Infantrymen were divided into companies of 50 originating
from Mexico City (200 infantry) and Puebla. Cavalrymen were recruited from Oaxaca,
Zacatecas, Puebla de los Angeles, and Mexico City (Priestley 1936:86–87). Luna wrote
personally to Philip II that 240 horses were brought on the voyage, but only 130 survived the trip
(Priestley 1928a:211). Testimonial after the expedition by Velásquez Rodríguez on his service
mentions bringing many horses as part of his personal belongings (Roqueno, 1562:2).
Accountant General of New Spain, Hortuño de Ybarra, also supplied arms and horses for those
he recruited to go to Florida (Ybarra 1560:2). These petitions emphasize that expedition officials
took multiple horses to supply themselves and their entourages, while recruits were given at least
a single horse and weapon. Providing specific numbers for the offices of infantry and cavalry is
difficult without a proper muster roll, but a conservative estimate is around 170 cavalrymen and
330 to 380 infantry as arquebusiers, shield bearers, and crossbowmen. These numbers are based
on the known muster roll from the Coronado expedition, where many officials and officers
brought anywhere between 4–8 (6 on average) horses (Flint and Flint 2012:135–163). When the
Luna expedition arrived and lost approximately half the horses, many of these cavalrymen may
have acted as infantry until fresh horses arrived in subsequent supply fleets.

Rodríguez also stated that married men volunteered to go on the expedition because
many bachelors from the central Mexican population did not offer to serve (Roqueno 1562:3).
Primary texts include a petition by 36 married soldiers who brought their families with them to
settle Florida (Priestley 1928a:134–15). Other soldiers were probably single and sought their fortune through conquest. Men of fortune were those vicar-provincial Feria commented on as being “hardened” and prone to bad customs (Priestley 1928a:325). One example includes a scuffle between soldiers and a bailiff in Mexico City. Hysteria over the incident required Velasco to confiscate all weaponry until the fleet’s departure from Veracruz (Priestley 1928a:234–235).

Luna’s communications with Philip II mentions 1,000 “personas de servicio” or serving people as part of the expedition (Priestley 1928a:210–211). These members were traditionally considered colonists or servants of soldiers. Alonso de Montalván, former horseman of maestre de campo, Jorge Ceron Saavedra, testified after the expedition that soldiers, horses, and 800 Spanish women, Africans, servants, and friendly Indians were disembarked on shore (Priestley 1928a:284–285). The discrepancy in numbers between Luna and Montalván may have to do with the amount of sailors employed in the fleet. Previous estimates calculate 273-285 sailors (Worth 2009:87), but Montalván’s testimony, with exact numbers and dates, supports an estimate that the 1,000 serving people was actually around 200 crewmen with 800 colonists or servants.

Exact numbers on gender, race, and occupation for each non-combatant member of the expedition remains unknown. At minimum, 36 Spanish and 3 enslaved African women were brought on the expedition, but complaints by Velasco on the number of women and children alludes to a larger cohort (Yugoyen 1569:folios 536-538; Priestley 1936:101). Many soldiers and non-combatant officials insisted on bringing one or two personal servants. If these demands were true, then a minimum of 506-556 servants were present on the expedition. These servants were likely male with a mixed background (mestizo), Mexican Indian, or African. The remaining 244-294 members included four royal officials, a doctor, a chaplain, and six Dominican friars. Petitions during the expedition from 21 Indians laborers and 10 skilled Mexican artisans indicate
an origin from Mexico City and Santiago Tlatelolco (Priestley 1928b:142–147; Worth 2016:6). Accounting records also specify 40 “Indios soldados” or Indian soldiers were carried from Xalapa to San Juan de Ulúa for the expedition, while the Osuna codex specifies an additional 60 were also in attendance (Yugoyen 1569:folios 492-493; Valderrama 1563:18). Another indication to the identity of the Mexican Indians includes six Aztec ceramic sherds from the Emanuel Point I shipwreck, originating from Cuauhtitlán, in the Central Valley of Mexico (Smith et al. 1995:101–102). Recent excavations at the likely site of the royal warehouse Luna constructed at Pensacola includes additional ceramics that are consistent with colonial Aztec red ware (Worth 2016:6–7). The remaining 101-151 expedition members may have been women and children, additional Mexican Indians, or African slaves brought to serve church officials, colonists, and soldiers.

Religious Members

One of the more traditional reasons for going to Florida was to convert the natives to Catholicism. On 30 September 1558, Velasco wrote that a meeting between the three religious orders (Franciscan, Dominican, and Augustinian) resulted in a decision for six Dominican friars to accompany the expedition (Priestley 1928a:258–259). Over the previous decade Dominican members had ventured to Florida, including Fray Luís Cánfer’s ill-fated mission in 1554, and the disaster that befell survivors from the 1554 fleet (Weddle 1985:234–235). Ecclesiastical divisions within New Spain also shows the Dominicans held dioceses primarily in areas where most soldiers and colonists originated (Gerhard 1993:17–21). Those chosen to go included vicar-provincial Pedro de Feria, Friars Domingo de Salazar, Domingo de la Anunciación, Juan de Mazuelas, Diego de Santo Domingo, and Bartolomé Matheos.
Naval Infrastructure

Velasco’s original proposal for the Florida expedition involved building six *barcas*, each with 4 artillery pieces at 100 tons apiece (Priestley 1928a:257). By the time Luna’s fleet departed on 11 June 1559, his armada was vastly different. Crown revenue spent 39,481 pesos, 2 tomínes, 2 granos of common gold and 1,556 pesos of fine gold on naval expenditures. Purchases included the galleon *San Juan [de Ulúa]* (written as simply *San Juan* below), the *nao Santi Espiritu*, and the *barca Corpus Cristi*. Officials also chartered five vessels at San Juan de Ulúa to carry surplus food and colonists. Chartered ships included the *urca Jesús*, the *nao San Andrés*, the caravela *Sancti Espiritu*, the *navío (ship) San Amaro*, and the *navío Santa María de Ayuda*. During the construction process, Velasco’s intended six *barcas* became one *galeón (San Juan de Ulúa)*, two *barcas* (the *San Luís Aragón* and the *Salvadora*), and a *fragata (San Juan)* (Yugoyen 1569).

Velasco’s original vision went against traditional Spanish colonization enterprises that relied on ships built in Old World shipyards, but that were already present in New World ports. Local officials were assigned the bold task of creating a new shipyard across from fortress San Juan de Ulúa. Personnel and ship materials were obtained from major towns along the main road network from Mexico City to the Gulf Coast. Oak forests surrounding Medellín, along the Rio de Medellín, provided the ideal timber and transportation network. African slaves were employed in cutting timber and in building the road that transported wood from the mouth of the Rio de Medellín to the shipyard. Timber was utilized as it arrived from Medellín, which meant that officials ignored seasoning wood to maximize available time in construction while sacrificing the long-term integrity of the hulls in the process. In fact, the green wood construction resulted in numerous repair expenditures for the *San Juan de Ulúa* after returning from Florida on its
maiden voyage. Crown officials (or the shipyard workers) eventually realized that building six ships would be too time consuming and would siphon off additional resources from the New Spain economy.

After the first wave of timber cutting and building from October 1558 to early January 1559, only two *barcas* were beginning to take shape. By late December 1558, shipyard officials decided it would be prudent to build one *galeón* rather than the other four *barcas*. The decision to make a *galeón* provided surplus compass timbers to build a fourth ship, the *fragata San Juan*, which would act as a scouting vessel and travel upriver. Once the first stage on building the frames was complete, a second period of timber cutting occurred throughout March (Yugoyen 1569:folios 325-326). The second stage presumably involved larger quantities of general timber to be cut into planks and other generic forms for building the outer hull and inner cabin space. Most ships were routinely worked on until the first week of June, when preparations began for departing to Florida.

Decisions made on the number of individuals and the amount of materials taken on the expedition gradually exceeded the cargo space of the new ships. Beginning on 3 January 1559, Velasco appointed Accountant General Hortuño de Ybarra to make all necessary preparations for the Luna fleet. The original intent was to embargo or simply charter available vessels present at the port of San Juan de Ulúa. These charters were intended originally to hire four ships to disembark with the fleet in late April or early May and return from Florida, or depart for Spain by 31 May. Ybarra's purchase of the *San Juan* and the *nao Santi Espiritu* were made due to political connections by expedition members. Admiral of the Fleet, Felipe Boquín, was the original ship owner of the *San Juan* and the *nao Santi Espiritu* was partly owned by Diego de Luna. Delays by the expedition in departing from Mexico City and construction/repairs being
made in the shipyard pushed the departure date to June. In the meantime, the assembled materials and personnel destined for Florida had exceeded available cargo space once again. Alcalade mayor of Veracruz Martínez remedied the situation by first purchasing the Corpus Cristi and then chartering the Santa María de Ayuda.

Crewmen and ship owners (except those from the Corpus Cristi and the Santa María de Ayuda) were under the impression that they would be released from their contracts by 31 May (Yugoyen 1569:folios 579-583). When the expedition had not arrived and shipyard maintenance on the fleet was incomplete, Martínez signed a new agreement for contractual ships to operate until the end of July. More delays on finishing the ships and the logistics of moving 1,260 people and materials from Xalapa to San Juan de Ulúa created further problems (Priestley 1928b:55–57). By 1559, Spanish pilots and sailors were aware of the Gulf Stream and the clockwise currents prevalent in the Gulf of Mexico. These groups probably argued that a departure date after the first week of June would not allow the fleet to return to San Juan de Ulúa until August. Martínez responded by signing an extended charter, promising to pay crewmen an additional month's salary until 31 August.

Luna's departure from San Juan de Ulúa on 11 June was successful in part due to the immense efforts by New Spain officials in creating the first royal shipyard in the New World. Havana's own shipyards at this time were still inconsequential and did not become centralized under royal patronage until the mid-1560s (Fuente 2008:128). Since the Veracruz shipyard and the ships themselves were built with Crown funds and a single objective in mind, it is understandable why this infrastructure did not last. Ybarra and Martínez's efforts to obtain additional transports for the fleet resulted in seven royal vessels and five private ships under contract. Four ships were built in New Spain, while the remainder arrived from Europe where
they were built in the Old World, repaired in the New World, and were present in port when officials originally sought them out.

Summary on the Luna Expedition

Various correspondence and accounting records provide primary sources for multiple components of the Luna expedition. Luna, a forceful and charismatic leader during the Coronado expedition, was chosen to colonize the southeastern United States to curb European encroachment and convert the native populace to Catholicism. Officers were given salaries and wages to be collected from what was found in Florida rather than New Spain’s treasury (Priestley 1928a:68–69). These decisions provided an opportunity for mercenaries and other expedition members to claim land, capture natives, or raid villages to obtain their fortunes. Evidence from legajo 877 Contaduría records prior to the fleet's departure indicate 77,204 pesos, 1 tomínes, 11 granos of common gold and 2,809 pesos 6 tomínes of fine gold were spent on equipment and personnel. New Spain’s treasury possibly paid 55,000 – 82,500 pesos to aid the soldiers. Private expenditures from soldiers and officers only, including the 15,000 pesos and 12,000 pesos of fine gold obtained by Luna (Priestley 1928a:215), amounted to 586,292 pesos. A conservative estimate of 723,145–750,645 pesos or, in modern terms, $33,610,464.79-$34,888,614.79 was spent on fitting out the expedition from August 1558–September 1559. These modern equivalents are based on the peso de común containing 25.563 grams of silver at the time (Haring 1915:435) and the current exchange rate at 55 cents per gram of silver.

Supplies and labor came from New Spain, relying on the local economy to support the colonizing effort. Fertile lands surrounding Puebla and Xalapa produced crops of maize and wheat to feed the colonists. Livestock from rancherías (ranches) near Perote supplied dried beef and meat to supplement the hardy diet. Finished goods came from Mexico City or Veracruz and
carried to San Juan de Ulúa. Grapes for wine and olive production were nascent in the New World, requiring higher payments for import from Europe. The majority of materials bought by royal officials were communal items that colonists would share. These materials included candles, medicinal items, grinding stones, and plowshares. Five hundred fifty-four axes would be used to cut timber, assuming that any other tools for constructing the settlements would be brought by craftsmen. Native Mexicans from several encomiendas were paid for their services in constructing stables, collecting grass to feed horses, and traveling to Florida. Indian laborers originated predominantly from towns along Río de Alvarado (modern Río Papaloapan).

Approximately 500-550 soldiers, 240 sailors and 760 colonists/servants disembarked in 12 ships from San Juan de Ulúa on 11 June 1559. Many soldiers brought their wives and children expecting to settle permanently. African slaves and Mexican Indians as warriors, farmers, servants, or skilled artisans also accompanied the expedition.

Several soldiers and expedition officials were experienced veterans from earlier colonization attempts. These veterans allowed Luna to have practical insight regarding what to expect upon arriving in Florida. Many soldiers attempted to bring large quantities of clothing due to earlier accounts that recalled harrowing experiences in winter camps (Priestley 1928b:56–57; Foster 2012:137). Two exploratory missions sent ahead of Luna sought natural harbors that would be ideal for settlement. Floridian Indians brought to New Spain from earlier conquests would act as interpreters. Six Dominican friars accompanied the expedition to convert any natives the Spanish encountered.

The Luna expedition was one of the better funded attempts at colonization through a combination of state and private capital. Experience had taught the Spanish what was required to become successful conquerors, but nature could ruin the best laid plans. Although Luna made it
to Pensacola and began colonization, on 19 September 1559 a hurricane arrived devastating the fleet and wrecked seven of twelve vessels (Priestley 1928a:245). Luna struggled to colonize Florida for two years, until Ángel de Villafañe arrived to replace him on Velasco's orders. Villafañe removed most of the colonists, leaving only a small contingent as he sailed east to locate Santa Elena. When his attempts at locating Santa Elena ended in failure, he returned to Pensacola via Havana to retrieve the surviving colonists before returning to Veracruz. The unfortunate failure of the Luna expedition prevented further attempts at colonizing La Florida in this region and Pensacola would not be revisited until the Spanish settled the area permanently in 1698.
EMANUEL POINT II AMIDSHIPS IN SITU AND POST-FIELDWORK ANALYSIS

The Emanuel Point II (EP II) shipwreck is situated in Pensacola Bay approximately 7.5 km from the modern coastline and is in close proximity to the recently discovered Luna settlement (Worth 2016). During the initial wrecking event from the 1559 hurricane, EP II was driven onto the edge of a submerged sandbar near the original outlet for Bayou Texar. The wreck sits in 4-5 m of water and is approximately 400 m west from the first Emanuel Point shipwreck (EP I). Original exploration by staff and students during a 2006 magnetometer survey located a 14 m long ballast mound flush with the natural bottom of the bay (Cook 2009:93). Conditions on site change based on climate variations throughout the year and the influx of sediment that arrives in Pensacola Bay from the terminus of various northern river networks. Over the summer months visibility can range from 1 cm to 2 m; this visibility improves during the winter months when the water temperature drops and less rainfall usually takes place.

Initial effort for this research was undertaken during three, 10-week field schools, while the bulk came after the University of West Florida was awarded a Special Categories Grant in 2014 by Florida's Division of Historical Resources. The terms of the grant were to allot funding for 2 consecutive years of Phase II excavation on EP II with additional survey to find the other missing Luna shipwrecks. Over the course of the grant, the author and archaeological staff were able to reveal the entire mainmast step, along with central hull structure within the vicinity. The hull was left in situ, except for broken components from the pump well, a deck stanchion, and temporarily moving the unfastened bilge boards between buttresses. The results indicate that much of EP II's overall hull structure is similar to other vessels built along the European-Atlantic coastline, although several idiosyncrasies set it apart from known archaeological examples.
Amidships Hull Construction

The focus of this thesis is to understand the mainmast step and bilge pump construction on a typical 16th-century shipwreck. Achieving this goal and answering the additional research questions that went with it required exposing a large section of amidships. Compared against the efforts by the original archaeological team on EP I, who chose to excavate only half of the mainmast step to keep the other half buried for future researchers (Smith et al. 1995:25), archaeologists working on EP II felt an entire excavation of the amidships hull was necessary. During the removal of ballast it also became clear that several issues arose, which made uncovering the entire mainmast step assembly beneficial. Over the course of excavation it became clear that most of the mainmast step on EP II was buried by the remains from the pump well. Various pump well planks, stanchions, and unrecognizable debris could not be removed without opening additional units surrounding the mainmast step. After these units were clear, the pump well enclosure had to be removed systematically, to access the vital areas of the hull. Following this initial issue, there was a constant problem with visibility created partially by the environment and the shape of the surviving hull remains.

Throughout most of the year the bottom current on site runs in a northwest to southeast direction. Since the ship settled on its portside, with the bow pointing north, there is a significant amount of preservation of the first futtocks not seen on the starboard edge. Combining the current with the tilt of the ship created a sediment trap for any excavation units that were opened at amidships, especially when the top of the keel was 1.5 m beneath the natural bottom of the bay. Countering the natural elements required opening up amidships further, thus allowing sediment to deposit evenly over the area and quickly be removed by the current during excavation. Often the low visibility on site was hindered further by the lack of natural light.
reaching the bottom of the unit complex due to the amount of particulate in the water column. By opening the additional units, to assist in water flow, more light was able to reach where the excavators were working and allow them to more easily measure and record the hull.

Examining the mainmast step complex without including the accompanying hull structure was detrimental to understanding the idiosyncrasies present in the assemblage. During the recording process it became evident that other components of the hull, especially the floor timbers and ceiling, were affected by the design of the mainmast step and had to be taken into account during construction. As shown in Figure 66, other parts of the hull were recorded within the amidships section opened for the purpose of analyzing the mainmast step. Each component is described under individual section headings for quick review and are labeled on Figure 67 of the amidships site plan. Fragmented timbers from the pump well recovery are also mentioned and include the timber numbering system (eg. Timber 15 or T-No. 15) that was used on site. All of the removed wooden fragments recovered have scaled figures that can be found in Appendix A.

**Keel**

Due to excavation constraints, access to the keel was extremely limited and only a few observations were made. The keel is 29-30 cm sided below the mainmast step. Examination of the top face of the keel revealed that no rabbets are present. Support for the absence of rabbets originated with the keel sharing a similar sided dimension compared with the 30.5 cm starboard garboard strake and the 34 cm equivalent on the portside. Earlier excavations at the bow uncovered the forward end of the keel and recorded this section as 30 cm sided by 27 cm molded (Cook 2009:94). The underside of the keel was also described as somewhat rounded either through wear throughout the vessels' life or due to the grounding of the ship. Recent excavations in the stern have also described a similar slightly rounded shape on the bottom side of the heel.
Rather than perceive the underside of the keel as rounded due to wear it seems that the keel shape was probably hexagonal as an intentional decision made by shipbuilders. The hexagonal shape is not surprising as the Studland Bay, Western Ledge Reef wreck, San Juan, and Mary Rose have the same characteristics from northern Europe (Thomsen 2000:70; Loewen 2007b:31; McElvogue 2009:81; Bojakowski 2011:23).

**Floors And First Futtocks**

Excavations beneath the unfastened bilge boards and within pump sumps allowed access to several accompanying floor timbers and inboard ends of the first futtocks. Recording the floor timbers revealed the master frame with the central floor approximately 3.22 m long and 22 cm sided by 25 cm molded. The master frame was discernible as the only floor with futtocks attached on either side and is positioned below the second pair of buttresses just forward of the mainmast mortise. Floors recorded are 25-26 cm molded and their sided dimensions vary depending on location. Floors beneath the expanded keelson are 22-23 cm sided and decrease at the third aft floor from the master frame and the first forward floor to 19-19.5 cm sided. Room and space, meaning the measurement from the face of one floor to the same face on the next floor, varies from 36.5 cm at the pump sumps to 41 cm on either side of the master frame. Each floor includes evidence of being trimmed smooth with an adze and there is no obvious carving of numbering into the wood. The floors also have rectangular limber holes cut along the centerline directly above the keel with the master frame limber hole measuring 4 cm by 6 cm. Only a single wronghead is exposed from damage to the starboard bilge clamp, there is a 13.5 cm sided notch cut 13 cm square allowing an angle cut 5 cm sided to remain to drive a fastener from the floor into the accompanying first futtock.
Along with the floor timbers, three pairs of inboard ends from first futtocks were recorded. The starboard futtocks are 15-18 cm sided and 20.5-23 cm molded. Carpenters working on these futtocks cut the ends roughly to fashion them into an angular point up against the floor timbers. Only the forward master futtock was cut with more precision, as the end is flat and square with a tab notch for an iron fastener. Although difficult to measure in situ, each futtock was attached to the accompanying floor timber with an iron fastener near the end by means of a 2 cm square shank and 5-6 cm square head. Portside first futtock ends are 14-18 cm sided by 19-23.5 cm molded and appear to have been cut by different craftsmen than the starboard equivalents. Rather than cut the futtocks into a rough point, the portside craftsmen chose to cut the futtock ends with an adze into a flat angular surface inward, towards the face of the floor with notches cut for the fasteners. Some damage was identified on the portside futtocks attached on either side of the master frame, especially the aft futtock, which was split lengthwise. Considering the 14.5° tilt to portside at amidships and the greater preservation of the hull structure it would be logical for the futtocks to fail over time, yet the damage is only attributed to specific futtocks with splintered wood present. It is more reasonable to conclude that the damage is evidence from when the ship was initially driven onto the submerged sandbar from the hurricane. On the outboard edge of the first portside futtock aft from the master frame is evidence of an incomplete 2.5 cm diameter treenail hole, which was made for temporary bracing during the initial construction of the hull.

**Keelson**

Approximately 3.53 m of keelson was uncovered at amidships, including the 2.15 m long expanded section for the mainmast step. The exposed section of the forward arm from the expanded keelson is approximately 69 cm long and 23 cm sided by 16 cm molded over the
floors. Along the forward and aft arms shipbuilders chose to cut 5 cm wide bevels to remove the top edges. Only a single 2.5 cm diameter treenail was located toward the centerline of the forward keelson arm connecting this timber to the floor and keel below. From the terminus of the forward arm, the keelson expands over 13 cm in length to become 44 cm sided by 31 cm molded. Between floors, the underside of the keelson extends further to 38-39 cm molded, creating a notched profile with scalloped bottom edges 6-8 cm wide. On either end of the top face are robust concretions denoting the locations for two through bolts, approximately 5 cm in diameter, which connect the expanded keelson, floor, and keel together. Behind the forward through bolt is an unusual deck stanchion mortise 31 cm long. Evidence on the aft end of the mortise suggests the last 6 cm by 5 cm section, 3.5 cm in depth, was cut and never used. The remaining forward 25 cm varies between 6-7.5 cm wide and approximately 2 cm deep.

There is also a channel cut with similar dimensions connected to the mortise at approximately a 65° angle due north toward the starboard area and terminates at the edge of the beveled forward face in front of the first buttress. Originally, the channel was perceived as evidence from the wrecking event, but with the surviving 62 cm by 10.3 cm by 13 cm deck stanchion (T-No. 15), shown in Figure 68, positioned with its 11.3 cm by 5 cm tenon still in the main mortise, this hypothesis was thrown out. Instead, the channel appears to have been a modification by the original ship carpenters due to the construction of the pump well. As described below, the pump well was one of the last components built in the hold and required the mainmast step to be finished before installation. It appears that sometime between the installation of the keelson and prior to mounting the pump well, a carpenter cut out the original deck stanchion mortise. When it was time to install the forward pump well stanchions, the craftsmen realized that the current position of the stanchion was going to block installation of the forward
pump well wall. Construction on the vessel may have already advanced enough for the superstructure of the deck above to already be installed, making repositioning of the deck stanchion difficult. What survives on the surface of the expanded keelson suggests the ship carpenters cut an indirect channel to remove the deck stanchion, modify the mortise, and reinstall the stanchion in place. Two rather robust mallet handles (T-No. 2 and T-No. 3 described below) were probably used to drive the deck stanchion back into place. The deck stanchion tenon is still too short for the current mortise and no wedge was found to keep the stanchion from shifting. Either this wedge was lost or the carpenters may have positioned the deck stanchion forward in the hope that if it did shift, the forward pump well wall would keep it from unstepping.

Adjacent, and on either side of the aft wall of the deck stanchion mortise, are two pump well stanchion mortises cut into the expanded keelson after the mainmast step was fully assembled. The portside mortise is 9 cm by 7 cm and 5-6 cm deep; it is cut into part of the first portside bilge board and the second buttress. Along the starboard side the carpenters cut a 9 cm by 8 cm mortise, 6-6.5 cm deep and, unlike the portside, this mortise is cut further outward into the second starboard buttress. As a consequence, the bottom of the mortise has a central seam where the buttress and expanded keelson connect. Five centimeters behind the deck stanchion mortise is the 73 cm long and 19.5 cm sided by 16 cm deep mainmast mortise. Although craftsmen cut the sides smooth, the bottom was rough cut with an adze. There is a single 1.5 cm diameter drainage hole near the starboard aft face that allowed water to enter the bilge between the second and third aft floor timbers.

The forward shim and chock for the mainmast tenon were discovered in situ. Both timbers were roughly hewn with adzes to fit the mortise and shape desired by the craftsmen. The shim (Figure 69) was found between the forward face of the mainmast mortise and forward
chock. It was driven into the mortise 3 cm on the starboard side, but only 1.5 cm along the portside. Overall, the shim is 18.8 cm sided by 10.9 cm molded and 4.5 cm thick reducing to a pointed end. Behind the shim was a 12.5 cm by 18.9 cm by 18 cm molded chock (Figure 70). When the chock was mapped in situ originally, the starboard side rose 3 cm above the mortise, while the portside was only a centimeter. Removal of the chock indicated that it was raised 1-2 cm from the bottom of the mortise. The forward top edge of the chock is smooth and the front edge is curved, perhaps indicating the natural curvature of the wood. On the aft top starboard edge is a smooth circular notch 3.5 cm in diameter. Near the aft face of the mainmast mortise on the portside, sitting at the top of the sediment strata, was a 10 cm by 10.5 cm shim, shown in Figure 71. Compared with the adze-cut forward shim, the aft shim appears to have been sawn off the end of a square timber centered on the heartwood. The aft shim is 6.1 cm wide and reduces down to 2.2 cm, although the end of the surviving shim suggests it once tapered to a point. The missing fragment was probably lost during the wrecking event, snapping at the point where the shim was driven in between the mortise and aft chock. Between the tree rings on the side of the shim is evidence for a concretion. Most of the bottom aft section of the mainmast mortise contained a brittle concretion that was removed during excavation. The concretion did not have a definitive shape and was later found to contain little iron with evidence for a single small tack.

Between the aft face of the mainmast mortise and the aft through-bolt, lying on the top face of the expanded keelson, was the aft mainmast chock. The 29 cm tall aft chock (Figure 72) is 17 cm by 15 cm at the top and reduces to 17 cm by 8.5 cm on the bottom. It is slightly wedge shaped and larger than the square forward chock. Both the inner face and outer face of the chock have evidence for concretions with the inner face containing a 7 cm oval shape that may be the remnants of some small tackle. The inward face near the top includes approximately a 5 cm by 5
cm portion of missing wood. Based on the in situ remains, it is believed that the mainmast tenon was removed from the mainmast mortise with such force as to partially damage the aft chock and unseat it from its original position. The same action also slightly lifted the forward chock and shim, but it appears that the direction of the uplift prevented these components from being removed from the mortise. There are no obvious signs from an impression of the mainmast surrounding the mainmast mortise. When taking into account the thickness of the shims and chocks, these components reduce the amount of space in the mainmast mortise to 40 cm. Both chocks are taller than the mortise, which would have prevented any mast larger than 40 cm in diameter from being seated properly. Since the aft shim and chock were displaced when uncovered, it is difficult to know precisely how deep the aft shim was inserted. The surviving section of the shim reduces to 2.2 cm and has been perceived here as to the extent it was inserted originally into the mainmast mortise. Near the edge of the aft wall of the mainmast mortise on the top face of the keelson is the presence of a 2 cm square iron fastener driven into the floor beneath.

The last section of keelson reduces 11 cm through another series of bevels down to 23 cm sided by 20 cm molded over the floors and 27-28.5 cm in-between. Over the span of the exposed 70 cm aft keelson arm includes a 40 cm long horizontal scarf 12 cm behind the reduction of the expanded keelson. The scarf was made by cutting each timber 5 cm deep into the outer face and fashioned on an angle so that the two pieces fit perfectly. There is a single 2 cm square iron fastener located 6 cm aft from the beginning edge of the second keelson timber. The lack of additional fasteners led to the single fastener being snapped in half and the scarf becoming disjoined so that a 6 cm gap now exists.
Buttresses

Transverse support for the expanded keelson is provided with four pairs of buttresses that share similar, but varying dimensions as shown in Table 13. All of the buttresses are positioned above floor timbers with their outboard ends accommodated by notches into the adjacent foot wales. The hypotenuse face of each buttress has 2.5-4 cm rebates cut on either edge lengthwise to allow bilge boards to rest flush and create a smooth profile. Subtle differences between the starboard and portside buttresses suggest two different carpenters were in charge of their installation. On the starboard side, the first buttress includes a 7 cm wide beveled edge. All of the starboard buttresses are installed with two 2-2.5 cm square iron fasteners. The first fastener near the top inboard edge is on an angle to connect the buttresses to the expanded keelson. Another fastener near the bottom outboard edge connects each buttress to the floor timber underneath.

TABLE 13
EP II BUTTRESS SCANTLING MEASUREMENTS

<table>
<thead>
<tr>
<th>Buttress</th>
<th>Length (cm)</th>
<th>Sided (cm)</th>
<th>Hypotenuse (cm)</th>
<th>Inboard Height (cm)</th>
<th>Outboard Height (cm)</th>
<th>Risen From Floor (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starboard 1</td>
<td>63</td>
<td>21</td>
<td>66.5</td>
<td>29</td>
<td>7.5</td>
<td>4</td>
</tr>
<tr>
<td>Starboard 2</td>
<td>64</td>
<td>19</td>
<td>65</td>
<td>23</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Starboard 3</td>
<td>65</td>
<td>19</td>
<td>67.5</td>
<td>32</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Starboard 4</td>
<td>65</td>
<td>19</td>
<td>67</td>
<td>30</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Port 1</td>
<td>62</td>
<td>19</td>
<td>66</td>
<td>26</td>
<td>7.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Port 2</td>
<td>61</td>
<td>19.5</td>
<td>65</td>
<td>28</td>
<td>7.5</td>
<td>0</td>
</tr>
<tr>
<td>Port 3</td>
<td>62</td>
<td>21</td>
<td>66.5</td>
<td>29</td>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>Port 4</td>
<td>63.5</td>
<td>20</td>
<td>66</td>
<td>26</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

Installation of the buttresses on the portside is similar with all four components having a single fastener at the top to connect the timber to the expanded keelson. Only the first and second portside buttresses include evidence for a second fastener connecting these buttresses to the floors. There is no evidence for concreted fasteners on the lower outboard faces of the third and fourth portside buttresses. Along the outer edge of the second portside buttress is a single 2 cm
diameter treenail connecting the buttress to the floor. All of the portside buttresses include evidence of a countersunk notch cut into their lower outboard ends. The first buttress has a fastener present at the notch with the second buttress having a treenail on the outboard end. The area surrounding this treenail is heavily eroded, but suggests that it might also have had a countersunk groove.

Several buttresses on either side were discovered lifted up on their bottom inboard edges from the floor timbers. Most of the portside buttresses were lifted 1-2.5 cm above the floor, except the second buttress, which was not affected. Only the first two buttresses on the starboard side were affected, with the first buttress lifted 4 cm and the second buttress 6 cm respectfully. Although all of the inboard faces of the buttresses were still pressed against the expanded keelson, the lift from several of the buttresses suggests the impact of the ship against the sandbar was forceful enough to shift the position of these components.

**Bilge Boards**

Between each of the buttresses, ship carpenters placed boards to seal off the bilge from debris. Each of the boards, as shown on Table 14, varies between 66 cm to 70.5 cm in length and 23-27 cm sided by 2-3.5 cm thick. No fasteners or treenails are present. Rather than affixing the boards in place, the carpenters chose to cut notches into the surrounding keelson, buttresses, and accompanying foot wales that matched to a specific board. The keelson notches vary between 1.5-4.5 cm, although the notching is consistent enough that measuring across the expanded keelson between buttresses reduces the 44 cm sided top face to 41 cm sided. Buttresses are notched 2.5-4 cm and the foot wales are further notched 8-11 cm. The rebates allowed a smooth profile without any hard edges that may have prevented cargo or ballast from damaging the structural components. Originally, the flush profile was achieved, but the fact that each of the
boards over the past four centuries were being held up only by their edges has created a concave profile. The author personally removed each board, finding the first board on either side the easiest to remove, while the last boards were the most difficult.

**TABLE 14**

**EP II BILGE BOARD DIMENSIONS**

<table>
<thead>
<tr>
<th>Bilge Board</th>
<th>Length (cm)</th>
<th>Sided (cm)</th>
<th>Thickness (cm)</th>
<th>Keelson Notch (cm)</th>
<th>Foot Wale Notch (cm)</th>
<th>Buttress Notch (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Star</td>
<td>68.5</td>
<td>23-25.5</td>
<td>2.5-3</td>
<td>2.5</td>
<td>8</td>
<td>2.5-3.5</td>
</tr>
<tr>
<td>2nd Star</td>
<td>68.5</td>
<td>26-26.5</td>
<td>2.5</td>
<td>2</td>
<td>9</td>
<td>2.5-4</td>
</tr>
<tr>
<td>3rd Star</td>
<td>70.5</td>
<td>26-27</td>
<td>2.5-3</td>
<td>3</td>
<td>10</td>
<td>3-4</td>
</tr>
<tr>
<td>1st Port</td>
<td>67.5</td>
<td>25-26</td>
<td>3.5</td>
<td>2.5-4.5</td>
<td>10</td>
<td>3.5-4</td>
</tr>
<tr>
<td>2nd Port</td>
<td>67.5</td>
<td>25-27</td>
<td>2-3</td>
<td>2</td>
<td>10</td>
<td>3-3.5</td>
</tr>
<tr>
<td>3rd Port</td>
<td>66</td>
<td>23.5-25</td>
<td>2-3.5</td>
<td>1.5</td>
<td>11</td>
<td>2.5-4</td>
</tr>
</tbody>
</table>

When the carpenters crafted these boards originally, the seams were so close that the absorption of water practically sealed them shut. The boards were eventually removed by scoring the seam lines and slowly lifting along the edges with a dive knife. None of the boards were removed without some damage along the upper corners, which was already brittle from past exposure. The third starboard bilge board during removal broke into four pieces and the second portside bilge board eventually broke into two pieces longitudinally. Another two boards were broken longitudinally later due to low visibility and divers accidentally placing pressure on the wood. All boards broke along previously opened seams formed from the concave shape caused over time by the ballast and sediment covering the boards originally. Based on the dimensions and thinness of the boards, these planks seem to have been excess timber from the pump well manufacture.

**Ceiling**

Several ceiling planks forward of the first buttress and aft of the fourth buttress were uncovered. These boards, 35-38 cm wide by 5-7 cm thick, were installed to seal off the bilge
between the limber boards and foot wales on either side of the ship. The forward two ceiling planks rest their aft edge on the first forward floor timber, causing the first buttress on either side to be offset toward the stern. Each fourth buttress is off-center toward the bow so that the forward end of the aft ceiling could rest on the floor timber beneath. Each of the ceiling planks were kept in place based on the individual decisions by various carpenters. The forward port ceiling plank only has two 2-2.5 cm square iron fasteners triangularly countersunk, while the starboard equivalent includes a treenail. On the aft port ceiling there are more countersunk fasteners and treenails, while the starboard ceiling only has fasteners present. There does not seem to be a pattern with the fastening of any ceiling components, only that the iron fasteners were driven in from inside the hull while all of the treenails were countersunk and drove through from the outside. Several treenails and a rectangular 2 by 2.5 cm wooden nail are present along the seams between ceiling, foot wale, and bilge clamps.

Foot Wale

Although most of the components uncovered on EP II have similar features when compared with other contemporary examples built along the European-Atlantic coastline, the foot wales on EP II are an exception. Rather than install pronounced longitudinal stringers, the carpenters on EP II chose to install planks measuring 40 cm sided and 7 cm thick. The foot wales are held in place with a series of 2.5-3 cm in diameter treenails and many triangular countersunk iron fasteners. Among all ceiling recorded at amidships, the foot wale planks are the widest and their positioning above the connection between the floor timbers and first futtocks supports denoting these planks as foot wales. Approximately 1.45 m aft from the fourth starboard buttress is a two-part foot wale scarf. The outboard end is an 8 cm straight horizontal scarf 5 cm deep, while the remaining 33 cm is a longer horizontal scarf cut on an angle. Based on what has been
uncovered, it appears that the bilge clamp widens while the foot wale is reduced the further away the latter is from amidships. Evidence discussed in Chapter 2 on Mediterranean and Scandinavian shipbuilding traditions indicate longitudinal stringers were robust pieces of timber that often sat proud above accompanying ceiling planking. Only the Romano-Celtic shipbuilding lineage, which eventually produced the medieval cog, includes stringers similar to EPII, composed of wide thick planks horizontally scarfed over the lower interior of the hull. Other closer examples in time stem from the 15th-century Newport shipwreck with 10 wide stringer planks across the lower surviving section of the hold and evidence for two wide bilge stringers on the early 16th-century Ria de Aveiro A (Alves et al. 1998:338–340; Nayling and Jones 2014b:18–21).

**Bilge Clamp**

Bilge clamps are planks found on the outward edge of the foot wales and complement the latter to clamp wrongheads of the floor timbers to the rising first futtocks. Bilge clamps are 32 cm sided on portside or 34 cm sided to starboard and 7 cm thick. Each side is held to the floor timbers and first futtocks through various 2.5-3 cm diameter treenails and triangular countersunk iron fasteners 2-2.5 cm square. Most of the countersunks across the ceiling have been filled in by the fastener concretions, but enough shape still exists to indicate a triangle cut made by an adze or axe. The starboard bilge clamp includes damage either from the hurricane or earlier that has removed a section adjacent to the fourth buttress location. Ballast stone and pottery recovered from the hole indicates that the damage was made before the ship sank.

**Sill**

The last strakes of ceiling planking in the hold, known as the sill, are crenellated along the outboard edge to cap off the bilge between first futtocks with filler planks. Ship carpenters
installed the sill by creating 6.5 cm diameter countersinks with an iron fastener along the inboard edge. Each fastener is centrally positioned over the first futtocks and between the filler planks. There is evidence of a second set of countersinks offset from the first on the portside and closer to the outboard ends between crenulations. The sills are 22-26 cm sided and 5-7 cm thick over the first futtocks, while the space for the filler planks varies around 15-20 cm sided. Filler planks cap off the wrongheads of the floors and prevent debris from entering the bilge or possibly clogging the bilge pumps. Each of the first futtocks sided measurements vary, thus the filler planks were custom cut to fit specific crenellations along the sill. Filler planks at amidships are 50-57 cm long, 19-22 cm sided, and 5-7 cm thick. No filler planks at amidships include evidence for being fastened down. Carpenters beveled each end so that the inboard created a smooth profile with the sill, while the outboard ends matched the curvature of the outer hull.

**Limber Boards**

Limber boards are removable planks to access the bilge and clean out debris that could clog the bilge pumps. Next to the ceiling planks, forward of the first buttresses, are two long limber boards without any fasteners present. These boards are 26-28.5 cm wide and 7 cm thick with their aft ends resting on the lip created by shifting the first buttresses back. The shape created by the expanded keelson in this area required carpenters to custom fit these limber boards. On the starboard side, aft of the fourth buttress, there is a large gap between the outboard ceiling plank and the expanded keelson where the limber board is missing. The board would have been 35 cm long by 16.5 cm sided and around 5 cm thick. Fortunately, the aft short limber board, 38.5 cm long by 27.5 cm sided and 4.5 cm thick, survived in situ. The latter board has a 4.5 cm bevel on the aft edge and is positioned so there is a 2.5 cm gap between it and the beginning of another 28 cm sided limber board. On the portside, a single short limber board 40.5
cm in length and 19.5 cm sided by 2.5 cm thick is positioned aft of the fourth buttress. Along the aft wall of the portside pump sump is a 30 cm long and 25 cm sided by 7 cm thick limber board with a 1.5 cm space between this board and the next consecutive limber board. Only the forward portside limber board has a beveled curved edge toward the pump sump. The presence of these short limber boards suggest that the carpenters wanted adjustable limber boards that could shift slightly depending on the shape of the pump tubes installed. Both aft limber boards have been shifted slightly forward covering part of the pump sump and suggests that when the bilge pumps were salvaged these boards were moved out of place.

**Bilge Pumps and Sumps**

Approximately 40 cm aft of the mainmast step two pump sumps were uncovered on either side of the reduction from the expanded keelson. When excavators originally removed sediment and ballast there was hope that the foot valves or associated pump artifacts may have been left in situ. Excavations, unfortunately, did not reveal any components, meaning that the pumps were probably still serviceable and were removed as part of the salvaging efforts. Documentary evidence from the account record for the Luna expedition also includes sending additional pumps with the first relief squadron (Yebra 1569:folio 32). Surviving pumps were probably combined with new pumps in an effort to remove water and refloat surviving parts of the fleet.

Both pump sumps are 31 cm deep from the top of the ceiling to the outer hull and include semi-circular cuts 24 cm deep on the back face of the third aft floor and the front face of the fourth aft floor. These shallower semi-circular notches create a 7 cm step on either side of the 17.5 cm space between floors. The starboard pump sump is 32.5 cm in diameter, while the portside is 29.5 cm in diameter. There is no significant evidence of modification on the keelson
to compensate for the pumps, except for the underside extension between floors. The lower sides of the keelson were cut with chevrons 7-8 cm high rather than the scalloped recesses found under the expanded keelson. Even though the ship carpenters went through the process of cutting circular notches into the floor, the surrounding ceiling and limber boards currently provide a 27 cm by 27 cm opening on both sides to insert the pumps. If the aft limber boards are shifted back into place the opening is widen to the diameter cut into the floor of each pump sump.

The box opening could be interpreted as the lower pump tubes were cut square, as seen on the San Juan (Loewen 2007a:165), although the circular cut of the forward portside limber board suggests that both tubes were rounded. On the other hand, San Juan's pump also sat on the edge of the keel and garboard seam. Other examples of the pump foot resting on the outer hull includes Highbourne Cay, Western Ledge Reef, Newport, and Angra D shipwrecks (Oertling 1989b:249 Garcia and Monteiro 2001:443; Bojakowski 2011:29; Nayling and Jones 2014b:24). The Cais do Sodré and EP I shipwrecks indicate burr pump foot valves in the Mediterranean tradition, where the foot valve rested over the floor timbers for support, rather than sitting on the outer hull (Smith et al. 1995:29; Castro et al. 2011:340). There is also an example from the Mary Rose where English carpenters chose to cut a step at the bottom of the pump sump, similar to the arrangement found on EP II (McElvogue 2009:289). Most of the other examples with surviving evidence for bilge pumps emphasize a burr pump configuration, while the Mary Rose has the earliest evidence of a common pump on board. Almost all of the burr foot valves require sitting on the very bottom of the hull and include notches along the underside to allow movement of bilge water into the pump. The pump sumps on EP II allow for at least 7 cm of water to move under the pump without the need for any notches to be installed in the pump itself. Although existing pumps include four underside notches, the pumps on EP II would only be able to use
two if the pump was situated for the notches to run transversally between the floor timbers. Based on the fact that the bilge pumps on EP II did not sit on the outer hull and that the steps within the pump sump created 7 cm of clearance to the outer hull suggests that the ship was equipped originally with common pumps.

**Pump Well**

Pump wells were a box-like enclosure usually built to encompass the pump tubes and protect them from shifting ballast or cargo within the hold. Pump wells were also intended to prevent debris from reaching the pump sump and causing irreparable harm to the actual bilge pumps. Initial excavations surrounding the mainmast step uncovered 31 disarticulated planks, stanchions, and various smaller wooden pieces, shown in Figure 73. Out of these timbers, 24 pieces were identified as part of the pump well construction. Four stanchions (Figures 74, 75, 76, and 77), uncovered in the vicinity of their respective mortises, provided the framework to which the planks attached. Starboard stanchions (T-No. 8 and T-No. 12) are 14 cm by 12 cm and both timbers survive to 63-66.5 cm in length. Portside stanchions (T-No. 20 and T-No. 27) are 15.5 cm by 13.5 cm and vary from 57.5 cm forward and 78 cm in length aft. The surviving length of the aft stanchion is due to the timber being surrounded by pump planks and other wood materials. All of the pump well stanchions include several fastener holes approximately 1 cm square on at least two faces.

All of the pump well stanchions, along with the single deck stanchion (T-No. 15) uncovered, have significant damage from teredo worms. Each stanchion was carved with a tenon 7-9 cm by 5.5 cm, except the portside aft stanchion, which has an 11 cm by 6.5 cm tenon. The significant survival in length of the aft portside stanchion also includes evidence for a triangular notch 2.6 cm by 2.1 cm and a 1.5 cm diameter hole through the inward face of the notch to the
other side. Rather than lower a ladder into the pump well from above, it appears that the carpenters chose to create several notches using an axe along the inside of each stanchion to act as a ladder system to enter and exit the pump well. The port aft stanchion was positioned in the corresponding mortise for the notch-step to be easily accessible inside the pump well. Timber 13 and 9 are two stanchion fragments (Figures 78 and 79) that were recorded next to the aft starboard stanchion and were probably once part of an upper section. Timber 13 includes two triangular notches 4 cm deep by 5 cm in length with one oriented above the other.

Mortises for the pump well stanchions were cut into the lower hull structure after the assembly was complete. Both forward mortises are 33 cm apart and cut into the surrounding expanded keelson, edges of the first bilge boards, and second buttresses. Forward stanchions were positioned lengthwise, parallel with the ship, while the aft pump stanchions were perpendicular. Aft mortises are 9-12.5 cm by 7-9 cm and 6 cm deep with both mortises cut directly into ceiling planking. Carpenters cut so deep into the ceiling that only a thin 1 cm layer was left on the portside, but the starboard mortise was cut all the way through and is positioned between floors. Compared with the forward mortises, the aft mortises are 1.02 m apart, causing the pump well to take on a long trapezoid shape, shown in Figure 80 and 81. Surviving pump well plank lengths also attest to the unusual shape with two (T-No. 14, T-No. 18) 52.5 cm by 24 cm forward planks (Figures 82 and 83), three (T-No. 5/6, T-No. 7/30, T-No. 10) planks 135-195.5 cm by 20 cm on starboard (Figures 84, 85, 86, 87, 88), another two planks (T-No. 11 and T-No. 23) 170-183.5 cm by 23-25.5 on portside (Figures 89 and 90), and two 119.5-129.5 cm by 24-28 cm planks (T-No. 25 and T-No. 26) along the aft walls (Figures 91 and 92). Based on tool marks, it appears that the planks were sawn lengthwise with all of the front planks and one of the starboard planks beveled on the edges with an adze.
Most of the pump well planks are around 2.5 cm thick, except along the portside, which are 4-5.5 cm thick. The latter planks are the same thickness as the outer hull planking on EP II and suggests that these planks were outer hull planking reworked from another vessel. Each portside plank also has multiple 1 cm square fastener holes spaced evenly along the edges. Both planks also include the remains of pitch used to seal the outer hull from leaking and marine organisms. Timber 23 also includes marks made by the carpenters into the wood of rectangular and square shapes for possible holes that were going to be cut into the board. One end of T-No. 23 has been cut for a vertical scarf to connect this plank with another. Several of the starboard side planks and both aft planks also show evidence of additional fastener holes 0.5-1 cm square; located in areas where no stanchions are present and suggests these planks were also reworked for building the pump well. Both aft wall planks have further modifications associated with other construction. The lower of the two planks (T-No. 26) has reverse bevels on either lengthwise edge and includes several nail holes along its face, including a larger 1.5 cm by 0.5 cm hole with a 2 cm square fastener head impression. Along the top edge of the upper aft plank (T-No. 25) is a 4 cm by 10 cm notch and evidence of another notch formed on an eroded edge. Several 0.5 cm square fastener holes are also present along both edges, suggesting that the plank was held at some point against several frames. When taking into account the placement of the mainmast and pump tubes, very little space was available to move and service the pump sumps. If the mainmast was 40 cm in diameter, it would only leave 16 cm on either side to move past to reach the pumps. The portside pump tube allowed 25 cm by 19 cm of clearance and the starboard was 22 by 25.5 cm. These compact spaces emphasize that either the pumps were pulled out to be serviced or a smaller individual, perhaps a paje, or cabin boy, was sent down to clean the pump
sumps. The fact that the pump well covered part of the bilge boards would have made it difficult for a sailor of any stature to clean the bilge in this area properly.

Pump well planks were most likely chosen from available scrap that could be found in the shipyard. The only exception to this assertion might be the forward pump well planks, but these were probably cut so short to fit between the forward stanchions that carpenters could easily cut out between fastener holes from previous use. Most of the pump well planks recovered indicate that these boards were not fashioned previously for another component on EP II and were instead refurbished, probably from the repairs to other vessels. During the rebuilding of the pump well it became apparent that several fastener holes on the pump well stanchions were also from previous use. There appears to be a difference and standardization in thicknesses for planks intended to be used in interior construction compared to the exterior of the hull. Several pump well fragments recovered from San Juan and Mary Rose also contain pump well planks 2.5-2.6 cm in thickness (Waddell 1985:251; McElvogue 2009:289). Additionally, the planks enclosing the internal cabins on the main deck of the Mary Rose were 2 cm thick (Marsden 2009:173). Although there appears to be similarities, the contemporary shipwrecks 29M and 27M from Red Bay have pump well planks 6 cm thick (Ringer 2007:206; Stevens and Waddell 2007:210). The difference from the latter vessels may have to do with available lumber supplies and regional shipbuilder preferences. Revisiting these ships might reveal that their outer hulls were also 6 cm thick.

Although the robust stanchions and pump well planks indicate building an enclosure to keep ballast and cargo from damaging the pumps or the mainmast step, it is the smaller fragments of wood recovered which suggest that the ship carpenters were concerned to seal smaller debris from reaching the pump sumps. By constructing the pump well enclosure to
include the mainmast it reduced the amount of planks and allowed carpenters to rely on smaller timber fragments to seal the space between the lowest plank and the ceiling aft of the buttresses. None of these pump well filler pieces have any standardization and it seems the carpenters chose whatever scrap timber was available in the shipyard. Only six filler pieces were recovered that could be associated with either side of the pump well. There are significant timbers still buried and exposed along the south walls of the excavated units that suggest these timbers, along with additional pump well material, are still buried and, for now, left in situ. On the portside, excavators recovered a sawn outer hull plank (T-No. 28) 26.6 cm by 21.5 cm by 3.9 cm with two countersunk 1 cm square nail holes present on one end, shown in Figure 93. There is a thick layer of pitch on the face with the countersunk, suggesting that the plank was another repurposed outer hull timber fragment. It was originally found beneath the portside pump planks just forward from the aft port pump well stanchion. The end closest to the fastener holes is cut straight, but the opposite end has been sawn on an angle. Timber 28 seems to correspond with T-No. 29 (Figure 94), which is a wedge 65.3 cm by 7 cm by 8.3-0.5 cm found in the same vicinity resting over the port pump sump. The wedge was worked from some unknown type of wood with a red tinge. It was carved using an adze with the top and bottom faces smooth and the sides left more rough and unrefined. The thicker back end has a rounded edge and there is evidence of some pitch on the top face at the other flat end. There is also a 1.5 cm extended lip on one side of the wedge, perhaps to help prevent the timber from flipping on its side. The last portside filler piece, T-No. 24 (Figure 95), is 73.5 cm by 4.5 cm by 2 cm and appears to be made from pine. It is smooth on the wider faces and has rough beveled edges lengthwise. When Timber 24 was recovered one end broke off and was subsequently lost during recovery, the lost section did not increase the length much further than what has survived.
Portside pump well filler pieces include a short plank, known as T-No. 19 (Figure 96), that is 32 cm by 9.6-10.2 cm by 3 cm with a slightly convex end and rough bevels on the edges. No other identifiable features are present and only the two ends where it was sawn show any evidence for tool marks. There are some small pieces of resin residue left on one of the faces. The plank was recovered adjacent to the lower starboard pump well plank. Another filler piece, Timber 17 (Figure 97), was found in the starboard strata near the starboard pump well planks and is a small shim 48.7 cm by 5.6-2.4 cm by 2.8 cm with .5 cm square fastener holes on either end. The shim appears to be a fragment from another internal plank with every face worked smooth except one of the long thinner faces, which is smooth at the ends and rough in the middle. A shim, labeled T-No. 21 (Figure 98), was found in the same vicinity and is 45.5 cm by 7.7-5.2 cm by 3.7 cm. There are no fastener holes present and this shim has been cut on all the faces. On one of the long wide faces there is a rectangular cut into the wood at the edge with the center wood left intact. Later excavations near the starboard aft pump stanchion mortise found a final shim (T-No. 32), 39.2 cm by 15 cm and 4 cm thick, shown in Figure 99.

What remains of the pump well filler pieces suggests that additional pieces are missing to complete the sealing of the pump well from the remainder of the hold, yet the surviving pieces provide a picture of how this construction took shape. Along the portside, T-No. 29 sat directly on the ceiling with the thicker end up against the port fourth buttress. Timber 28 may have sat on its side with the flat edge against the keelson and the angle edge following the shape of the port aft pump well stanchion. On the starboard side, T-No. 17 and T-No. 21 were most likely shims that were used to seal off the lower pump well plank on top of the buttresses and bilge boards. Timber 19 is difficult to ascribe to a specific section of the pump well, but it may have been positioned aft of the fourth starboard buttress.
The deposition of the different pump well components revealed another aspect into the wrecking event. All of the starboard pump well stanchions, planks, and filler pieces were spread out along the edge of the keelson and suggest these components fell through natural decay and the tilt of the entire hull in this direction. The forward port pump well stanchion was held in place by the accompanying pump well planks, ballast, and sedimentation. Only the aft portside of the pump well indicates that some force was applied in this area causing all pump well components to be found clustered toward the keelson rather than outward, as would be expected. The aft portside pump stanchion was laying with the tenon on the ceiling approximately 21.5 cm away from its associated mortise, while the upper surviving section was running parallel with the keelson and laying against the aft pump well planks towards the stern. These aft pump well planks on the portside were also shifted backwards with the portside pump well planks swung inward. All of the filler pieces ascribed to the portside were found inside the pump well near or against the keelson. It appears that when the ship grounded against the sand bar, the forward port stanchion was less affected due to its position being supported by the accompanying deck and starboard stanchions, along with support from the heavier portside planks. The aft portside stanchion did not have similar support and was displaced from the mortise toward the centerline of the hull with adjacent assembly in tow.

Disarticulated Timbers

Several timber recovered from the mainmast step area in the hull were not associated with the pump well enclosure. The first timber, T-No. 1 shown in Figure 100, is 62 cm by 7.2 cm and has a flat side and a convex side resulting in 3-4 cm of thickness. Originally the component was found approximately 30 cmbs beneath a layer of ballast and forward from the mainmast step complex. There is no other evidence for the intended use of the timber, except that the convex
side was shaved to a smooth profile. Since the pump well had an internal ladder system, the current theory is that T-No. 1 may have been the step to a ladder for entering the remainder of the hold.

Two other timbers, T-No. 2 and T-No. 3 (Figures 101 and 102), were located near each other pinned against the hull beneath the ballast. Timber 2 is 41.6 cm by 6 cm by 5.6 cm and T-No. 3 is 37.8 cm by 6 cm by 5.5 cm. Both timbers were heavily worked with an adze and include beveled edges creating a rounded octagonal profile. One end of T-No. 2 is shaped with the remains of a 4.5 cm by 2 cm tenon. The other end is trimmed into a convex shape with evidence for three 0.5 cm square nail holes along one side. Timber 3 has both ends trimmed and evidence for a 6 cm by 1.5 cm tenon on one end with a more pronounced 5.5 cm by 3.5 cm tenon on the other. Along the side of T-No. 3 is a 3 cm in diameter natural knot that the carpenters appeared to have left intact besides shaping it to the rest of the timber. The closest comparisons for these artifacts are the numerous mallet handles found on the *Mary Rose* and amongst a ship carpenter's kit also found onboard (Gardiner and Allen 2005:309–310). While the length and shape fits the mallet handle characteristics, the 6 cm width makes these timbers slightly larger than those found on the *Mary Rose*. The possible mallet handles on EP II may represent a larger style of mallet intended to be used in shipyards rather than for shipboard use. Since the tenons for the mallet handles were broken and both timbers were located beneath the ballast, it is believed that these handles were thrown away purposely because there is no evidence that the hull was cleaned from wood waste after construction. The handle locations are also adjacent to the channel cut into the expanded keelson for repositioning the deck stanchion and may be remnants from this laborious task.
Three other timbers recovered during excavations either have no known comparisons or are broken segments without enough recognizable features to provide definitive context as to their purpose. As with the mallet hammers, the fourth timber, or T-No. 4 (Figure 103), was recovered beneath the ballast layer on the starboard edge of the buttresses. It is a worked and relatively square piece of wood 45.3 cm by 5.2 cm by 5.7 cm that shows evidence of being smoothed on three faces and split away on the last face. There is a single knot toward the middle of the timber that appears to have affected how the split occurred. This piece may be the remnants of another carpentry tool that was left behind when broken within the hull or a fragment from a shim as part of the lower section of the pump well. Found amongst the pump well components was a broken rounded piece (T-No. 22) 35.6 cm by 5.5 cm in diameter, as shown in Figure 104. It appears to be a thicker piece of a tree branch that has had the bark removed and a possible nail hole on one end due to the presence of a small concretion. The last timber, T-No. 16 (Figure 105), was located between the forward pump well stanchions and against the inside face of the portside pump well planks. The timber has an off-centered pyramid shape 9.5 cm by 8.3 cm at the base and rises 11.6 cm in height with a 1 cm square nail hole at the tip. All of the corners have been beveled off using an adze to create the shape. It is difficult to ascertain the reason for this timber and it may be a unique piece that a carpenter designed for a specific function.

Analyzing Amidships

Throughout the excavation phase and during the recording of the hull many idiosyncrasies became apparent on how the ship was constructed and the events that unfolded around its demise. Based on differences seen in the fastening pattern from the buttresses, it appears that individual ship carpenters decided on how certain components of the hull were
installed. The presence of unused countersunk notching along the outboard edges of the portside buttresses further suggests that individual decisions affected how and whether fasteners were required. Other idiosyncrasies include the decision by ship carpenters to build a pump well enclosure that included the mainmast. By including the mainmast inside the pump well, craftsmen had to reposition the deck stanchion in front of the mainmast further forward. Furthermore, a possible lack of available wood or the ingenuity of the ship carpenters is apparent by choosing to build the pump well with repurposed scrap wood removed from other ships.

Recording components individually and analyzing them cohesively has provided insight into the wrecking event. Based on the lifting of the buttresses, the splitting of portside first futtocks, and the damage to the aft portside pump well, the ship likely broke away from its mooring anchors somewhere southeast of its current location. The destruction within the hull emphasizes that the storm surge and wind drove the ship northwest into the sandbar with enough force that the aft scarf fastener for the keelson was sheared in two. Either during the wrecking event, or prior to because of hurricane winds, the mainmast was lifted out of its mortise causing the aft chock to be flung out and snapping off the edge of the aft wedge. It is difficult to imagine that the ship was jolted with this much force, but the fact that the aft port pump stanchion was found popped out of socket seems to support this scenario.

There are also several observations that can be made about the vessel simply from the excavation. Throughout the ballast strata and accompanying sediment, most of the artifacts recovered were smaller incomplete ceramic fragments and barrel components; the largest of which was a 1.275 m long barrel stave. Most of these artifacts were located higher up in the strata, although there were still some artifacts recovered closer to the hull. Everything that survived the hurricane and remained in the ship was picked clean by the colonists and mariners,
leaving behind only broken pottery and few barrel pieces that could not be reused. It still seems unusual though that more debris was not found and suggests that the ballast had been installed recently or the hold had been cleaned thoroughly prior to the voyage. Another possibility is that the ship was already offloaded in Pensacola and may have been preparing to leave with little remaining on board. Cleaning out the bilge beneath the expanded keelson between the bilge boards there were some expectations that artifacts would be found in this area. Only a few ceramics were located beneath the starboard third bilge board and none were recovered along the portside where the tilt of the ship in situ made this area the deepest point for objects to settle.

Excavation revealed concretions all along the top face of the keel clogging the limber holes and dredge spoil was mainly composed of wood chips or excess worked wood. The investigation of the pump sumps included more ceramics, although these appear to be fragments that tumbled into the pump sumps after the wrecking event when the pumps themselves were removed.

An example of ceramics moving within the hold includes two recovered pieces of El Morro pottery (15W-5908 and 15W5924) that mend together; however, one section was found above the ceiling planking in the lowest ballast strata while another was found inside the pump sump on the outer hull away from the sump opening. Other ceramics from the pump sump were left in situ because the concretion in this area cemented everything to the outer hull. The only other area in the bilge where artifacts were found was behind the starboard fourth buttress, where the absence of a limber board left access for an animal bone and a bung to enter the bilge. Several pools of mercury were also found along the outer hull throughout the bilge, which is likely evidence from the cargo the ship was carrying across the Atlantic. Cleaning the bilge and the pump sumps on this ship would have been extremely difficult due to the positioning of the pump well and the lack of space to work; even if the pumps were removed temporarily. The fact
that little was found in the bilge under the expanded keelson and in the pump sumps may suggest that either the bilge was cleaned prior to the expedition or it may have been a recently built ship.

Other evidence that the ship was built recently includes an unused treenail that was found lying beneath the first portside bilge board. Removing the treenail revealed that carpenters repurposed the wooden fastener into a wedge with the head exposed and the remainder inserted in the space between the foot wale and the first futtock. The reason for the presence of the treenail wedge was due to a section of the foot wale being cracked between the first and second portside buttresses. As mentioned above, there were also the two mallet handles (T-No. 2 and T-No. 3) that were recovered, pinned to the hull beneath all of the ballast. The location for the mallet handles and their larger thickness suggest these were for shipyard use rather than utilized by the ship's carpenter. Furthermore, there is a general lack of repairs amidships with little damage to the mainmast step components. Compared to EP I, which is believed to have lost the portside of the vessel beyond the end of the ceiling planking during the hurricane (Smith et al. 1995:34), additional sections of EP II's hull remain intact, thus allowing the possibility to find repairs to the hull along the ceiling or to the outer hull when accessible. The surviving sections at amidships indicate that the vessel was relatively new at the time of sinking, although it remains possible that future excavations elsewhere may reveal repairs on the outside of the hull.

Could EP II Be A Northern-Built Ship?

Questions still remain as to why the ship carpenters chose to include flat wide foot wales rather than the more traditional pronounced stringers found in other shipbuilding traditions. The shape of the pump well with the inclusion of the mainmast is a unique feature when compared to known archaeological examples and is not necessary for sealing off the pump sumps. Additionally, the wide keel without rabbets at amidships seems to stem from a northern
European influence. When examining the account records from the expedition, almost all of the ships that were either bought or contracted for the voyage were specifically charged with repairs in the shipyard at San Juan de Ulua. Only the urca Jesús was an exception to the rule, as there is no mention of a single caulker or carpenter paid to repair this vessel. Annual fleet lists for ships sailing to the New World indicate that the Jesús (departs 1557), Santa María de Ayuda (departs 1559), and Corpus Cristi (departs 1559) were new vessels taking part in state sanctioned voyages across the Atlantic (Chaunu and Chaunu 1955:552,572,578). Research focused on the Jesús because the other vessels were both smaller and had different ship masters by the time they reached San Juan de Ulua. For some reason the ship master of the Jesús, Francisco de Ecija, chose to remain with the ship and is never mentioned as overseeing any previous annual fleet voyages. Prior to the Luna fleet departing for Pensacola, the royal treasurers provided half the promised pay to each vessel with expectations that the remainder would be given once the ships arrived at their destination. The Jesús is once again an oddity because Ecija is the only ship master paid in full before departure from San Juan de Ulua, due to an understanding he was to offload at Pensacola and sail directly back to Spain (Yugoyen 1569:folio 505).

Additional evidence as to the identity of EP II stems from the tonnage ratings that were given to contract Luna ships at San Juan de Ulua. Ship masters were paid 6 tomínes per tonelada per month, which meant that the accuracy of these tonnages was very important. Tonelada was a 16th-century Iberian volume measurement based on the number of wine barrels that could fit into a vessel. Each ship at San Juan de Ulua was rated through a committee of pilots, ship masters, and master carpenters present at the time (Yugoyen 1569:505–506). The tonnage formula used on the Luna ships was not written down, but two out of the three largest ships in the fleet were given ratings. The Jesús was 570 toneladas, while the nao San Andrés was rated at 492½
Sixteenth-century tonnage formulae relied on geometric principals based on the beam, length of the keel, overall length, and the depth of the hold (Casado Soto 1988:74,81). Renaissance art and mathematics heavily influenced shipbuilding design at the time by incorporating an ideal ratio as 1: 2: 3, where the keel was twice the beam and the overall length three times the beam. The depth of the hold was represented usually as half the beam. Several contemporary naval treatises and personal letters mention and describe various tonnage formulae and slight differences in the ideal ratio (Casado Soto 1988:73–93). Although the beam and overall length on EP I and EP II could not be obtained by the lower hull, the preservation in Pensacola Bay meant that both ship's keels are fully preserved. The remaining aspects of the hull could be found simply by using the ideal ratio and converting the overall keel lengths into the codo, which was the 16th and 17th century unit of measure in Spain.

There were two means of measuring the codo, depending on whether the ship came from the Cantabrian or Andalucían coasts (Casado Soto 1991:103). Measurements originating from the Basque shipbuilding community (Cantabrian) relied on the codo cantabrico, also known as the codo de ribera or codo real (0.57468 m). Spanish Crown officials and local shipwrights operating out of Seville for the Indies trade utilized the codo castellano (0.55726 m). The difference between the two measurements (0.01742 m) was significant in the overall dimensions of the vessel and the subsequent tonnage formulae rating system in place at the time. Further confusion on tonnage semantics developed due to differences between the tonelada and toneles. Originally a unit of account, tonelada referred to the addition of 20% or 25% from the tonnage of a vessel measured in toneles. This estimation was considered a bonus to be paid to ship owners when their vessels were in service to the Crown. Toward the middle of the 16th century, toneles and tonelada were semantically combined in southern Spain (Casado Soto 1988:69–70).
Tonnage formulae in the 16th century required the total length of the keel, which is misleading due to ship construction at this time. The overall length of the keel is from the beginning of the aft face from the stem-keel scarf to the terminus connection between the heel timber and sternpost rabbets (Loewen 2007b:37–38). Ship construction at this time included a main keel timber and a heel timber, which was the connection between the keel and the sternpost. Investigations on EP I located the forward scarf of the keel, but were unable to reach the bottom of the sternpost to know exactly the terminus of the overall length (Smith et al. 1995:35). Since the team was able to measure the angle of the sternpost, the final reports estimate EP I's overall keel at 23.6 m (Smith et al. 1998:32). Excavations on EP II have also included finding the keel's forward stem scarf and excavations have reached the bottom of the heel at the sternpost. The aft scarf between the main keel timber and the heel has not been located, but it is believed that the working estimation of the main keel timber is around 21.5 m long (Greg Cook 2014, pers. comm.). Recent excavations at EP II's sternpost included uncovering the bottom of the heel timber on the starboard side revealing evidence that the distance from the lower edge of the garboard to the bottom of the heel is approximately 13 cm as shown in Figure 106. With this information, along with the 69° rake of the sternpost, the length of the overall keel on EP II is estimated at 22.52 m.

Through trial and error between various tonnage formulae and ideal ratios research uncovered the possible variation that was used in the San Juan de Ulua shipyard. The ideal ratio provided by Juan de Escalante de Mendoza in his 1575 ‘Itinerario de navegación de las tierras y mares occidentales’ (Itinerary of navigation for the western lands and seas) as 1: 2.2: 3.2 was combined with a formula written down by Captain Rodrigo de Vargas, inspector of naos from 1565 to 1575 (Casado Soto 1988:271–274). Vargas' letter is dated to around 1570 and was
written to address concerns to the Duke of Medina Sidonia on how an inspector was needed at San Lúcar. He includes his formula for rating ships based on the overall length (Eslora), depth in hold (Puntal), and beam (Manga). Beginning with the depth in hold added to half the beam, this amount is then divided in two. The result is squared and multiplied by the overall length, allowing the total to be divided by 8 to convert to toneles.

\[
\frac{E\left(\frac{P + M}{2}\right)^2}{8} = \text{toneles (ca.1570)}
\]

\[
\frac{56.999 \left(\frac{8.906 + \frac{17.812}{2}}{2}\right)^2}{8} = 565.122 \text{ toneles}
\]

After converting the overall keel lengths for EP I and EP II from meters to codo de ribera, the results indicate that EP I is 651 toneles and EP II as 565 toneles. Reviewing the Luna documents written down by colonial notaries, it becomes clear that these officials did not differentiate between toneles or toneladas and that the semantic combining of these words had already taken place in New Spain by 1559. Both Emanuel Point ships have been estimated as two of the largest three vessels in the fleet, simply by their overall dimensions. Nevertheless, scholars have remained cautious in applying identities to the remains (Worth 2009:88). Original investigations on EP I included an underlying assumption due to the length of the keel, along with its slender bow and stern, that the ship was a galleon (Smith et al. 1995:140; Smith et al. 1998:165). Based on the known documentary tonnage ratings of the other large vessels in the fleet, the larger tonnage implicates EP I as the older galleon San Juan de Ulua. Rating EP II at 565 toneles further adds evidence that the ship might be the urca Jesús, which was reported prior to the fleet leaving New Spain at 570 toneladas. If the committee was unable to properly
measure the keel length because the aft rabbet line was covered with lead sheathing and instead measured to the outboard face of the lower sternpost (at 22.58 m as shown in Figure 106), then the result from the formula reaches exactly 570 toneladas and may account for the 5 tonelada error.

When the Jesús departed from Cadiz it was described officially as a nao (Paz 1558), after it arrived at San Juan de Ulua with the rest of the annual fleet, it was described solely as an urca (Yugoyen 1569). Apparently this discrepancy was normal, due to contemporary sources stating that urcas were registered as naos when accompanying the annual fleets (Casado Soto 1988:116). The identity of the Jesús and origin for the unusual construction features of the mainmast step on EP II are difficult to pinpoint based on available evidence. All of the urcas that were confiscated for the 1588 Grand Armada against England were built in Northern Europe and were considered by Iberians as ships inferior to those built along the Cantabrian coast of Spain (Casado Soto 1988:201–202). This opinion did not stop Cadiz merchants from purchasing and using these ships, although with the understanding it was out of necessity rather than preference. Based on the foot wales, the unusual construction of the pump well, and the keel at amidships, EP II may have been built within the northern European sphere of shipbuilding. Whether or not the ship was built in the Basque country or further north requires dendrochronological analysis of the hull timbers. None of the pump wells identified so far on known Basque built ships encompasses the mainmast and the trapezoid shape might indicate carpenters unfamiliar with traditional construction of this feature or a perceived innovation. In either case, the oddities in ship construction and the size of EP II's keel emphasize a larger vessel that fits the known tonnage of the Jesús, although additional research is needed to provide a more definitive answer.
CONCLUSION

One of the original research questions for this thesis included answering why 16th-century shipbuilders chose to rely on an expanded keelson for the mainmast step configuration and why the installation of adjacent bilge pumps required modifying existing hull structure. By following the *annales* approach and discussing the long term trends in building these components, this research illustrated their origins and development as revealed through archaeological sources. Although contemporary shipwrights preferred Scandinavian-style mast steps, based on the expanded keelson and lateral support structure, this decision belies the origin for the mast step being originally utilized in the Mediterranean.

Shell-first construction did not require the mast step to be incorporated into the frame and instead allowed this component to exist as an independent timber to hold the mast heel while protecting the hull from vertical pressure. Early ships were shallow drafted with a single deck and relied on lateral reinforcement for the mast at deck level rather than at the mast step. Only the rather large and square shape of early-Mediterranean mast steps kept the mast from unstepping. Over time, shipbuilding in the Mediterranean underwent a transformation from shell-first to frame-first construction and the mainmast step sat over the keelson before becoming combined as a single component. Ships grew exponentially; as a result, the keelson stretched longitudinally and masts increased in diameter, requiring lateral support adjacent to the mast mortise rather than the earlier robust components seen at deck level.

Reducing keelson widths also saw a decline in the number of mortises present for mast crutches and guiding boards. In fact, as the tradition of customarily unstepping the mast ceased, and the weight from the mast kept it from unstepping easily, these support components disappeared altogether. Lateral support from sister keelsons declined as of most Mediterranean
ships relied on the lateen sail configuration. These stringers then slowly expanded outward over the centuries to become foot wales, while the return to larger shipbuilding and square sailing required shipyards to implement new mast step configurations. Available evidence suggests that the introduction of ship construction from Northern European counterparts developed two Mediterranean mast step methodologies. The first relied on the traditional thin and square keelson to hold the mast heel while being supported by lateral knees. The second included modification of the floor timbers beneath the mast step with built-in knees for lateral support. Mast mortises in the latter ships were created by installing boards between the floor timbers with chocks fore and aft.

Sailing in the Mediterranean was an established principle long before the sail became standard on ships found in Northern Europe, although eyewitness accounts claim Celtic shipbuilders already knew and utilized the sail for cross-channel voyages from Britain to the continent. Archaeological evidence attests to northern shipwrights incorporating this new propulsion through modification of a lateral floor timber rather than attempting to install a new component. Obvious longitudinal reinforcement from nailed on boards found on several examples emphasizes the weaknesses apparent in installing a mast into a frame. Most vessels from this shipbuilding tradition were single-decked and included the need for lateral reinforcement above the mast step, as seen on earlier Mediterranean ships. The Romano-Celtic shipbuilding tradition eventually brought sailing to Scandinavia and incorporated the mast-frame typology into ships built during the medieval period.

Scandinavian shipbuilding, the origin for the 16th-century mainmast step configuration, initially sought to minimize the mast step as a light timber for holding the mast heel. Many features from the initial incorporation of the sail into Scandinavian ships have parallels in earlier
Mediterranean trial and error. Rather than installing separate keelsons and mast step components, Scandinavian shipbuilders sought to simply modify the mast step to become a keelson for longer and larger vessels. Support for the mast included choosing compass timbers with an extended branch forward from the mast mortise and installing lateral knees or *snelles*. Scandinavian mast steps extended further longitudinally in succeeding decades as a result of the exponential growth in ships' sizes. Only the largest Scandinavian cargo transports varied from the initial mast step typology by including rider timbers that kept the keelson in place and provided additional support for the mast at its base.

Combinations from the Romano-Celtic and Scandinavian shipbuilding traditional-mast step designs were applied similarly to the medieval cog typology. Both mast step configurations were used; however, the Scandinavian versions, being more robust and able to survive the rough conditions on longer voyages, proved more capable than the Romano-Celtic version. As a result, this component was seen on more northern European ships as they began to descend down the southern coast and entered into the Mediterranean. Available evidence suggests that the modifications seen in Mediterranean mast step typology after this point were clear borrowings from the Scandinavian version. This interchange between the western edge of the Mediterranean and Northern Europe allowed the Iberian Peninsula to become a middle ground where the sharing and development from multiple shipbuilding traditions were incorporated together. Sixteenth-century Iberian shipbuilders constructed ships based on known regional traditions, which were influenced from their geographical location. As time progressed, these shipbuilders implemented the same dramatic change as experienced earlier by northwestern Europeans when adopting the Scandinavian mast step.
Mediterranean elements nevertheless were incorporated into the Scandinavian design, such as increasing the length of the keelson to terminate only at the rise in deadwood. Clearly, in regards to the original research question, the answer on why 16th-century shipbuilders chose to build expanded keelson mast steps is as complex as the development of the entire mainmast step complex. Shipbuilders eventually chose a version of the Scandinavian mast step typology that was modified for medieval cog design and improved throughout the 16th century. Probable reasons for this choice were the more robust dimensions and additional lateral reinforcement that were prevalent in this typology and less obvious from contemporary Mediterranean examples. This observation unfortunately cannot be considered as a complete or overarching trend due to the regional preferences and development in shipbuilding that took place during the first quarter of the 16th century.

Bilge pumps share a similar scenario as mainmast steps in technological development based on regional necessities and available shipbuilding methodologies. Whereas the earliest Mediterranean mast steps were simple large rectangular blocks, shipbuilders sought to build complex chain pump systems that were in operation earlier than available archaeological evidence indicates. Since contemporary accounts never mention the device, it has been left to archaeological investigations to eventually piece together how this pump operated. Cultural factors, rigging changes, and the efficiency of the device allowed it to remain prominent with only minor modifications over subsequent centuries. Several bilge pumps were positioned near the bow, but the majority were built along the central axis just forward from the sternpost. Previous scholarly work has postulated that the device fell out of use until it was rediscovered in the 15th century and eventually returned to shipboard operations in the last quarter of the
succeeding century. Evidence in this thesis emphasizes continual use of the chain pump in the Mediterranean and that its rediscovery was not necessarily as clear as others have proposed.

Although the chain pump was in operation on Romano-Celtic ships, it apparently did not find favor within this shipbuilding tradition and eventually fell out of use. Not until the rise in Scandinavian shipping does evidence emerge for a new pump typology that relied on a piston and a separate claque valve inserted inside a wooden pump tube. Scandinavian shipbuilders were already modifying internal framing as dales to allow easier bailing for removing bilge water from inside the hull. The appearance of the burr pump was an additional component that made this bailing easier, but kept the earlier dale system in place. As with the Mediterranean chain pump, the burr pump was always situated at the lowest point in the hull and positioned along the central axis. Recent archaeological evidence has shown that burr pump technology was well known throughout Northern Europe at least by the mid-15th century. Toward the end of the same century, burr pumps were transformed into common pumps by installing a valve at the end of the piston and including a lower claque valve inside the wooden pump tube. Common pumps eventually superseded the burr pump, due specifically to the efficiency that the former produced as pump makers improved the design.

As mentioned, all pumps have been shown archaeologically to be installed at the lowest point in the hull along the central axis. When Northern and Mediterranean shipbuilding traditions combined to create the trans-oceanic ship typologies, an issue arose on the position of the bilge pump within the hull. Northern European shipbuilders were familiar with installing the pumps aft of the stem and forward from the sternpost. Both traditions sought previously to employ half-frames at the pump area to provide enough space for the apparatus. Trans-oceanic vessels required keelsons that spanned the central axis between dead wood, blocking previously
traditional areas for the installation of the bilge pump. Shipbuilders originally chose to install the bilge pump in the traditional places, but unfortunately these locations were no longer the lowest points within the hull. Modification in ship typology and hull design due to *carvel* style hull planking created rounded hulls, placing the lowest point near the center of the hold. Shipbuilders were then required to modify the keelson to install the pump in this area, as well as place it on the keel to alleviate any stress that might damage the garboard or outer hull planking in the immediate area. These modifications have been seen as detrimental to the specific purpose of expanding the keelson in this area for the mast heel (Waddell 1985:257). Some weakness was probably explicit in cutting into the keelson, though the mainmast step typology chosen for trans-oceanic vessels included lateral reinforcement. Most notches cut for the bilge pump were also placed further aft and away from this area.

Over the 16th century shipbuilders slowly began to incorporate the new bilge pump position into the trans-oceanic vessel typology. Initial ships either followed traditional regional positioning for the bilge pump or cut into the keelson near amidships. Examples, such as Cais do Sodré, provide major differences to this scenario due to the positioning for two bilge pumps located away from the central axis on either side of the keelson (Castro et al. 2011:340). This positioning must be seen as explicit evidence of bilge pump development within the Mediterranean tradition at this time rather than part of the trans-oceanic typology. By the end of the century, keelsons were designed to both expand and reduce in dimension as to incorporate the bilge pump without the need for cutting into surrounding frames.

*Redefining Oertling's Atlantic Sub-Tradition*

Another research question initially included whether enough contemporary archaeological information, along with new data obtained from work on Emanuel Point II, could
expand Thomas Oertling's Atlantic sub-tradition hull characteristics. As described previously, Oertling's initial research focused on finding differences between 16th-century Iberian hull designs for indicating ship typology designations (Oertling 2001:233). His results revealed that examining the surviving lower hull alone could not provide a concrete answer, in fact most of the ships in his study revealed similarities rather than any remarkable differences. Oertling's analysis amidships was brief, noting that the keelson was notched to accept the floor timbers and that the mainmast step was an expanded section of the keelson. His examination became more descriptive when describing differences in lateral support structure between the Ria de Aveiro A, Western Ledge, and Cattewater shipwrecks (Oertling 2001:236). This thesis has already shown that Oertling's issues were based on the regional shipbuilding methodology, as the Ria de Aveiro's buttress system was built into the floors as part of the Mediterranean tradition or due to a lack of surviving hull structure, such as the case with the Cattewater wreck. Oertling was also not sure if there were stringers on the Western Ledge wreck, but subsequent publication has proven that foot wales did exist (Bojakowski 2011:28).

Although Oertling addressed hull construction in general, instead of a specific hull feature as this research has done, there are general observations that must be addressed. First, although many of the examples are Iberian in origin, the *Mary Rose* disproves the notion that a specific region was the source for this style of construction. Research has also proven that influences in shipbuilding methodology between Northern Europe and the Mediterranean were already taking place centuries earlier than previously noted. Ship construction by the mid-15th century revealed differences in methodology between northern- and southern-Iberian shipbuilding, which lasted until the end of the first quarter of the 16th century. The transition period from earlier mainmast steps to those throughout the remainder of the 16th century is
difficult to describe with the limited available archaeological examples, but general observations made by Oertling on the keelson having notches to accept accompanying floor timbers can be kept, as both major shipbuilding traditions shared this trait. Exceptions are made for the absence of notches from a section of the Newport keelson, due to the need for additional support of an upper deck stanchion and the possible absence of notches aft from the Arade 1 mainmast step (Loureiro 2004:49–51; Nayling and Jones 2014b:12, figure 12). Expanded keelsons cannot be considered universal. The Cais do Sodré has an approximately square keelson throughout and Arade 1 has roughly a square mainmast step section, although it is unclear whether the remaining timber shared the same dimensions.

Consideration must also be taken when discussing the lateral support network surrounding the mainmast step, specifically the buttresses and foot wales. Many contemporary shipwrecks include triangular buttresses notched into the accompanying foot wales, but there is still a greater diversity in this characteristic than in the traits mentioned previously. For example, lateral support on the Ria de Aveiro A wreck follows the Mediterranean style; built-in support floor timbers that accompanied the mainmast step area. Cais do Sodré included a single buttress, although this component was a rectangular timber rather than the traditional triangular form. Minimal evidence recovered from Arade 1 does not indicate whether any lateral support was present originally. When evidence for the buttresses and foot wales survive in situ, only the Emanuel Point I does not have the buttresses notched into the foot wale. Further differences include the rebates cut beneath buttresses found on Emanuel Point I and the Western Ledge Reef wreck. Buttresses are always present in pairs and throughout the 16th century there is a linear trend in the expanding dimensions of ships along with the number of buttresses employed. Only
the Western Ledge Reef wreck is an exception, as it is a smaller vessel compared to the other shipwrecks in this study.

Oertling mentions briefly that 16th-century ships usually have part of the expanded keelson cut away to accommodate the bilge pump (Oertling 2001:236). As stated previously, the repositioning of the bilge pump in this period provides a new characteristic that could assist in placing the shipwreck chronologically by quarter century increments. Earlier ships, such as the Newport or Cattewater wrecks, provide evidence for deeper notching or the unusual placement for the device. Throughout this period the pump sump notch becomes shallower and more finesse in design reduces earlier and obviously awkward installation into the expanded keelson. Eventually these notches were reduced significantly or were no longer applicable, as shipbuilders began to design the expanded keelson to terminate in areas that allowed for bilge pump assemblies along the central axis. As with the other characteristics, there are exceptions. For example, the Cais do Sodré and Arade 1 have pump sumps that are away from the central axis.

Reinterpreting characteristics for the mainmast step and bilge pump assemblies from Oertling’s original list, along with additional discoveries attributed to the same shipbuilding tradition, has allowed this research to exclude several examples from the trans-oceanic tradition. Enough evidence throughout this thesis concludes that Ria de Aveiro A, Cais do Sodré and Arade 1 are part of the Mediterranean tradition. Several aspects from the Newport shipwreck and the limited information available from the Rye A mainmast step indicate key aspects from the Scandinavian tradition. Removing these ships leaves twelve vessels with similar characteristics that could be used when identifying trans-oceanic shipwrecks based on the following traits:
1. The keelson is notched underneath to accommodate resting over the floor timbers.

2. Keelsons after 1550 cease having complete beveling along the bottom edges in exchange for chevron or scalloped beveling between notches.

3. Beveling across the top edges of keelsons and stringers appear in the latter half of the 16th century.

4. The mainmast step consists of an expanded section of the keelson supported by pairs of triangular buttresses resting on floor timbers on either side.

5. Buttresses are either fastened to supporting frames and/or kept in place by having the foot wales notched to accommodate their outboard ends.

6. When buttresses do not reach the foot wale, they include rebates along their outboard ends to accommodate ceiling planking.

7. The number of buttresses increases over the century, but is also dependent on the size of the vessel.

8. Bilge boards are present between buttresses or fastened over all buttresses to keep debris out of the bilge.

9. Bilge pumps are located along the central axis near the deepest point in the hull.

10. Pump sumps are initially cut deeply into the expanded keelson and slowly reduce in size over the 16th century until there is no longer an obvious modification of the keelson.

11. Evidence for burr pump typology indicates a ship dating after 1425, common pumps after 1540, and chain pumps after 1575.

After Oertling finished compiling his twelve general characteristics, he concluded that Iberian-Atlantic ship construction, or the "Atlantic Vessel" concept, was a sub-tradition of the Mediterranean tradition (Oertling 2001:237–238). Reexamining the archaeological sites and
following the long term trends in mainmast step and bilge pump assemblies through an *annales* perspective have shown that Oertling's original concept is not entirely correct. Oertling omits the large internal structural foundation and other features that are Northern European in origin. Instead, he chose to describe shipbuilding traditions based on their prominent hull construction methodology (lapstrake vs. *carvel*) rather than based on regional influences. As a result, these earlier analyses were skewed toward promoting in favor for a Mediterranean sub-tradition.

Enough similarities exist between archaeological examples to conclude that a novel shipbuilding tradition formed along the Atlantic coastline. Compared with earlier traditions, this tradition was distinctive due to borrowing heavily from Scandinavian, Mediterranean, and even Romano-Celtic (medieval cogs) characteristics, which were economically and structurally sound. Attempts to organize these ships as part of a sub-tradition of the Mediterranean or Scandinavia would be overtly simplistic as Atlantic shipbuilders combined the best of two different regions for their own agendas. Calling this novel regional methodology as the "Atlantic" or "Trans-Atlantic" tradition would also be unwise, due to the number of ships that arrived successfully in the Indian and Pacific Oceans during this time. Instead, "Trans-Oceanic" or "Oceanic" tradition encompasses the ingenuity that Atlantic-coast European shipbuilders were able to accomplish within two centuries of exploration and expansion.

*The Tristán de Luna Expedition*

Numerous shipwreck catastrophes and the threat of outside European encroachment were major incentives in colonizing the Pensacola region. Tristán de Luna y Arellano was chosen based on his known experience as a successful leader during previous expeditions and his connections with local officials. Compared against earlier colonial attempts, Crown revenue was heavily applied for communal resources that were accumulated throughout the New Spain.
economy. The expedition also became an experiment on whether large scale expeditions could be handled by New Spain resources or were required to depart directly from Spain. Several who chose to accompany the expedition were not necessarily new adventurers or colonists, as many were experienced conquistadors from earlier failed expeditions. These individuals knew what to expect in the unforgiving landscape and were vocal in their concerns on what should be brought for a successful colonial venture. Dominicans supplied religious conviction and sent several representatives to proselytize Christianity, although many colonists were there for more secular reasons.

Earlier colonial ventures relied upon confiscating or purchasing available ships rather than building vessels tailored to a specific purpose. The Luna expedition was unique, due to New Spain officials deciding to build one of the earliest shipyards in the western hemisphere. Although the infrastructure that was built to supply raw materials and the shipyard itself were temporary, it resulted in several vessels being built completely with New World resources but using the Oceanic shipbuilding methodology. Original plans called for six *barcas* to be built, but the limited amount of craftsmen and time allotted only allowed for two *barcas*, a galleon, and a *fragata* to be built by the departure date. Several other ships, originally at San Juan de Ulua to participate in the annual fleet back to Spain, were drafted. Ship masters probably saw contracting their vessels to offload colonists as a lucrative business opportunity and did not perceive a downside to additional payments beyond what they already had sold. Several ships were contracted at various times and carried colonists, animals, and supplies to Pensacola for an agreed shipping rate. Once these ships arrived at their destination they were to unload and depart for San Juan de Ulua or return directly to Spain via Havana. The 1559 hurricane altered these expectations, creating an incredible loss for the Luna colonists and Spain.
The Luna expedition was one of the better organized colonial ventures. Every aspect was considered, including sending several scouting expeditions that chose the most secure site to begin expansion. Appropriate measures were also undertaken to prevent conflict between colonists after their arrival with any local native populations. Only the incalculable appearance of the hurricane that destroyed the fleet at anchor, while still carrying much of the colony's food supplies on board, brought the initiative almost to a standstill.

*Analysis of Emanuel Point II Amidships*

Significant excavation on Emanuel Point II (EP II) at amidships uncovered a large section of the hull. The quick burial and anaerobic environment in Pensacola Bay provided ideal preservation of organic remains. Many fragments and sections from the pump well enclosure were uncovered over or surrounding the mainmast step. These pump well pieces and other components were removed systematically and cataloged. The mainmast step underneath was found completely intact with little wear and no apparent repairs. Further excavation within the bilge found only wood chips and waste product from the original construction. Other evidence from unused treenails and ship carpenter's mallets suggest that the ship was built relatively recently prior to its demise from the 1559 hurricane. Other unique aspects include a decision by ship carpenters to use wide planks as foot wales rather than the pronounced stringers found on all other contemporary archaeological examples. Rebuilding the pump well enclosure also revealed that the pump well incorporated the mainmast and was trapezoidal in shape. The keel's sided dimension at amidships, along with earlier observations at the bow and stern, suggests that the timber was cut in a hexagonal shape as opposed to rounding with wear.

Comparing EP II's mainmast step and hull structure with other known examples indicates that the ship is one of the largest known ships recorded archaeologically. Only EP I, Red Bay
29M, and Angra D have similar or slightly larger scantling dimensions. EP II's 19.5-22 cm sided by 25 cm floor timbers are also larger than other contemporary examples and suggest that the ship was intentionally built for carrying bulk amounts of goods or materials. Although no evidence from the bilge pumps survive, the remains from the pump sumps indicate that shipbuilders by the mid-16th century were already positioning the keelson so that no notching would be required. Most Iberian archaeological examples include evidence for burr pumps, due to the positioning of these pump sumps cut into the keelson and leaving room for the foot valve to rest on the keel or keel-garboard seam. The pump sumps on EP II are unusual in having the floor timbers cut with semi-circular notches that create a shelf rather than allowing the pumps to sit on the hull. Only the Mary Rose shows a similar arrangement for the main bilge pump and includes evidence that a common pump was installed in this area. The position of the pump sumps on EP II with the shelf suggest that the ship was built with common pumps, a possibly northern European trait, rather than the burr pump typical of most Iberian shipwrecks.

The combination of the plank foot wales, hexagonal keel, and trapezoidal shape of the pump well suggest that the ship was built under a heavily Northern European shipbuilding influence. Whether or not the ship was built along the northern Cantabrian coast of Spain cannot be definitively determined with the current data. Earlier examples, such as the Newport shipwreck, suggest this possibility by sharing wide plank stringers with EP II, although the construction of the pump well is unique by including the mainmast. Documentary evidence sheds light on the composition and identities of several of the ships in Luna's fleet. The sheer scantling dimensions rule out EP II as any of the smaller ships and suggests that it is either the galleon San Juan de Ulua, the urca Jesús, or the nao San Andres. Spanish officials wrote down the tonnages for the latter two ships, allowing the author to apply known ratios and tonnage formulae from the
period to assist in identifying EP II. Based on the total length of the keel, the unique construction features, the scantlings from ship components, and the results from tonnage calculations, EP II may be the *urca Jesús*. Additional evidence for EP II as the *urca* will require further excavation and dendrochronology to figure out a possible source of the wood. As mentioned in the previous chapter, many *urcas* were built along the northern coast of Europe and were perceived by Iberians as inferior to their native built ships. There is some mystery behind the *Jesús* ship master Francisco de Ecija, since he is the only mariner in command of a vessel from its departure at Cadiz until it wrecks in Pensacola Bay. He is also paid in full to sail directly back to Spain rather than wait to sail home in the safety of the return fleet. Further archival evidence may shed additional light on the identity of the *Jesús* and where the ship may have originated.

*Further Research in the Annales Nautical Archaeological Perspective*

Nautical archaeologists are often criticized as simply concerned with understanding the technological development and idiosyncrasies in ship construction (Delgado 1998:259). This observation cannot be further from the truth and this thesis has sought to discredit the notion that any single vessel can be understood outside the culture and historical events that assisted in its creation. By incorporating the *annales* approach into nautical archaeology, shipwrecks can be seen not only through the micro perspective in obtaining idiosyncratic data, but it allows scholars to create a holistic dataset that provides a set of traits connected to regional and cultural preferences in ship design, along with understanding the cultural influences upon shipbuilders as members of their own societies. Fernand Braudel proposed that historians examine history through a three-tiered system because he understood that the traditional historic narrative was counterintuitive to understanding the larger aspects of societal constructs that were either already influencing events or being adopted through encumbered change (Braudel and Wallerstein
An *annales* nautical archaeological perspective seeks to obtain this same sense of combining the macro and micro perspectives within a single narrative. The author has provided an example of a successful interpolation between the micro through examining EP II and the macro by incorporating this data into an analysis of the larger regional shipbuilding preferences found throughout Europe.

Understanding the development of mainmast steps and bilge pump assemblies has shown that there are remarkable shipbuilding differences between northern and southern Europe. Based on utilizing the *annales* method, research revealed that the 16th-century mainmast step was not an invention by contemporary European-Atlantic shipbuilders. Over many centuries the mainmast step assembly and sail configuration diffused from the Mediterranean and were modified every time the technology came into contact with a new culture. These idiosyncrasies allowed the shipbuilder to incorporate ideas and influences that were pragmatic and traditional at the same time. Although this analysis has answered several questions and provided a better understanding for ship construction, there are still unresolved issues that require further research and discoveries. There is a lack of archaeological examples from the 12th through the 15th centuries that leave large gaps of time during which archaeologists do not know how technological transitions took place. The lack of shipwrecks from this time period only allows the author and other researchers to infer what took place and require further publication and fieldwork to answer how mainmast step construction progressed. The development of bilge pumps are even more difficult to trace, with a longer blank space from the 11th century until the beginning of the 16th century. Until the excavation of the Newport shipwreck, the earliest known example of the burr pump on ships was from the 16th century. Based on this discovery, and
through this thesis, it is now understood that this pump was probably in use on earlier vessels, yet there is a significant lack of evidence for the appearance of common pumps and later chain pumps.

A greater study of ships dating to the 16th century has produced significant examples found and excavated by archaeologists; unfortunately, greater numbers have been plundered and destroyed through treasure salvage. Even with the current sample size, there is still a need to find new examples that can be researched and excavated by archaeologists. The larger the sample size, the further a regional analysis can be made to assist in identification of ships based on shipbuilding characteristics rather than dendrochronology alone. Emanuel Point II provides additional evidence on why more 16th century and earlier examples need to be found. The difference in foot wales may point in a ship typology not identified previously in the archaeological record and may support that certain lower hull characteristics could identify vessel typology. On the other hand, additional evidence may come to light that various Spanish shipbuilders had differences even within their own region on how certain components should be built. These differences can be found with the addition of new shipwreck discoveries and by archaeologists beginning to invest in outside evidence.

Archaeologists using the *annales* approach are not only in a better position to answer various questions by examining the archaeological record, but can also consider the cultural, historical, and environmental impacts. Historic ships are often described as one of the most advanced pieces of technology of their time and were made for the transportation of goods, people, and ideas; nevertheless, this statement often forgets that the ship itself is the product of human endeavor. Generations of shipbuilders, through trial and error, eventually reached a point where ships became seaworthy enough to cross oceans and visit distant lands. The societies that
built these ships typically utilized them as multi-purpose vessels that could be called upon to carry cargoes or bring supplies for colonial expeditions. These concepts are ideally situated for an *annales* methodology that incorporates various sources tied to a shipwreck through multiple perspectives. Many methodological approaches are difficult due to the amount of work that it takes to complete the project from research to publication and the *annales* approach is no different. There is a significant amount of work that has to be done for a multi-perspective analysis, but nautical archaeologists need to move past the historical particularistic tradition if there is to be any new insight on understanding ships outside the confines of an idiosyncratic analysis. The analysis provided in this thesis is only one step in that direction, as there are many more avenues to pursue in understanding the development of ship design and applying the *annales* viewpoint into nautical archaeology.
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APPENDICES
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FIGURE 90. Scale drawing of Timber 23. (Image by author, 2016.)
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Dear Charles,

Thank you for asking. I am delighted that you find my drawing of use, so please use it as you wish.

It was all subsequently developed and published in my "Ships of the port of London, first to eleventh centuries AD", English Heritage 1994. This was my DPhil thesis at Oxford University.

By the way, I am deeply involved in research on the Mary Rose (1545) and have found that the early 17th century formulae used in England to fix the dimensions of masts and yards appear to have been used when Mary Rose was rebuilt around 1556. I shall be publishing this in due course, but you might like to bear in mind that when people first started writing such things down they were usually describing what already had been the normal practice for some time in the past. By using the 17th century formulae to determine the diameter of the main mast of MR (based on the width of her keelson and length of her mast-step) I find that it exactly works. That means that much of the masting and rigging of the ship can be reconstructed.

With best wishes for your thesis and degree!

Regards,
Peter Marsden
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Mark Redknap <Mark.Redknap@museumwales.ac.uk>
To: Charles Bendig <cdb48@students.uwf.edu>

Wed, Feb 3, 2010 at 9:12 AM

Dear Charles,

I drew it, and presumably hold the copyright. Very happy for you to use it – just cite original source.

Yours,

Mark

Dr Mark Redknap
Pennerth Casgliadau ac Ymchwil / Head of Collections & Research,
Adran Hanes ac Archaeoleg / Department of History & Archaeology,
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From: Charles Bendig [mailto:cdb48@students.uwf.edu]
Sent: 01 February 2016 18:17
To: Mark Redknap <Mark.Redknap@museumwales.ac.uk>
Subject: Requesting Copyright Permission for Cattewater Shipwreck Keelson Drawing

YMWADIAW
Mae pob negos oboist a anfonir i law gan Amgueddfa Cymru yn cael ei

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Copyright Permission Request of Western Ledge Reef Wreck Images

Jane Downing <register@nmb.bm>
To: Charles Bendig <ccdb48@students.uwf.edu>
Cc: Deborah Atwood <research@nmb.bm>

Tue, Jan 19, 2016 at 6:52 AM

Hello Charles,

Thanks for your enquiry.

We are happy for you to use the Western Ledge Reef Wreck drawings 91-02-D6 and 91-03-D3 in your thesis on the condition that you credit the National Museum of Bermuda, and send us a copy of your completed thesis.

Best of luck in your research,

Jane Downing

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Jane Downing
Registrar
Cell: (441) 234-1333

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