MEDITERRANEUM MARE: SHIPBUILDING IN THE LATE MEDIEVAL AND EARLY MODERN PERIOD (AD 1000 – 1700)

A Dissertation

by

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ABSTRACT

Nautical archaeologists over many decades have uncovered a plethora of Mediterranean shipwrecks from different periods. Debates about how shipbuilders organized, designed, and constructed ships developed alongside the subdiscipline. Most archaeologists agree that a significant shipbuilding transition occurred during the early medieval period (AD 600 – 1000). Shipbuilders previously assembled the hull with edge-joined planks before installing a rudimentary supportive frame network. By the beginning of the late medieval period (AD 1000 – 1500), most ships were assembled with the frames erected first and non-edge-joined planking afterward.

Recent investigations explored this transition in some detail, but there has not been a similar comparative analyses about the lingering effects from this change for subsequent periods. This study explores Mediterranean shipbuilding in the late medieval and early modern period (AD 1000 – 1700) to understand how the new construction technique was adopted and matured. The dataset utilizes the operational process as a lexicon, methodology, and analytic technique, while gauging whether this material should be organized based on hull profile typologies or as communities of practice, as envisioned by practice and social learning theories. Preserved state papers and a gradual interest by Renaissance merchants and sailors writing about shipbuilding also provide a supplementary dataset that is discussed and compared against the archaeological material. Findings suggest that shipbuilding in this period was much more complex than assumed and not all previous techniques were abandoned.

DEDICATION

To my parents,

Charles J. Bendig and Susan E. Bendig,

for letting me follow my dreams.

To my brother,

James E. Bendig

for his close friendship.

And to the family puppies,

Molly and Lola,

for their unconditional love.

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He is a wealth of information on topics about artifact conservation, family genealogies, the history of nautical archaeology, and any other subject that he felt was necessary to instill within me. He always told me to find a professor to be my shield in the academic environment and to remember that I could accomplish anything. Donny was my shield and mentor. I will always be grateful for his support and providing me with a real-world tool set that is applicable well-beyond archaeology.

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Contributors

This work was supervised by a dissertation committee consisting of Professors Filipe V. Castro, Kevin J. Crisman, and Donny L. Hamilton of the Department of Anthropology, and Professor Brent R. Fortenberry of the Department of Architecture.

All work conducted for the dissertation was completed by the student independently.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

The archaeological study of shipwrecks is a relatively recent phenomenon spanning back a little over half a century. The first full underwater excavation took place in southern Turkey at Cape Gelidonya in 1960 under the leadership of George F. Bass.[1] Many findings from this thirteenth-century BC site summarily changed the archaeological narrative for the Bronze Age, including evidence proving that many Near Eastern cultures were involved in overseas trade. Bass was the first archaeologist who learned to dive so he could conduct the project with the same scholarly rigor expected at a terrestrial site. Prior to Bass's work in 1960, archaeologists studying shipwrecks remained on the surface while professional divers worked underwater, randomly retrieving anything they found.[2]

Pioneering expeditions by Jacques Cousteau at Grand Congloué in 1948 or by the Cannes Submarine Alpine Dive Club near Chrétienne in 1955 provided testing grounds for developing appropriate underwater technologies and excavation techniques. Cousteau's early projects involved the archaeological expertise of Fernand Benoit, Director of Provence Antiquities, but he always remained topside awaiting results from below.[3] Members from these earlier investigations subsequently approached Bass about

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[1] Bass, 'The Cape Gelidonya Wreck: Preliminary Report', 269
[2] Throckmorton, 'The road to Gelidonya', 16-7; Catsambis, 'Before Antikythera: The First Underwater Archaeological Survey in Greece', 105-6
[3] Rieth, *Pour une histoire de l'archéologie navale: Les bateaux et l'histoire*, 286-9, 296-9.

participating on the Cape Gelidonya project. Cousteau's colleague, Frédéric Dumas, was appointed lead diver, while a British aquanaut from Chrétienne, Honor Frost, also joined providing dive expertise and advice based on earlier experiences.

Proving to the wider archaeological community that materials could be recovered from an underwater context with the same level of rigor and could yield the same level of information as terrestrial excavations took some time.[4] Scholars nowadays rely on these sources and consider them equally beneficial for their own analyses and interpretations. In the ideal environment, many underwater finds are often better preserved than comparative material from land sites. For example, organics breakdown through normal decay unless they become desiccated or preserved by chemical reactions. Many shipwrecks provide anaerobic environments that allow these types of materials to maintain their original shape, coloring, or quality.[5] These same conditions also allow preservation of the ship itself and provides archaeologists with evidence for some of humanity's most complex machines.

Evidence suggests that soon after the arrival of early humans along the Mediterranean coast, they quickly took advantage of offshore islands and marine resources. Artifacts on Cyprus, across the Aegean, and from other archipelagoes indicate that early settlers built rudimentary watercraft to voyage several kilometers offshore. No

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[4] Bass, 'A Plea for Historical Particularism in Nautical Archaeology', 91-2.
[5] Gregory, 'Re-burial of timbers in the marine environment as a means of their long-term storage: Experimental studies in Lynaes Sands, Denmark', 349-52; Gregory, 'Characterizing the Preservation Potential of Buried Marine Archaeological Sites', 852-4

direct evidence exists of the watercraft, but it is assumed that these were created from bundles of reeds or wooden logs.[6]

As technology progressed, vessels were created from timbers modified into planking and frames. Planks were initially stitched or lashed together using rope with frames installed afterward to provide support to the overall hull.[7] This methodology transitioned to a system with the planks held together using edge-joined pegged mortise and tenons. Treenails held the framing in place, while copper nails were driven through at the extremities.[8] Copper was replaced with iron as technology progressed near the beginning of the AD first millennium. Shipbuilding transition again during the medieval period, when frames were erected prior to the attachment of thinner planking. The planks were fastened to the frames with iron nails and without edge-joinery.[9] This last system remained the preferred construction technique until advent iron and steel hulls in the nineteenth century.

Only after decades of research and excavations were archaeologists able to piece together these general shipbuilding trends in the Mediterranean. Many questions remain about the decisions by individual shipbuilders and about the transitional periods between construction methodologies. These concepts have elicited debate between scholars since

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[6] Broodbank, *The Making of the Middle Sea: A History of the Mediterranean from the Beginning to the Emergence of the Classical World*, 150-1; Bar-Yosef et al., 'Neolithic Voyages to Cyrpus: Wind Patterns, Routes, and Mechanisms', 416-7

[7] Steffy, *Wooden Ship Building and the Interpretation of Shipwrecks*, 25-8; Kahanov and Pomey, 'The Greek Sewn Shipbuilding Tradition and the Ma'agan Mikhael Ship: A Comparison with Mediterranean Parallels from the Sixth to the Fourth Centuries BC', 11-13

[8] Steffy, 'The Kyrenia Ship: An Interim Report on Its Hull Construction', 84

[9] Bass, Steffy, and van Doorninck Jr., 'Excavation of an 11th-Century Shipwreck at Serce Limani, Turkey', 166

the very beginning of the subdiscipline when few remains were scientifically published.[10] This dissertation explores one of these transitions, from shell- to frame-based shipbuilding, during the late medieval and early modern periods (AD 1000 – 1700). Many scholars focus their research on the epochs before or after this era, often due to the limited finds reported in between. The research presented here comprises over 40 archaeological sites located in this timeframe with an analysis of their construction and design. The remainder of this chapter introduces the Mediterranean as a geographic region and how its denizens perceived the basin. The text will then discuss the implementation of the operational process as a lexicon, methodology, and analytic tool for shipwreck studies. Comparative analyses that had a significant influence on this investigation and the research design applied here are also reviewed.

The Mediterranean as a Geographic Region

Any scientific summary on the geomorphology of the Mediterranean should begin with the mountain ranges that dominate most of the sea's coastline.[11] The mantle comprising the Mediterranean is composed of slow shifting tectonic plates that have continually migrated for millions of years. Most of the sea is comprised of the major tectonic Eurasian plate to the north, the African plate in the south, and the Arabian plate to the far east. Fractures from the edges of these plates produced minor continental plates positioned along the fault lines. In the west, the minor continental Iberia plate originally

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[10] Hasslöf, 'Main Principles in the Technology of Ship-Building', 42, 55; Casson, 'Ancient Shipbuilding: New Light on an Old Source', 28-31; Casson, 'New Light on Ancient Rigging and Boatbuilding', 86-8

[11] The Annales historian, Ferdinand Braudel, seemed to agree, as he began his monolithic work on the Mediterranean with this same topic: Braudel, *The Mediterranean and the Mediterranean World in the Age of Phillip II*, 25.

comprised the Iberian Peninsula, Balearic Islands, Corsica, and Sardinia.[12] Subduction of the African plate against the Eurasian plate produced an accretionary wedge now recognized as the Atlas Mountains along northwest coast of Africa, while collisional mountain ranges were produced throughout the Iberian Peninsula creating the Cordillera and Pyrenees in the north.[13] Similar geologic forces from the Gulf of Lion to the Balkans produced various other mountain ranges in between, including the Alps, Apennines, Dinaric, and Hellenides (figure 1).[14]

In the east, the subduction of the African plate continues along a fault line south of Crete and Cyprus (creating these rocky island outcrops in the process), while the Arabian plate generates a convergent boundary with the Eurasian plate to the north and a rift along its western border.[15] The faster movement of the Arabian plate has also caused the rotation of the minor Anatolian plate creating active faults along the Aegean seafloor. These subduction and convergent faults produce the Taurus mountain range along modern Turkey’s southern shoreline and are part of a much longer Eurasian Alpide belt.[16] Only the coastline from Tunisia to Syria lacks high elevations and provides direct access to interior plateaus.

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[12]Romagny et al., 'Detailed tectonic reconstructions of the Western Mediterranean region for the last 35 Ma, insights on driving mechanisms', 23-6

[13] Vicente et al., 'Inversion of moment tensor focal mechanisms for active stresses around the microcontinent Iberia: Tectonic implications', 3, 15

[14] Golonka et al., 'Plate-tectonic Evolution and Paleogeography of the Circum-Carpathian Region', 21-3, fig. 7; Krigsman, 'The Mediterranean: *Mare Nostrum* of Earth sciences', 2-5

[15] Ahadov and Jin, 'Slip Rates and Seismic Potential Along Main Faults in the Eastern Mediterranean and Caucasus from dense GPS Observations and Seismic Data', 41-2

[16] Koç et al., 'Miocene tectonic history of the Central Tauride intramontane basins, and the paleogeographic evolution of the Central Anatolian Plateau', 84-6

Figure 1   The Mediterranean with the major mountain ranges and regional seas labelled. (after Wikipedia Commons, 2021)

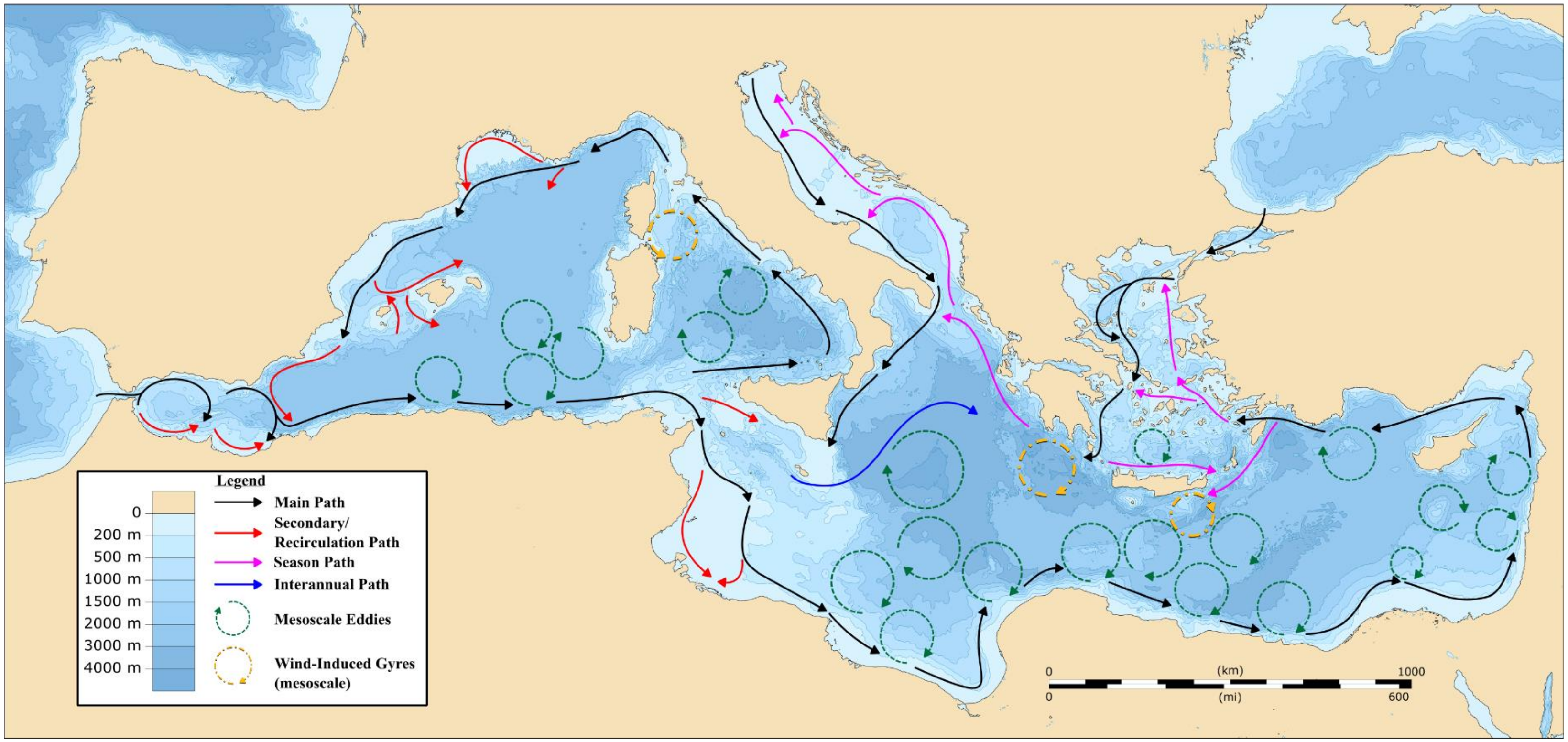

Figure 2 Surface currents from the Atlantic Ocean with supplementals from the Adriatic and Black Sea. (after Wikipedia Commons, 2021; Current: after Millot and Taupier-Letage, 'Circulation in the Mediterranean Sea', 13)

Between the mountain ranges and the coast are the vital floodplains from river networks that interconnect and follow the path of least resistance to the sea. Discharge from the larger networks of the Nile, Po, and Rhone Rivers provide the greatest contribution in runoff, while the Ebro, Tiber, Drin, Evros/Maritsa, Seyhan, and Ceyhan provide moderate amounts. Much smaller contributions are measured for the Moulouya, Shellif, Adige, and Neretva Rivers. Even with the combination of these outlets (along with the rest of the smaller networks), only one-third of their total discharge supports the sea due to high levels of evaporation.[17] Most inward flow stems from the Atlantic Ocean through the Strait of Gibraltar with smaller amounts via the Sea of Marmara at the Dardanelles and Red Sea (after the completion of the Suez Canal in 1869).

Atlantic waters comprise the surface currents that first flow along the Mediterranean’s southern shore, sometimes diverting into unstable eddies west of Sardinia or continuing northeast along the Sicilian coast and the Italian Peninsula. Figure 2 shows that the latter current reaches the Ligurian Sea before traveling west along the French Riviera and southwest against the Iberian Peninsula. Surface flow not directed northward crosses the Strait of Sicily and continues along North Africa to the Levantine coast following a similar Coriolis effect as the western basin. The eastern flow follows counterclockwise around Crete, the Peloponnese, and along the western extents of the Ionian Sea (creating additional eddies in its wake). For most the year (except the summer

[17] Struglia, Mariotti, and Filograsso, 'River Discharge into the Mediterranean Sea: Climatology and Aspects of the Observed Variability', 4742-5; Ludwig et al., 'River discharges of water and nutrients to the Mediterranean and Black Sea: Major drivers for ecosystem changes during past and future decades?', 202-4; Bethoux and Gentili, 'Functioning of the Mediterranean Sea: Past and present changes related to freshwater input and climate changes', 39-41

months), the Atlantic waters flow upward into the Adriatic and Aegean along the eastern coasts before being pushed from the respective Po or Black Sea outlets back down to the lower basin.[18] Atlantic seawater is warmer (15-16 °C), less dense (26-27), and has a lower salinity (36-37 ppt) than the Mediterranean (temp: 13-13.5 °C, density: 28-28.5, and salinity: 38-40 ppt), which explains why there are two underlying layers throughout this space.[19]

As surface currents push Atlantic seawater northward, the colder latitude and wind cause excessive evaporation and cooling, making the water become denser and sink. The denser intermediate layers follows a current pattern similar to the surface, while providing major outflows through both the Straits of Sicily and Gibraltar along their respective northern shores.[20] Continental shelves in the Gulf of Lion, Adriatic, and Aegean, along with factors in the Ligurian Sea and Levantine basin, produce dense water that falls to the seafloor and mixes with the intermediate currents. Compared to the intermediate waters that may take several years to exit into the Atlantic, the bottom layer circulates over much longer periods (years or decades). When surface eddies and gyres form from the incoming Atlantic current at the Strait of Gibraltar, these may force the original deep layer to be superseded and mix with less dense water above, eventually climbing along the southern edge over the submerged sill. The shallower depths (4 km

[18] Rohling et al., 'The Marine Environment: Present and Past', 40-1; Poulain et al., 'Mediterranean Surface Currents Measured with Drifters', 42-4

[19] Millot and Taupier-Letage, 'Circulation in the Mediterranean Sea', 31.

[20] Millot, 'Another description of the Mediterranean Sea outflow', 104-5; Jiménez-Espejo et al., 'Geochemical evidence for intermediate water circulation in the westernmostMediterranean over the last 20 kyr BP and its impact on the Mediterranean Outflow', 42-3; Fach et al., 'Water Mass Variability and Levantine Intermediate Water Formation in the Eastern Mediterranean Between 2015 and 2017', 13

max; avg. 1,500 m) and lesser volume (3.75 million km^3) of the Mediterranean prevents a permanent bottom and instead acts as a circulation device for producing denser marine layers for the far deeper Atlantic (avg. 1,000 – 2,000 m).[21]

Situated between five degrees in the northern latitudes, the entire Mediterranean basin surface area (2.5 million km^2) fits beneath a subtropical high-pressure system in the south and the westerly wind belts of the north. Coastal zones often experience heavier precipitation in the winter with dry summers that can occasionally lead to drought. Roughly half of the expected rainfall occurs in the deepest part of winter (December - February) with additional amounts during seasonal transitions.[22] The western limits experience much milder temperatures throughout the year compared to the eastern extent. Influence by the proximity of the Atlantic is a contributing factor in the west, while the southeastern coast is affected by the subtropical high-pressure belt that keeps this area warm and dry.[23] This temperature gradient and seasonal changes provide the impetus for many wind patterns that develop throughout the Mediterranean. Many of these winds flow through mountain corridors or are channeled by surrounding formations (figure 3).

Mariners traveling along the Iberian shore in the summer experienced the Sirocco from the southeast. Italians living along the western coast of the Adriatic would find

[21] Rohling et al., 'The Marine Environment: Present and Past', 42-4; Millot and Taupier-Letage, 'Circulation in the Mediterranean Sea', 48-53.
[22] Hans-Jürgen, 'Climate, Climate Variability, and Impacts in the Mediterranean Area: An Overview', 8-12, 28-9, 69-70.
[23] Harding, Palutikof, and Holt, 'The Climate System', 70-4.

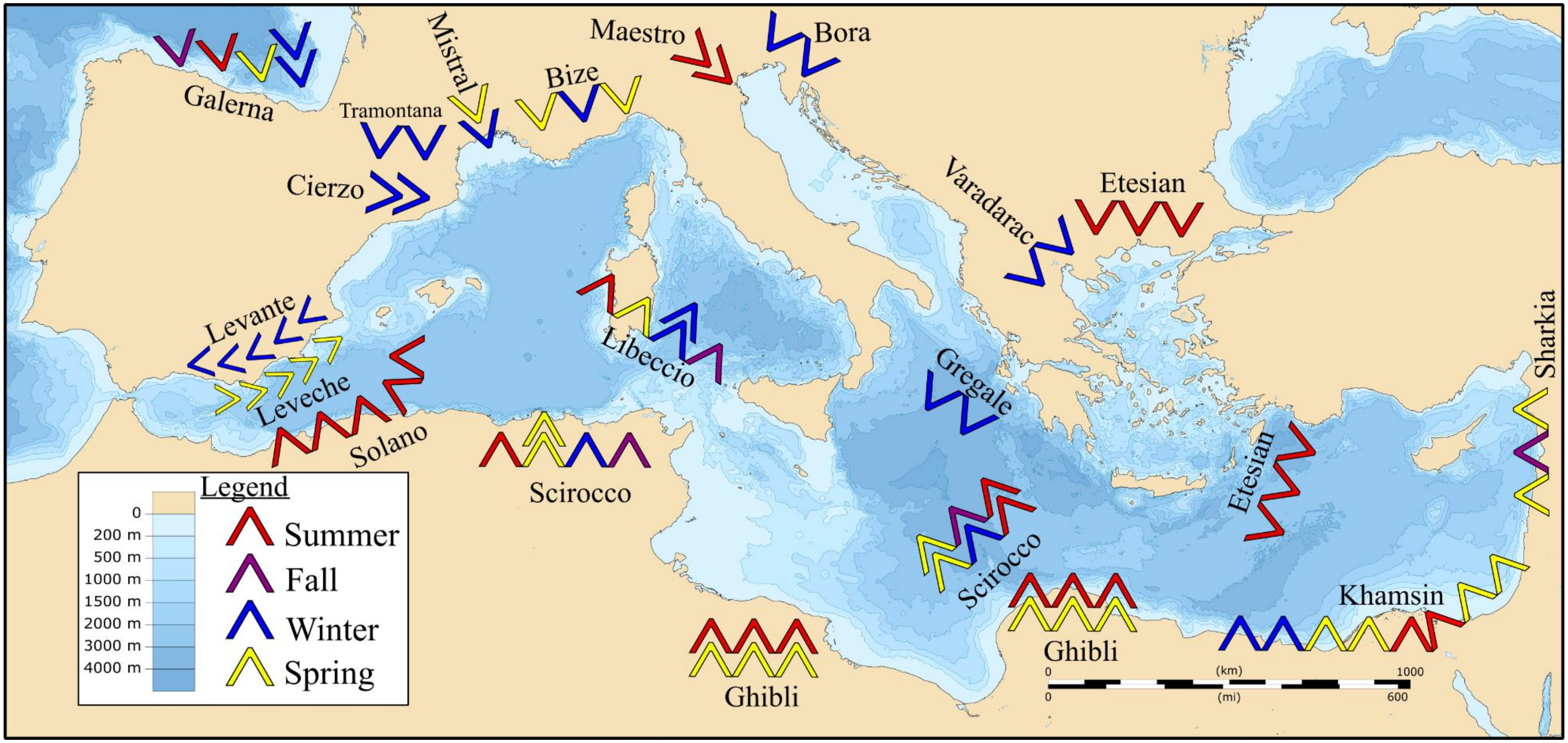

Figure 3   Arrows point from the general wind origin and are color coded based on season (additional arrows of the same color emphasize the main season this wind is present). (Map: after Wikipedia Commons, 2021; Wind Patterns: Harding, Palutikof, and Holt, 'The Climate System', 79)

themselves facing the northwestern winds of the Maestro. Most of the Aegean appreciates pleasant conditions from the Etesian (or Meltem) that steadily blows southward from the Balkans. East of the Atlas Mountains, sailors plying the waves anywhere in the Ionian Sea or further east could utilize the southern Ghibli. These winds transitioned in the fall and winter months to the Mistral, Levante, Tramontana, Galerna, Cierzo in the northwest and east, the northeastern Gregale in southern Italy, and the Bora from the northwest in the Gulf of Trieste. On the other side of the Dinaric Alps, the Varadarac blows into the Gulf of Thessaloniki. Spring also brings the northwestern Bize near Languedoc, France, the southwestern Leveche along the coast of Cartagena, Spain, and dust storms of Khamsin originating from the Sahara and moving across the eastern Mediterranean. Atmospheric conditions in the Atlantic or the surrounding continents produce high or low pressures that may cause some of these winds to appear outside their normal season.[24]

Pressure changes also induce lee-effect cyclogenesis with stronger formations depending on the location and season. Most cyclones move in an eastern or northeastern direction. The stronger winter versions that form in the Gulf of Genoa (or Adriatic) will travel over the Alps or towards the Ionian Sea. These storms will pick up strength if they continue into the Aegean and head toward the Black Sea. North African winds in the spring may develop dry cyclones with high winds that travel east along the coast and

[24] Bakun and Agostini, 'Seasonal patterns of wind-induced upwelling/downwelling in the Mediterranean Sea', 251-5; Zecchetto and De Biasio, 'Sea Surface Winds over the Mediterranean Basin from Satellite Data (2000-04): Meso- and Local-Scale Features on Annual and Seasonal Time Scales', 816-24; Barry and Chorley, *Atmosphere, Weather and Climate*, 301-7; Harding, 'Changes in Mediterranean Climate Extremes: Patterns, Causes, and Impacts of Change', 68-9.

provide the necessary energy for greater development around Cyprus before traveling overland into the Near East.[25] Only the thermally induced low-pressure cyclone forming over the southern Iberian Peninsula during summer remains stationary. Many ships traveled during the winter season, but the combination of low temperatures, rain, and the formation of the powerful central cyclones were presumably reasons why some traffic avoided sailing during this time.[26]

The Mediterranean as a Place

The Mediterranean Sea was home to many of the first civilizations that originally clustered around its eastern coastline. These early groups often referred to the sea with differences in description, understanding of its scope, or assumed a possessive tone. Ancient Egyptians called it ‘the Great Green’ (*wadj wer* or *wꜣḏ-wr*), which may have also described the Red Sea or any large bodies of water.[27] Their lexicon did not denote the color blue and primarily relied on green as a “cold” hue utilized for anything that fit this temperature spectrum.[28] Several of the other early Levant cultures associated the cardinal directions with specific colors. Bodies of water that surrounded these civilizations took on generic names based on a specific hue and direction. Black was

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[25] Harding, Palutikof, and Holt, 'The Climate System', 74-7; Kaznacheeva and Shuvalov, 'Climatic Characteristics of Mediterranean Cyclones', 317-8; Kouroutzoglou et al., 'A high-resolution climatological study on the comparison between surface explosive and ordinary cyclones in the Mediterranean', 1839-43; Trigo, Bigg, and Davies, 'Climatology of Cyclogenesis Mechanisms in the Mediterranean', 552-64

[26] For enterprises that required significant manpower, major cargo investments, or poor navigational equipment, the arrival of the colder climate usually meant awaiting until spring. For examples, see Casson, *Ships and Seamanship in the Ancient World*, 297-9; Lane, *Venice: A Maritime Republic*, 49, 120, 193.

[27] Kitchen, 'The Sea Peoples and Egypt by Alessandra Nibbi', 170; Kitchen, 'Ancient Egypt and some Eastern Neighbours by Alessandra Nibbi (in Reviews)', 78; Bard and Fattovich, 'Spatial Use of the Twelfth Dynasty Harbor at Mersa/Wadi Gawasis for the Seafaring Expeditions to Punt', 8; Lieven, 'Le delta et la vallée du Nil: Le sens de ouadj our by Vandersleyen', 383

[28] Schenkel, 'Colours as Viewed by the Ancient Egyptians and the Explanation of this View as Seen by Academics Studying Colour', 40.

associated with the North (Black Sea), green, yellow, or blue conferred the East, red represented the South (Red Sea and Indian Ocean), while white referred to the West (Mediterranean).[29]

Phoenicians and other ancient Semitic groups described the western sea as 'the Great Sea' (*ym ᶜꜣ*) or 'the Great Sea of Syria' (*ym ᶜꜣ n ḫꜣrw*).[30] In a similar vein, the Ancient Greeks described it as 'the Sea' (*hē thálassa* / ἡ θάλασσα) or 'the Great Sea' (*hē megálē thálassa* / τη μεγάλη θάλασσα). These broad descriptions coexisted with terms applying local ownership, such as 'Our Sea' (*hē hēmetérā thálassa* / ἡ ἡμετέρα θάλασσα) or 'the Sea Around Us' (*hē thálassa hē kath'hēmâs* / ἡ θάλασσα ἡ καθ'ἡμᾶς).[31] Latin terminology follows a similar sentiment, presumably using the equivalent term 'Great Sea' (*magnum mare*).[32] The more popular term 'Our Sea' (*nostrum mare*) was used by the Romans to describe the Tyrrhenian Sea before the conquest of Sicily, Sardinia, and Corsica.[33] After the transition from Republic to Empire, several later authors begin to use 'Internal Sea' (*internum mare*) to separate it from the Atlantic.[34]

Gauis Julius Solinus is often credited with the earliest known usage of 'Mediterranean Seas' (*mediterranea maria*) from the late AD third century in his

[29] Schmitt, 'Namenkundlicher Streifzug ums Schwarze Meer', 411-2; Schmitt, 'Black Sea', 310-1.
[30] Krahmalkov, *Phoenician-Punic Dictionary*, 209; Schipper, *Die erzdhlung des Wenamun: Ein literaturwerk im spannungsfeld von politik, geschichte und religion*, 45.
[31] Purcell, 'The Boundless Sea of Unlikeness? On Defining the Mediterranean', 14; Seirinidou, 'The Mediterranean', 80.
[32] Clement, 'The Mediterranean: What, Why, and How', 115
[33] Tellegen-Couperus, *A Short History of Roman Law*, 32.
[34] Brodersen, 'Mediterranean Sea and Region', 2.

Collectanea rerum mirabilium or *Polyhistor*.[35] Solinus relied on Pliny the Elder's *Naturalis historia* when composing his own geographical text, but this earlier work describes the same body of water only as the *internum mare*.[36] Solinus' new term can be broken down as a compound between the Latin words "middle" (*medius*), "land" (*terra*), and "pertaining to" (-*āneus*), it is also a calque of a Greek equivalent (*μεσόγαιος)*.[37] Bishop Isidore of Seville borrowed heavily from Solinus when he compiled his *Etymologies* in the early seventh century, including using *mediterraneo mari*.[38]

Scholars believe *Etymologies* originally included a world map (*mappamundi*) that was comprised of two concentric circles and followed earlier versions. The outer circle represented a single world ocean, while the inner circle was divided into three sections to represent the continents of Europe, Asia, and Africa. Division inside the inner circle was accomplished using a "T" shape with the trunk representing the Mediterranean. The top part of the "T" was divided in two between the Nile and Don rivers. On most of these early maps, Jerusalem was purposely placed in the center of the world.[39] Isidore's *Etymologies* remained an important and influential literary work throughout the medieval period and its popularity allowed it to become one of the first printed books in 1460.[40]

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[35] Brodersen, 'Mapping Pliny's World: The Achievement of Solinus', 84-5
[36] This difference between the Atlantic and Mediterranean is seen in Pliny, *The Natural History*, 120, 152, 157.
[37] Oxford English Dictionary Definition: Mediterranean, accessed 12 Mar. 2021, https://www-oed-com.srv-proxy2.library.tamu.edu/view/Entry/115766?redirectedFrom=Mediterranean.
[38] Barney et al., *The Etymologies of Isidore of Seville*, 14-15, 277-8.
[39] Woodward, 'Medieval *Mappaemundi*', 301-2.
[40] Barney et al., *The Etymologies of Isidore of Seville*, 25.

Isidore also lived toward the beginning of the medieval period in Visigothic Spain. By the time he was born around AD 560, the western half of the Roman Empire had already collapsed, and the eastern equivalent achieved its greatest territorial extent at around this time under Justinian I (AD 527-65).[41] The Byzantines never relied on a specific general term for the Mediterranean. Most of their correspondences focus on more regional levels with references to the Aegean, Ionian, Tyrrhenian, Sicilian, and Cretan "seas" (*pelagos*) to name a few.[42] This provincial focus could reflect the fact that the Byzantines never achieved the same territorial consolidation of the entire Mediterranean like their forebearers. By the following century, the Byzantines were facing a new opponent from the Arabian Peninsula. United behind their new religion of Islam and the teachings of the Prophet Muhammad, Arab armies quickly took over the Levant. These new conquerors subsequently extended their reach across North Africa and into the Iberian Peninsula.[43]

Early Arab geographers often cite the "inland sea" surrounding their territory as the "Sea of the Greeks" (*Baḥr Al-Rūm*). This phrase seems to fluctuate in its intended use as either a definition for the Mediterranean as a whole, areas owned by the Byzantines, or as a territorial ethnic division collectively between Europeans and the Andalusians / North Africans / Levants.[44] Other geographic terms, such as "Sea of Greater Syria" (*Baḥr Al-Shām*) or "Sea of the Western Islam" (*Baḥr Al-Maghrib*) are

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[41] Browning, *Justinian and Theodora*, 139; Haldon, *The Palgrave Atlas of Byzantine History*, 22.
[42] Kazhdan, 'Mediterranean Sea', 1329.
[43] Pourshariati, *Decline and Fall of the Sasanian Empire: The Sasanian-Parthian Confederacy and the Arab Conquest of Iran*, 283; James, *Early Islamic Spain: The History of Ibn al-Qūṭīya*, 51-2.
[44] Kahlaoui, 'The Depiction of the Mediterranean in Islamic Cartography (11th-16th Centuries): The Ṣūras (Images) of the Mediterranean from the Bureacrats to the Sea Captains', 28-9, 45-6.

also applied as broad encompassing definitions used originally by scholars living in these areas but became regional identities of the Mediterranean as the original centralized Caliphate began to disintegrate.

All three of the above definitions are intended to describe the sea only as a territorial division rather than acknowledging the maritime space itself. Yaqūt Al-Ḥamawī is believed to be one of the first to use the Arabic equivalent to 'Mediterranean Sea" (*Al-Baḥr Al-Mutawassiṭ*) at the beginning of the thirteenth century. The inclusion of this word into the lexicon brought a recognition that multiple separate Muslim polities (and others) operated within a specific maritime sphere encapsulated within this broad term.[45]

Whether late medieval maritime communities along the coasts of the Mediterranean generally acknowledged each other in this space as a single geographical collective is unclear. The shared connection operating within the same encompassing sea may not have been appreciated beyond the sailors and traveling merchants who carried goods to far-flung destinations. Improvements to navigation, due to the thirteenth-century invention of the portolan chart, provided greater accuracy of the Mediterranean coastline. Hundreds of labels on each chart described key coastal features and compass roses with rhumb lines connected major ports.[46] These early charts were mainly concerned with displaying the Mediterranean as a conduit rather than labeling the maritime space itself. Portolan cartographers by the fourteenth century were at least

[45] Ibid., 48.
[46] Nicolai, 'The Premedieval Origin of Portolan Charts: New Geodetic Evidence', 517-8; Armienti and Venger, 'A Middle Age Qibla Finder and the secret code of Portolan maps', 141-3

writing “Mediterranean Sea” in the center of the region.[47] The label suggests that mapmakers acknowledged an encompassing term to define the sea, but there is no similar evidence for a contemporary shared identity between coastal communities. This concept does not appear to gain any significant traction until scientific expeditions in the nineteenth century began to rationalize the Mediterranean as a distinct geographic entity.

Enlightenment ideals incentivized explorers and early scientists to record remote locations throughout the Mediterranean. The upheaval of traditional political boundaries during the Napoleonic Wars also necessitated new spatial divisions on a geographic framework.[48] German geographer Carl Ritter was among the first to conceive the Mediterranean in this new context. He argued in 1817 that the shared geologic and cultural landscape determined physical characteristics not necessarily considered by previous scholars.[49]

While other German scientists embraced Ritter’s concepts and expanded upon them further, one of their French counterparts, Elisée Reclus, proposed an economic approach with similar sentiments in 1879. Reclus argued that the Mediterranean was a holistic space that included physical characteristics, along with a historical, economical, and political portrait distinct from other maritime areas.[50] Many of these discussions shared an environmental determinism that influenced cultural development and was

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[47] See the 1375 “Catalan World Atlas” made by Abraham Cresques and possibly the earliest example for labeling the sea on these types of maps.
[48] Seirinidou, 'The Mediterranean', 85.
[49] Ben-Artzi, 'The Idea of a Mediterranean *Region* in Nineteeth- to Mid-Twentieth-Century German Geography', 4-7
[50] Ruel, 'L'invention de la Méditerranée', 9; Deprest, 'L'invention géographique de la Méditerranée: Éléments de réflexion', 20

compatible with the positivist scientific paradigm continuing to take shape.[51] Nationalism and imperial interests took advantage of this work at the beginning of the twentieth century to reimagine geopolitics in the Mediterranean for their own agendas.[52]

Several groups of scholars continued to argue for a Mediterranean universalism that provided an intellectual setting, a trend which culminated in such works as Fernand Braudel's *The Mediterranean and the Mediterranean World in the Age of Philip II* (1949). Braudel focused on the Mediterranean Basin's epoch formation and considered source material from other disciplines as a valuable resource for historiography. By applying a similar environmental determinism as his predecessors, Braudel removed time (in the form of minute cascading human events) as the framework for social history.[53] Instead, time becomes a multifaceted concept layered between long-term effects (*longue durée*) on geologic scales, a medium level (*conjunction*) following the cyclical loop of changes that occur over decades or centuries, and the traditional historical narrative focused on major events (*histoire événementielle*).

Arguments by later social scientists for how well this approach was conceived, applied, or applicable continues to be debated.[54] The concept of the Mediterranean as a distinct region required early civilizations to originally perceive the sea as a space for commerce and that it could be defined within coastal borders. Whether or not

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[51] Seirinidou, 'The Mediterranean', 86.
[52] Agbamu, '*Mare Nostrum*: Italy and the Mediterranean of Ancient Rome in the Twentieth and Twenty-First Centuries', 255-6
[53] Braudel and Wallerstein, 'History and the Social Sciences: The Longue Durée', 178, 199
[54] Horden and Purcell, *The Corrupting Sea: A Study of Mediterranean History*, 41-2; Voigt, 'Um debate sobre a descontinuidade temporal: Fernand Braudel, Gaston Bachelard, Gaston Roupnel e Georges Gurvitch', 193; Lee, 'Lessons of the *Longue Durée*: The Legacy of Fernand Braudel', 75

Mediterranean actors began to conceptualize a separate distinct maritime space or even saw themselves as a part of a wider shared community, scientists (and many other interests) over the last few centuries argued that a regional perspective supported their research as a preferred descriptive context this approach continues to be used in many modern disciplines.

Conceiving Principles and Methods of Ship Construction

Over the past several decades, French maritime archaeologists Patrice Pomey and Eric Rieth have routinely published research using the operational process as a theoretical approach to understand the growing database of shipwreck remains.[55] Originally proposed by André Leroi-Gourhan, the operational process was adopted by Robert Cresswell and Pierre Lemonnier for their anthropological studies of technological development.[56] Archaeologists often adopt this approach for understanding technological sequences, such as the manufacture of lithics.[57] Pomey and Rieth apply the operational process in nautical archaeology by developing principles that fit earlier discussions on understanding ships as products of their parent cultures. An early practitioner of the subfield, Keith Muckelroy, was a proponent of finding nomothetic patterns between underwater sites. His initial work engineered statistical analyses of site formation processes to determine archaeological significance based on a set of environmental characteristics.[58] Muckelroy also proposed that ships could be seen through three

[55] Pomey and Rieth, *L'archéologie navale*, 20.
[56] Soressi and Geneste, 'The History and Efficacy of the Chaîne Opératoire Approach to Lithic Analysis: Studying Techniques to Reveal Past Societies in an Evolutionary Perspective', 335-6
[57] Sellet, 'Chaine Operatoire: The Concept and its Applications', 108-10
[58] Harpster, 'Keith Muckelroy: Methods, Ideas and *Maritime Archaeology*', 70-2

intertwined aspects that involved their anticipated careers prior to deposition on the seafloor. In this representation, the ship could be seen as a machine designed for transport, as an element in an economic or military system, and as a closed community with hierarchy, customs, and conventions.[59]

According to Pomey and Rieth, the ship is defined as an architectural structure combined with a technical system that transforms it into Muckelroy's machine (figure 4). Architectural structures are watertight hulls that float and interact with both the aquatic and aerial environment. Harnessing these environments require means of propulsion (paddle, row, oar, sail, etc.) and steering devices (rudders or steering oars) that are the mechanical principles of a technical system. Ships as elements of an economic or military system refers explicitly to the functional ensemble, such as a capacious hold for a merchantman or a warship with a slender body to facilitate sailing upwind.[60] Differences in hull forms are reflected in general geometrical proportions that are based on the length of the hull, its beam (width), and maximum depth in the hold. Sailing environments (riverine, coastal, oceanic, etc.) can also be another factor in the selection of hull forms. Shipboard artifacts such as tools, instruments, personal items, and other objects are evidence of the closed community onboard, but the aspect of families living on inland waterways suggests a more appropriate terminology as a "micro-society".[61] One of the great strengths of this approach is that these definitions can be equally relevant for watercraft of all sizes.

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[59] Muckelroy, *Maritime Archaeology*, 216.
[60] Pomey and Rieth, *L'archéologie navale*, 16.
[61] Muckelroy, *Maritime Archaeology*, 221-5; Pomey and Rieth, *L'archéologie navale*, 19-20.

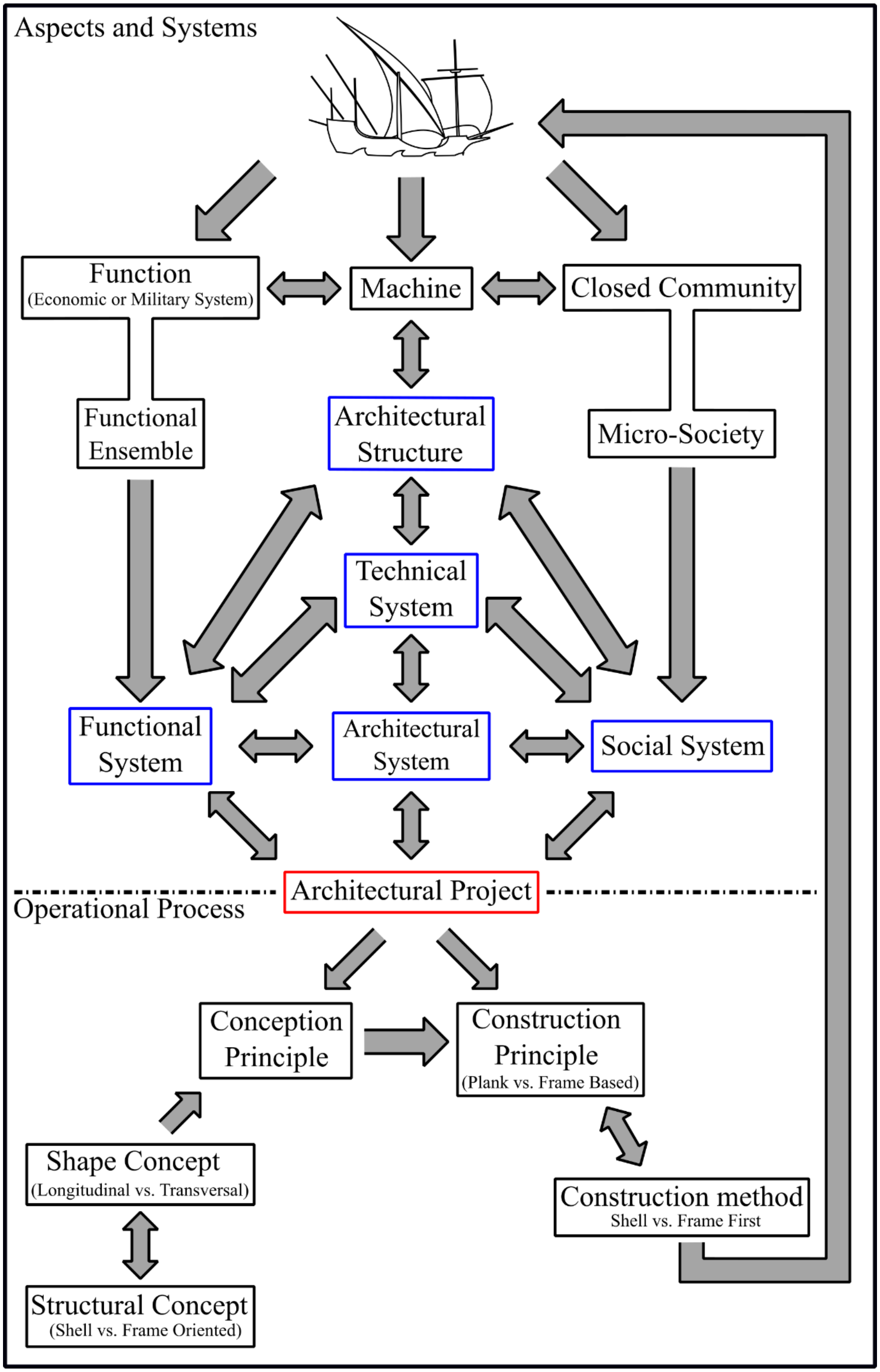

Figure 4 A ship ontology relating the aspects defined by Muckelroy (top row) and the systems presented by Pomey, and Rieth (everything else). (Author's drawing)

Each of the three aspects originally described by Muckelroy are interdependent and can be summarized into four systems: architectural, technical, functional, and social. When an architectural structure is combined with the necessary equipment for an adapted function, it is considered an architectural system. Architectural systems determine the conception and construction for geometric form and the mechanical role between constituent parts of the hull. Each architectural system is reliant on the technical system composed of the propulsion and steering devices.[62] Features from both systems will be adapted to the ship's role as an instrument involved in a specific functional system. The latter system includes arrangements or unique modifications necessary for the intended task of the ship. Typology is determined based on the criterion of all three systems combined. Lastly, the social system codifies the earlier micro-society by discussing the social aspects of the crew, daily activities, and necessary tasks for the functional operation of the ship.[63]

Shipbuilding is described as an architectural project divided into the conception and construction phases of manufacture. During the conception phase, the shipbuilders must consider several operations, such as the financial investment, functional purpose, technical systems, sailing environment and conditions for outfitting the vessel.[64] Each of these considerations involves subsequent actions by choosing the main dimensions, geometry of the hull form, and the propulsion and steering systems. Structural conception of the hull theoretically defines the type of structure that ensures the cohesion

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[62] Pomey and Rieth, *L'archéologie navale*, 19.
[63] Pomey, 'Defining a Ship: Architecture, Function, and Human Space', 27.
[64] Pomey and Rieth, *L'archéologie navale*, 20.

of the assembled elements on a mechanical level and those relations between constituent parts.[65] How these elements are initially assembled during construction provides a technical viewpoint into the mental map of the original builder.

Many ships were assembled in antiquity as a "shell" structural conception that involved edge-joined planking erected prior to the insertion of frames. Most medieval and modern shipbuilding in the Mediterranean involved assembling frames before attaching planking in a "frame or skeleton" structure concept. Another important conceptual operation in the architectural project was determining the overall shape concept of the hull. Shape concept assumes that a geometric proportion based on a certain amount of reference dimensions were used to conceive the entirety of the hull.[66] Concurrent with the structural concept, the shape concept is the perspective of the shipbuilder in designing the hull through a longitudinal (shell) or transversal (frame) vision. Both the structural and shape concepts are combined with the functional decision of the architectural structure to be considered as the conception principle.

Once the shipbuilder has chosen the conception principles, the second phase is the realization or operational process of construction. Surviving hull elements from shipwrecks are the most tangible elements of the original architectural project that archaeologists can easily document. The construction phase is also subdivided into three operations that include the acquisition of materials, their transformation, and the procedural method of construction.[67] For the first two operations, archaeologists are now

[65] Pomey, 'Principes et methodes de construction en architecture navale antique', 400
[66] Pomey, 'Principles and Methods of Construction in Ancient Naval Architecture', 26.
[67] Pomey, 'Defining a Ship: Architecture, Function, and Human Space', 22-3.

engaging in larger interdisciplinary studies to understand the procurement strategies by shipyards for various raw resources.[68] These studies also consider the surviving characteristics left on finished materials as an avenue of research into the manner of how they were created. Lastly, the procedural method explains the assembly process when sawn planks and completed frames were installed in specific orders. Construction sequences vary based on the time and geographical area where the ship was originally built.

Hulls are broken down into three major ensembles: axial timbers, transversal timbers, and planking. Axial timbers refer to the major elements along the longitudinal symmetrical axis composed of the stem, keel, and sternpost. Another form includes flat bottom vessels located along coastal and riverine environments that utilize one or more thick planks that act as the keel. Transversal timbers are the series of frames assembled perpendicular to the axial timbers and planking.[69] Each frame is composed of a floor timber and several futtocks that work in tandem as part of the conception of the hull and in the assembly of the entire structure. Planking serves to provide a watertight hull by being affixed solidly to the outer face of the frames.

There are two families of planking (carvel or lapstrake), which necessitate differences in their assembly to the frames. Carvel-built refers to planking that is either attached to the frames or edge joined together creating a smooth profile because each row (called a strake) is butting against the side of the next. On the other hand, lapstrake-

[68] Domínguez-Delmás, 'Seeing the forest for the trees: New approaches and challenges for dendroarchaeology in the 21st century', 2

[69] Pomey and Rieth, *L'archéologie navale*, 25.

built construction requires each strake of planking to be partially overlapped.[70] Two unique plank types include garboards as the first strake adjacent to the keel and wales, which are thicker strakes that provide longitudinal reinforcement for the hull. An important consideration to remember for the architectural project is that the conception principles and methods can be mixed construction. For example, a shipbuilder might choose to construct a ship based on laying down the lower planking to form the bottom of the hull before inserting framing that is followed instead to complete the remainder of the form.[71]

Each of these structural elements are often discussed based on traditional designations of three construction methods. The first two construction concepts (shell- or frame-first construction) rely on the initial assembly of the axial timbers. Shell-first construction is the older process of shipbuilding that can be seen in many cultures around the world. These shipbuilders utilize conception principles of a plank-based (structural concept) and longitudinal vision (shape concept) to form the hull in a shell-first construction process. Planking fulfills the leading role in design and construction through edge-joined strakes that are either partially or completely assembled prior to the installation of a supporting frame (figures 5-8).[72]

Frame-first construction follows the opposite conception principles by following a frame-based and transversal vision for hull form. Assembled frames provide the shape

[70] Pomey, 'Principes et methodes de construction en architecture navale antique', 397
[71] Rieth, 'La construction navale à fond plat en Europe de l'Ouest', 52
[72] Hasslöf, 'Main Principles in the Technology of Ship-Building', 42-5.

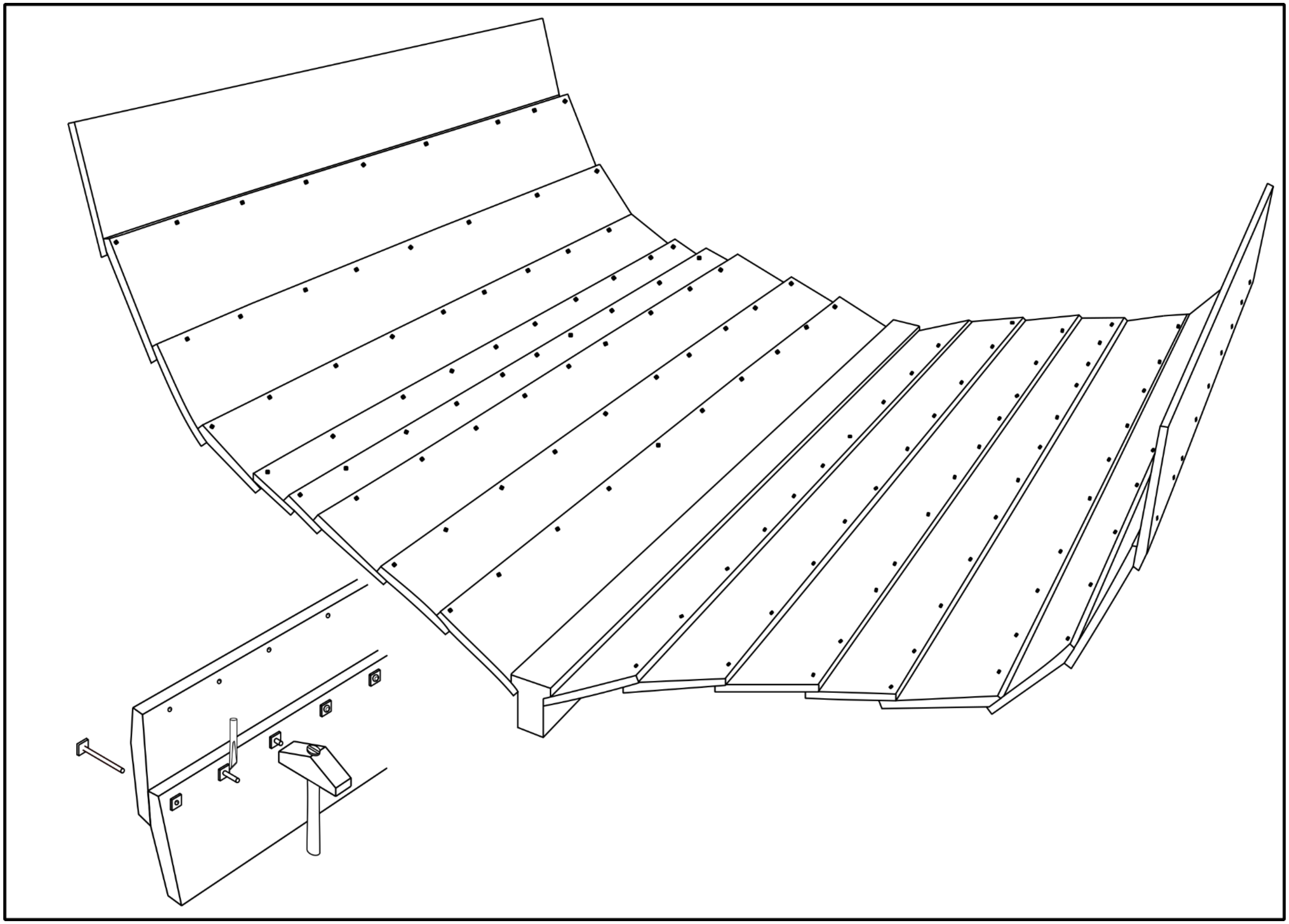

Figure 5   Lapstrake construction showing the assembly of the hull planks first. The method of fastening planks together using nails and roves is shown on the bottom left. (Author's drawing)

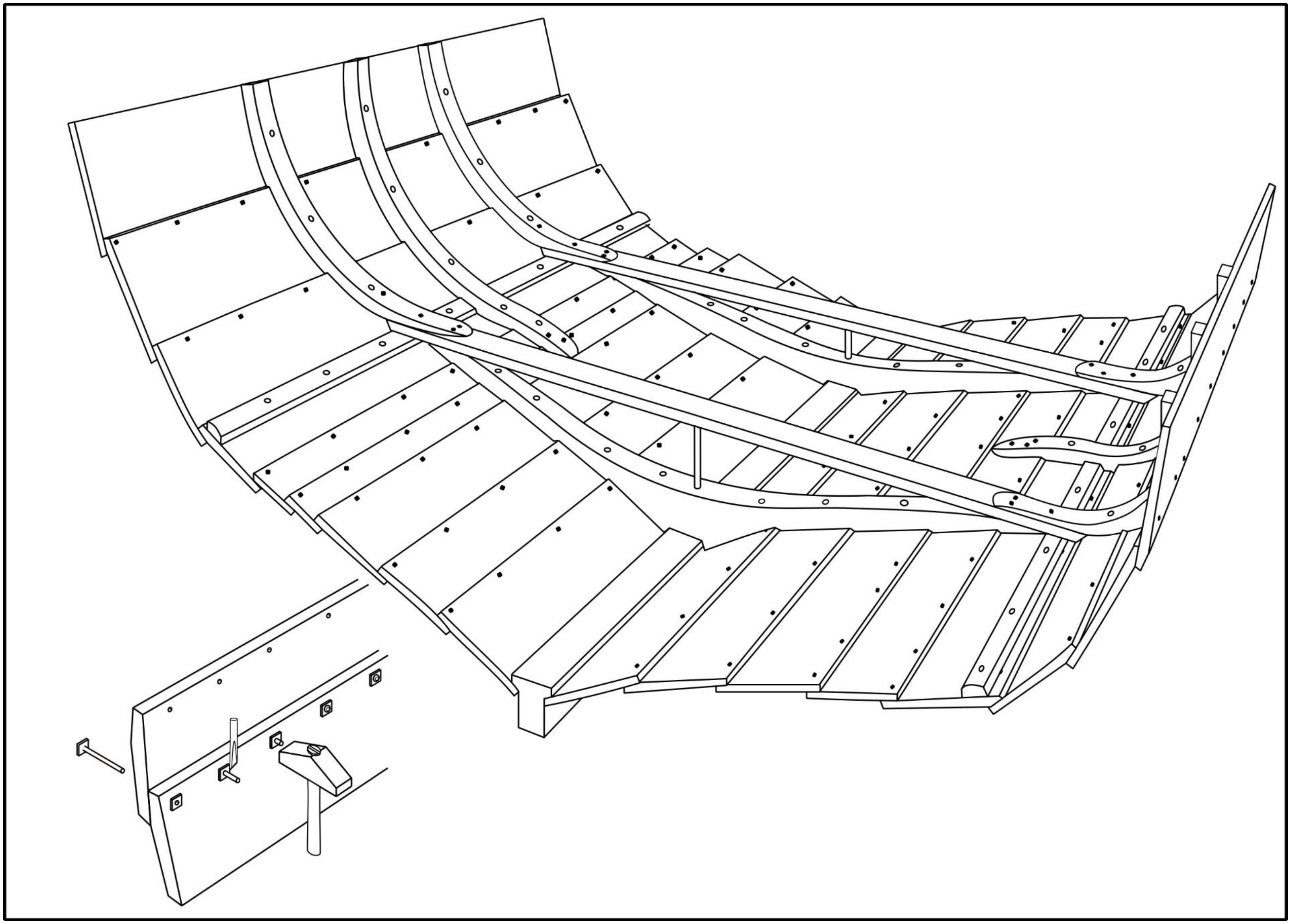

Figure 6 Lapstrake construction with the floor-timbers and futtocks installed after the lower hull was complete. (Author's drawing)

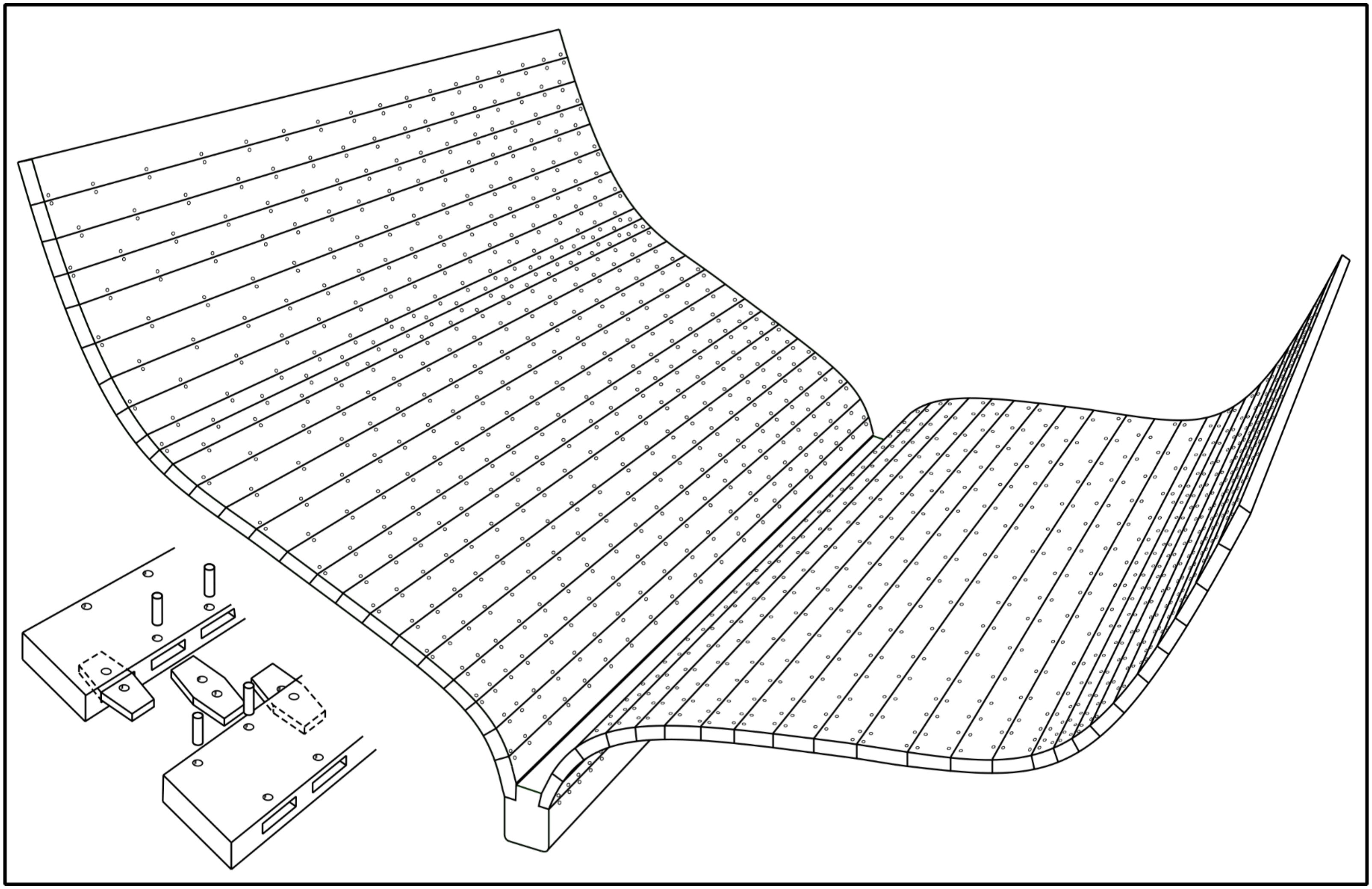

Figure 7 Shell-built carvel construction with the planking first assembled using pegged mortise and tenons (as shown in the bottom left). (Author's drawing)

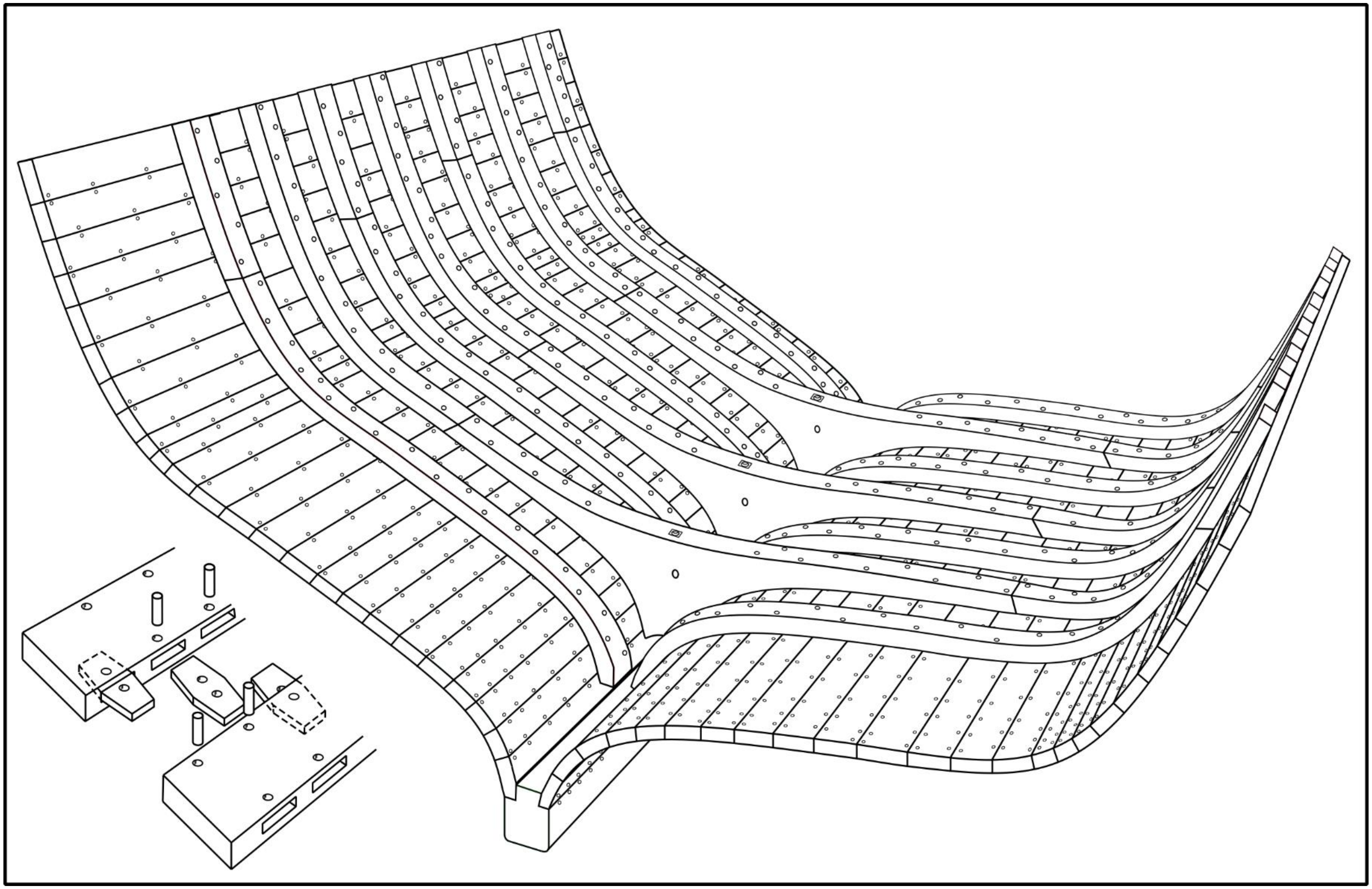

Figure 8   Installation of floor-timbers and half-frames after the planking was assembled. (Author's drawing)

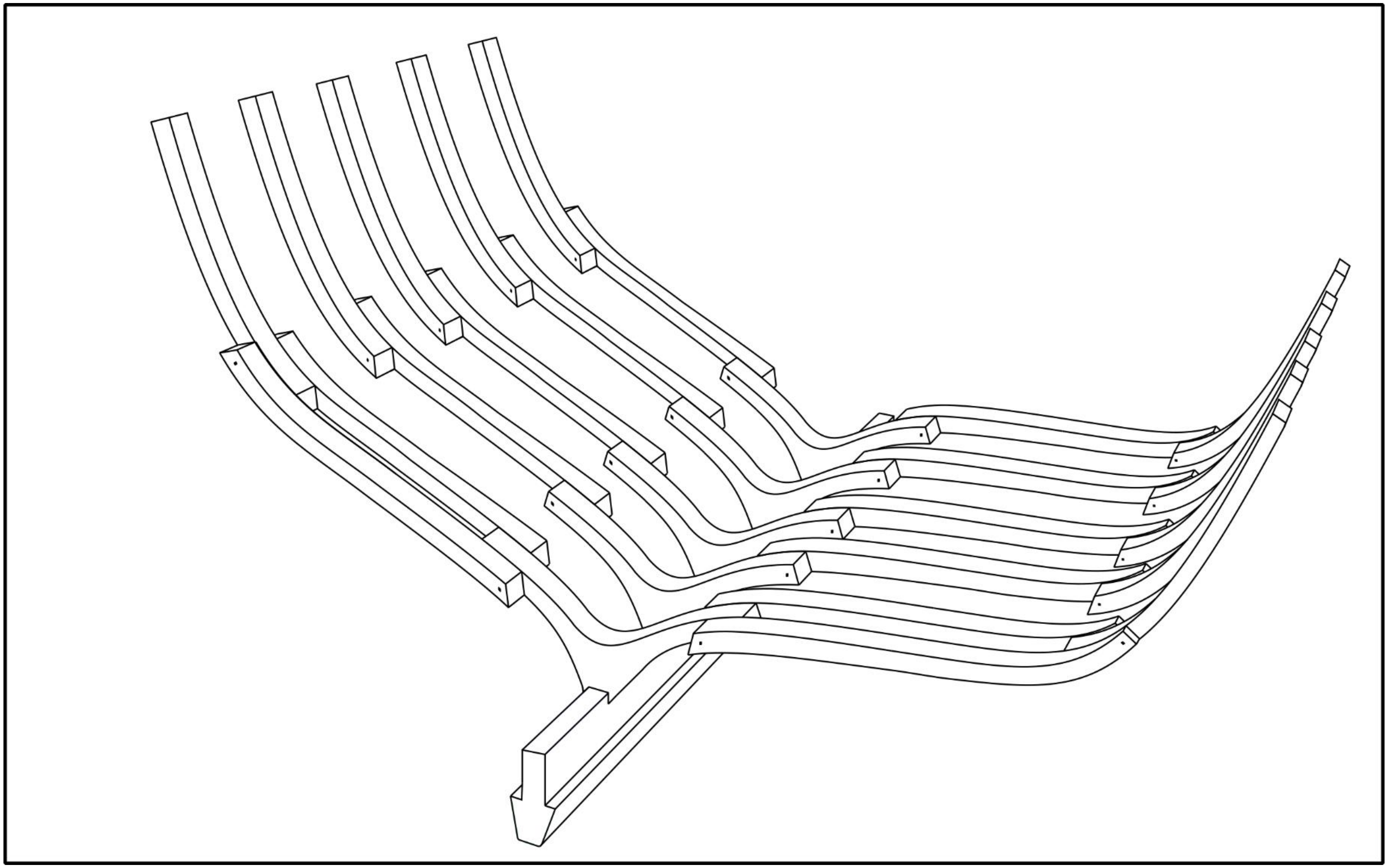

Figure 9   Frame-based construction with the master frame and key design frames erected on the keel. (Author's drawing)

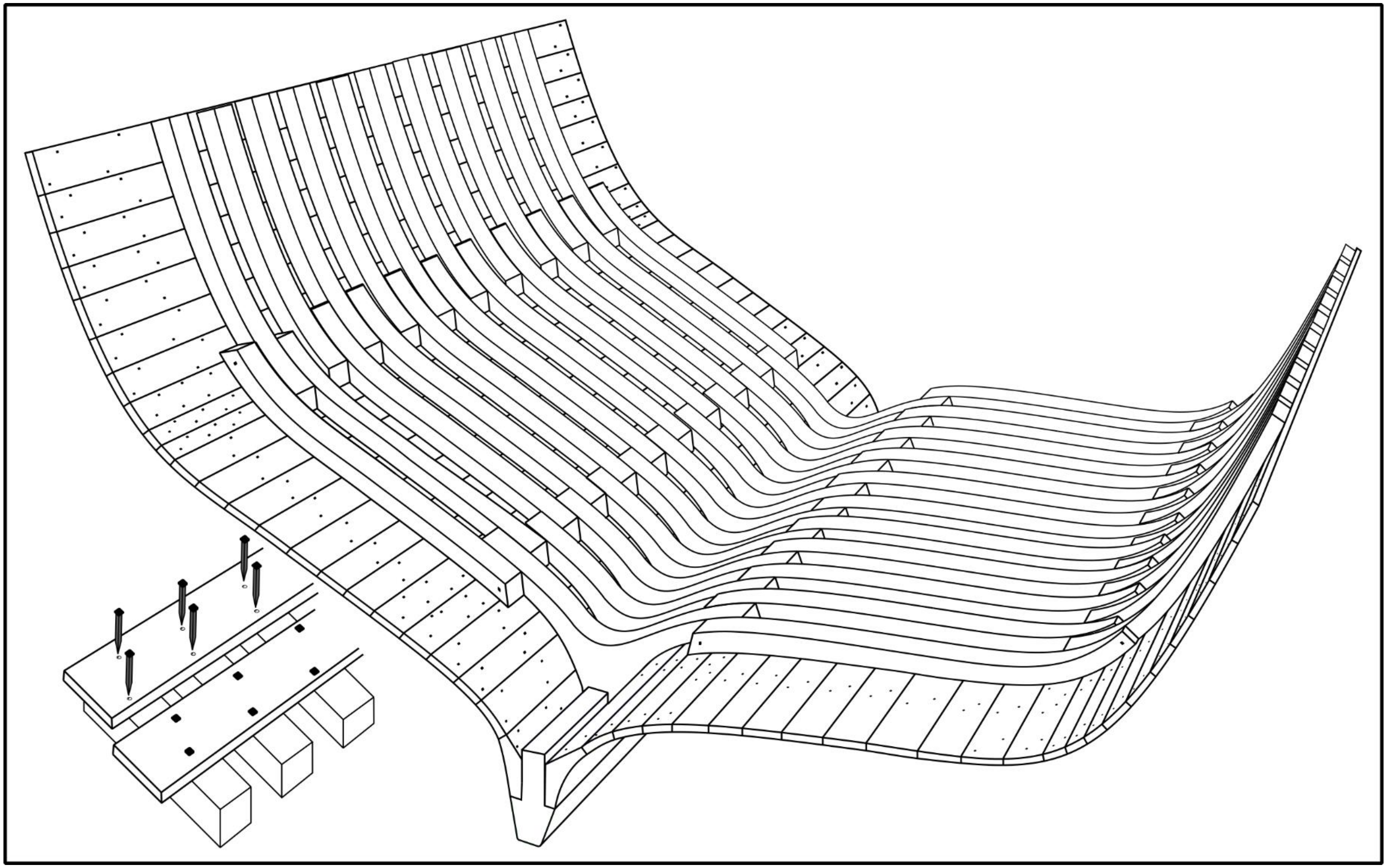
Figure 10 Installing the planking by exclusively fastening each strake with iron fasteners (although treenails could also be used depending on regional preference). (Author's drawing)

and structure of the ship in the frame-first construction process with the planks attached afterward to complete the hull form (figures 9 and 10). Another method is bottom-based construction, which refers to ships without robust keels (often a similar size plank) that utilized flat bottoms composed of several strakes.[73] Examples of bottom-based construction may include edge-joined bottoms that are assembled to lapstrake sides. The flat central area could narrow and twist to attach in a lapstrake manner to the stem and sternpost. Maritime archaeologists often associate bottom-based construction with the medieval cog of Northern Europe, but it also appears throughout the fluvio-maritime environment due to the shallow nature along coasts and river networks.[74]

The above examples showcase ships built within an exclusive conception and construction (i.e. “shell or frame-first”). Over the AD first millennium shipbuilding in the Mediterranean underwent drastic changes from shell-first to frame-first construction. Details on how this transition occurred emphasize a multilinear process that was geographically dependent. Revaluation of many shipwrecks suggest mixed construction depends on whether the frames were “active” or “passive” in the assembly process.[75] In shell-first construction, the frame plays a passive role compared to frame-first construction, where the frame has a primary function in the construction of the hull. Pomey and Rieth acknowledge that one or more active frames might be utilized in a shell-built process as a mold to guide positioning strakes, but this does not change the

[73] Arnold, 'Embarcations romano-celtiques et construction sur sole', 79-81.
[74] Hocker, 'Bottom-Based Shipbuilding in Northwestern Europe', 66-7.
[75] Basch, 'Ancient wrecks and the archaeology of ships', 16

conception principle or construction methodology.[76] An alternative example is the technique in the medieval and modern periods of erecting one or more frames at key points along the keel and attaching ribbands (wooden slats) to act as active strakes in frame-first construction. A. E. Christensen and Pomey describe this as the "shell-builder's solution to skeleton problems" or "vice versa" for active frames in shell construction.[77]

Pomey and Rieth organized their shipwreck data into concentric circles in a synchronic to diachronic pattern. Individual shipwrecks are called "architectural units" that are defined by their conception principles and its method of assembly. Once multiple architectural units are found to share identical functions and are built with similar form or structure, then this larger group is classified as an "architectural type (or model)". Broader connections are made based on the morphology, structure, and technical devices (also including the historic descent), which are considered an "architectural family". Neither dimensions or date affect the grouping of shipwrecks into architectural types/models or families. Architectural families require a decisive criterion between shipwrecks, while the function, sailing routes, and maritime zones in which these vessels operate will vary. Overlapping families that cover the same geographic and cultural dimension are classified as an "architectural tradition". This culture shares

[76] Pomey and Rieth, *L'archéologie navale*, 33-4.
[77] Christensen, 'Lucien Basch: Ancient wrecks and the archaeology of ships, a comment', 143; Pomey, 'Principes et methodes de construction en architecture navale antique', 403-4

technical characteristics in conception principles and methods that persist over long periods across ships from different architectural families and types.[78]

Architectural units provide information on the conception principles and methods for the assembly of the hull. Shipbuilding also includes individual practices that are viewed as characteristics or "architectural signatures" used for comparative analyses. Essentially, architectural signatures relate to the morphological and structural nature revealing specific aspects of an architectural system but are separate from the overall conceptual principles or processes involved in the construction of the vessel.[79] Examples of architectural signatures include the types of fasteners used in construction, the typology of the timber element that holds the foot of a mast, or various methods for waterproofing the hull. Although form and function also play important roles when classifying architectural units into respective types or families, identification of several architectural signatures is paramount for accurate interpretation. Careful consideration should also take place when determining the difference between an architectural signature and a shipyard practice. The latter is often an idiosyncratic preference often with regards to the shapes of individual elements during ship construction (such as chamfering keelsons or stringers) and do not affect the installation or intended purpose of these timbers.[80]

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78 Pomey and Rieth, *L'archéologie navale*, 35; Rieth, *Navires et construction navale au Moyen Âge: Archéologie nautique de la Baltique à la Méditerranée*, 11-13.

79 Rieth, 'Consruction navale a franc-bord en Mediterranee et Atlantique (XIV^{e}-XVII^{e} siecle) et 'signatures architecturales': Une premiere approche archeologique', 178-9.

80 Pomey and Rieth, *L'archéologie navale*, 35-7.

Previous Comparison Studies and Research Design

Debate about shipbuilding and design transitions existed well before nautical archaeology began to coalesce into a new subdiscipline in the 1960s. Most of the early years for the pioneering generation remained concerned about locating preserved hull remains and producing scientific reports or peer-reviewed publications. Bass emphasized the need for more scholarly work at a 1980s conference, stressing that the initial data gathering still left voids in the archaeological record due to the lack of reported material.[81] His concern about this issue remained relevant several decades later when he wrote that too many excavations were taking place without the subsequent data being published for further study.[82] In the meantime, several scholars at the end of the 1980s and early 1990s debated the commonalities and differences between an expanding datasets of various shipwrecks. Pomey and Rieth's application of the operational process coalesced around the same time and were influenced by these same arguments. Besides the continual debates on Mediterranean ship construction, the authors below focused more on periods and regions where archaeological findings provided clues to other shipbuilding transitions.

Ole Crumlin-Pedersen reviewed 40 shipwrecks located in Scandinavia and the northern coastline of Europe dating to AD 800-1400. He argued that shipwrecks could be compared to weapons, jewelry, and wagons as transportable objects whose final resting place was normally not the same location where they were constructed.

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[81] Bass, 'A Plea for Historical Particularism in Nautical Archaeology', 97.
[82] Bass, 'The Development of Maritime Archaeology', 9-11.

Relocating the original place of manufacture for shipwrecks required dendrochronological analyses and tracing the origins of cargos or personal possessions on board. Crumlin-Pedersen stressed that each individual timber needed to be examined to understand its transformation from raw material to finished product by selected toolsets and techniques. Choices made by the shipbuilder for fastening the plank at each frame station or their decision on how to scarf two longitudinal elements together were seen as “fingerprints” alluding to a shared tradition.[83]

Crumlin-Pedersen reviewed archaeological material as a case study to define differences between cogs, and Danish or West Slavic longships. Each group chose to fasten their hulls in a different pattern that allowed further classifications to take place. By figuring out these fingerprints, Crumlin-Pedersen was able to point out developments in construction techniques versus repairs installed over the life the ship. He also stressed that the difference in hull design, cargo capacity, and stability were aspects that could differentiate the intentional purpose of a specific ship. For example, although the remains of the Skuldelev shipwrecks (sunk purposely as part of a navigation barrier) were traditional lapstrake vessels assembled with clinker assembly (nails peened over square washers), subsequent analysis revealed that the shorter and wider profiles of Skuldelev 1 and 3 suggested these vessels were cargo transports rather than the typical Viking longships often assumed to be ubiquitous during this period. The Skuldelev cargo vessels could be related to much larger craft that followed similar construction techniques, which allowed bigger lapstrake longship-type vessels to compete against the

[83] Crumlin-Pedersen, 'Ship Types and Sizes, A.D. 800-1400', 69-70.

traditional cog designs. Nonetheless, Crumlin-Pedersen also cautioned that shipbuilders inspired one another, and this led to technical solutions combining the best construction features. The products from this union would be harder to pinpoint for their construction origin, as well as defining their typologies, both historically and archaeologically.[84]

Sean McGrail echoed similar thoughts as Crumlin-Pedersen in his review of Romano-Celtic shipbuilding based on a handful of archaeological sources. McGrail downplayed particularism for simplifying the complexities in structure and form to designate shipwrecks as being from similar origins. He considered his approach as polythetic by incorporating hull remains based on the largest number of common characteristics, even though several members of the group still contained traits that were outside the expected range of construction techniques. McGrail also emphasized that archaeologists should be studying shipbuilding based on the builder's conceptualization on how the hull was assembled.[85] His subsequent discussion on whether the overall hull was plank or frame "oriented" were incorporated by Pomey and Rieth as part of their concept distinction of the build process.[86]

Thomas Oertling approached Iberian shipbuilding by first analyzing seven known sixteen-century shipwrecks in 1989 looking for similarities and differences to associate with historic typologies.[87] He also revisited this topic in the late 1990s using additional finds. Oertling's conclusions on both occasions revealed more ubiquity in

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[84] Ibid., 72-7.
[85] McGrail, 'Romano-Celtic boats and ships: Characteristic features', 141-2
[86] Pomey and Rieth, *L'archéologie navale*, 30.
[87] Oertling, 'The Few Remaining Clues', 102.

construction techniques than was originally assumed. Specific typologies could not be identified in the archaeological record because similar construction methods were used regardless of hull shape or size. Since these hull remains could not be classified based on the known types (caravel, *nao*, galleon, etc.), Oertling proposed an archaeological taxonomy separate from the historical record. The shipwrecks were classified as part of the "Atlantic Vessel tradition", which quickly brought the ire of critics who responded that these ships shared a heritage with earlier shipbuilding from the Mediterranean. Oertling's response to this critique was to redefine the Atlantic Vessel as a sub-tradition of the overarching Mediterranean tradition absorbed by western Iberian shipbuilding in the fifteenth century.[88] Limited proposals for multitiered frameworks that differentiated between regional shipbuilding and small groupings (i.e. architectural unit vs. model vs. tradition) led to many disagreements over such comparative analyses. Critiques aside, Oertling's classification scheme was still adopted by those studying shipwrecks from this area and period who retitled the shared traits as part of an "Ibero-Atlantic tradition".[89]

Rieth also conducted a similar survey of limited hull remains from the Mediterranean. His analysis echoed Crumlin-Pedersen and McGrail's statements that comparative analyses should emphasize the importance of hull design in comparison to the technical features in assembling the ship. In this case, the architectural signatures were considered secondary, but they nevertheless represented an important technical

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[88] Oertling, 'The Concept of the Atlantic Vessel', 237-8.

[89] Loewen, 'The Structures of Atlantic Shipbuilding in the 16th Century: An Archaeological Perspective', 252.

legacy illustrating regional historical trends in construction techniques. When several shipwrecks with similar architectural signatures are compared, further questions are generated about the possible exchanges or influences between localized traditions (such as the differences in regional fastening patterns noted by Crumlin-Pedersen).[90] Rieth's sample of five Mediterranean shipwrecks dating between the fourteenth to seventeenth centuries provide only a few shared architectural signatures. Most of the examples include hook scarfs connecting the floor timbers to first futtocks and the predominant use of iron nails for assembling the entire vessel. Several shipwrecks share a similar composite mainmast step built over a thin rectangular keelson. Rieth also mentions the use of rebated outer longitudinal planking that was more common to eastern Mediterranean shipbuilders.[91] Although the shipwrecks that Rieth used in his analysis included unique architectural signatures, he emphasizes that the frame-based construction remained constant throughout the centuries under consideration. Differences in technical choices were apparent and provided details on where ships originated, but it did not significantly change the overall architectural system.

The main themes that appear between each author's analysis (along with Pomey and Rieth's operational process) is to strip the historical taxonomy often used by researchers and replace it with an artificial classification system. Debate on what terminology to use for creating this new taxonomy depends on regional studies and personal preferences. Several authors argue that design and construction techniques are

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[90] Rieth, 'Consruction navale a franc-bord en Mediterranee et Atlantique (XIV^{e}-XVII^{e} siecle) et 'signatures architecturales", 178-9.
[91] Ibid., 186-7.

two sides of the same coin. The tangible remains are evidence of the cognitive abilities of the shipbuilders and their decisions during construction. Newer ships will also present shared traits from previously separate traditions and require a shared cluster for analysis. Cargo remains an important commodity for hull studies, as this material can offer evidence about an area of operation for each vessel. Crumlin-Pedersen also highlighted dendrochronology as a crucial area of interdisciplinary collaboration that provides insights into the origin of timber and the location of a shipyard. The longtime incorporation of dendrochronologists in Northern European research has provided information that many other regions are only now taking steps to emulate.

Out of the comparative analyses conducted over the last several decades, Rieth's examination of late medieval and early modern shipbuilding includes the smallest sample size. This research was carried out over 25 years ago and provides the main premise for this dissertation. My objective is to revisit this period to identify whether new archaeological material can provide insight into Mediterranean shipbuilding from AD 1000 to 1700. This period overlaps with the purported abandonment of shell-based construction and prior to the beginning of naval architecture as a true discipline. By examining this dataset, we may consider whether earlier examples of frame-based construction continued to utilize shell-based techniques long after the supposed change in methodology. Recent research has also argued that Mediterranean shipbuilders in antiquity did not share the same construction techniques across the basin.[92]

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[92] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 307

Another objective of this dissertation is to explore whether this conclusion also applies to the late medieval and early modern period. Studies of sites dating to antiquity often rely on the archaeological material alone, due to limited associated documents describing shipbuilding. Detailed record keeping for shipbuilding became a state necessity (or the subject of intellectual curiosity) during the late medieval and early modern period. Surviving documents on this topic will be reviewed for evidence of change and construction in design methods and construction procedures. Recent archaeological investigations also report new hull shapes that were not encountered before.[93] These shapes will be compared with the documentary material to determine if there is any correspondences between them.

This dissertation is laid out using the parameters outlined by Pomey and Rieth for employing the operational process. The focus of this research is on archaeological remains using a basic taxonomy which divides them between longships or round ships. Based on their overall length to breadth ratios, any ship greater than 1 to 5 is considered a longship for this discussion. Historical typologies will be addressed in Chapter 2 as part of the background for each archaeological site. Most sites in this discussion were ships that could operate offshore or along the coastline with scant mention of contemporary rivercraft.[94] Due to the size and scope of this dissertation, its focus is on

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[93] Cazenave de la Roche, *The Mortella III Wreck: A Spotlight on Mediterranean Shipbuilding of the 16th Century*, 128.
[94] For a brief discussion on rivercraft found in this period and a general source of Mediterranean maritime archaeology, see Beltrame, *Archeologia marittima del Mediterraneo: Navi, merci e porti dall'antichià all'età moderna*, 214-5, 221-2.

the surviving hull remains without attempting to discuss propulsion systems unless evidence survives in the archaeological record (i.e. the mainmast step or rudder).

For some scholars, the absence of discussions of propulsion systems limits the pertinence of this research. The taxonomic differences longships and round ships should coincide with the preferred propulsion systems and their influence upon the design. Both ship types utilize sails during this period, but longships also rely on rowing that is closely dependent on a long narrow hull. Limited discussions are included about superstructure since few examples survive. Most of this dissertation focuses instead on the surviving hull remains below the waterline that also serve as the most consistent material for comparison.

Chapter Summaries

Chapter 2 of the dissertation provides background and archaeological information for 41 individual sites. Each example first includes contextual history supplied by the original investigators or a discussion of associated events that transpired around the dating of the wreck. The late medieval and early modern period comprises 700 years of Mediterranean history, including the Crusades, decline and fall of the Byzantine Empire, rise of Italian Republics, domination of European politics by the Habsburg family beginning in the sixteenth century, Battle of Lepanto, and the seventeenth-century shift of trade focusing toward the Atlantic. A lengthy historical context for this 700-year span would be unwieldly to include here. Therefore, the historical background is limited to events associated with the individual wrecks, acknowledging that much more transpired between these losses. Each site is also described with the known excavation history and hull findings.

Chapter 3 compares the archaeological material by identifying similarities or differences in the construction characteristics. Shipbuilding in the late medieval and early modern period did not occur in a vacuum, so the beginning of this chapter includes a summary of recent comparative results on earlier ships from antiquity and the transition to frame-based construction. The remainder of the chapter discusses framing patterns, scarf connections, mast steps, surviving upper hull structures, fastener types, and waterproofing techniques. There is also a subsection discussing the available information on dendrochronological analyses. Most of this information is only species identification, for scholars have found it difficult to produce master chronologies for forests in the Mediterranean region. The immediate goal is to make this information available for future work and to incentivize dendrochronology research on future projects.

Chapter 4 is a discussion about two different avenues for organizing and understanding the data presented in the previous two chapters. The first approach follows recent research by Rieth organizing hull forms and locating the origins of these shapes in antiquity. This method is taken a step further by using the same approach on slightly later forms and debating its merits. The other half of the chapter suggests that the operational process can utilize practice and social learning theories to understand the development of shipbuilding across the Mediterranean. The discussion revolves around the theory that traditional craft apprenticeships reinforce longstanding practices within a given industry. Shipbuilding, as a traditional apprentice-based education system, fits this model well and suggests that multiple communities around the basin shared commonalities but also developed different solutions.

Chapter 5 reviews the conceptualization of shipbuilding by examining its development in antiquity and subsequent periods. The design and concept of ships takes place before or amidst construction, but its consideration is placed last in this dissertation because most of our earlier theories for this period are based on archaeological material. Early documents are mainly composed of shipbuilding estimates that mention little in design methodology. Venetian arsenal records provide offsets and other information by the beginning of the fifteenth century. These documents were mainly generated by individuals who had an interest in shipbuilding but were not actual practitioners. Documents prepared by shipbuilders only become commonplace in the sixteenth century and thereafter. Most available historical documents for this period focus on longship construction with a limited number of details on contemporary round ships. Any archaeological material with surviving evidence for how the ship was designed is also included and compared.

Chapter 6 is the dissertation's summary and conclusion and addresses the original research design and all significant findings. This section also critiques the application of the operational process and the two additional approaches applied to the data in Chapter 4.

The intention of this dissertation is to address the archaeological material available in the Mediterranean from the late medieval to early modern period. Nautical archaeological research on ships and maritime sites from this era often summarizes major changes as a bridge extending from antiquity to the early modern period. The reasons for this limited description are due to the small number of shipwrecks dated to this era, changes in cargo types that previously preserved underlying hull, and archaeological interest in excavating these sites. Based on this consideration, the hope is that the description of shipwrecks and analyses below provides an updated guide for those interested in pursuing this topic further.

The archaeological site plans presented here are color coded and labeled for the express purpose of making it somewhat easier to understand and access this information for the novice. The dataset also allows the implementation of theoretical ideas from mainstream archaeology into shipbuilding. As more shipwrecks are published, future archaeologists will ask general questions that are answered through datasets based on multiple shipwrecks and not exclusively tied to comparison with an individual site. The discussions in this dissertation will provide the impetus for continued work about a period where frame-based shipbuilding in the Mediterranean developed and matured.

CHAPTER II

SHIP DESCRIPTIONS

Archaeologists studying technological changes between lithic manufacturing communities are fortunate to often have large sample sizes for statistical analyses.[95] Similar observations can be equally applied to investigations on ceramic manufacture or other materials that survive in large quantities.[96] Nautical archaeology struggles with collecting, reporting, and disseminating information about surviving hull structures from archaeological sites.[97] Part of this issue is due to the nature of the material studied. Historic ships were mainly built with biodegradable resources that frequently do not survive in the material record. Ships were also lost in remote places and these same locations remain dangerous even for modern shipping.[98]

Artifacts recovered from underwater sites often survive much better than their terrestrial equivalents. When a ship is lost at sea the aquatic environment often proved a natural barrier for systematic underwater salvage. By way of contrast, terrestrial locations for human habitation were typically abandoned with only broken or disused items left behind. Both terrestrial and underwater sites also benefit from site formation processes that bury or inundate archaeological remains, creating waterlogged and/or anerobic environments which result in a higher level of organic preservation.[99]

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[95] For an example of estimated lithic scatters in the thousands, see Fernández-López de Pablo and Barton, 'Bayesian Estimation Dating of Lithic Surface Collections', 563

[96] For an example of large scale quantification of amphora rims, see Corredor and Vidal, 'Archaeological Quantification of Pottery: The rims count adjusted using the modulus of rupture', 338-41

[97] Bass, 'The Development of Maritime Archaeology', 9-11.

[98] See subsections below on Chrétienne K and Sardinaux, both wrecks are in ship traps where modern beacons now warn of the submerged hazards.

[99] Gregory, 'Characterizing the Preservation Potential of Buried Marine Archaeological Sites', 853-5

Shipwrecks are not necessarily violent events, sometimes a ship is grounded and cannot be refloated or is abandoned after a long life. Preservation of the hull depends on the ballast, abandoned cargo, and any sediment covering the remains from being exposed to wood devouring marine organisms. Corrosive bacteria, mollusks (such as *teredo navalis*), and other creatures lead to a much faster breakdown of ship remains generally in warm water environments.[100] Entire hulls can survive on the sea floor in the cold Arctic or in the low salinity Baltic Sea, whereas ships lost in the warm waters of the Mediterranean are visually reduced to fragmentary remains in short order.[101] This does not mean that no ship remains survive in the Mediterranean, only that a greater level of preservation is typically found in colder or freshwater underwater environments.

Mediterranean shipping in antiquity relied on ceramic amphoras for transporting many commodities. After a wrecking, this pottery (whether intact or broken into sherds) becomes a sediment trap that affectively preserves the hull structure underneath.[102] Modern ships survive in either due to their greater numbers, younger age, or because they were built of composite metallic materials that survive in a different state than organic equivalents. Preferences for wooden barrels and crates as shipping containers also led to less preservation for shipwrecks dating to the medieval period or early modern period.[103] Archaeologists excavating medieval and early modern shipwrecks also benefit from the increased use of sand and stone ballast that offset the buoyancy of the hull and replaced earlier amphora as the protect layer. Nonetheless, current

[100] Varinlioğlu, 'Assessing a Decade of Kaş Underwater Archaeopark', 79-81, fig. 5
[101] Lippert et al., '*Teredo navalis* in the Baltic Sea: Larval Dynamics of an Invasive Wood-Boring Bivalve at the Edge of its Distribution', 2-3
[102] For a significant list of intact hull remains from antiquity, see Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 286-90
[103] Bevan, 'Mediterranean Containerization', 397-9

trends still skew the reported information on ships from earlier periods than the late medieval era.[104] On the other hand, recent archaeological excavations are poised to provide a significant amount of data about early modern Mediterranean shipbuilding over the next decade.

This chapter reviews 41 archaeological sites throughout the Mediterranean dating between the eleventh and seventeenth centuries. Few of the wrecks discussed include complete hull structure. Many are only comprised of timbers from the centerline to the turn of the bilge. The ships range in size between the 8 m Precenicco boat that plied river networks and coastal trade to the 47 m long Villefranche shipwreck that was built for long-distance oceanic sailing. Instead of compiling a seven-century narrative for the Mediterranean, most subsections include a discussion on the available historic regional context where a ship was lost. Each description also includes a brief report about the archaeological operations, including any important artifacts that provide a date for the site.

Several of these reports attempt to attach a historic typology or identity to the remains. Associations are included for the reader but will not be used in any subsequent analysis. Each wreck is described for the current study as a round ship, longship, or based on its construction tradition. These labels are established by the length to breadth ratio, operational process, or group identities discussed in Chapter 1. Further comments about these categories will be discussed in the following chapters. The current discussion mainly focuses on the construction characteristics as described in publications and with members of the associated excavation teams. Elements related to the conception of the hull, such as measurement proportions, the use

[104] Wilson, 'Developments in Mediterranean shipping and maritime trade from the Hellenistic period to AD 1000', 33-7.

Table 1 Ship dimensions, cross sections, and fasteners

Shipwreck	*Date*	*LOA (m)*	*Beam (m)*	*Depth (m)*	*Ratio*	*Cross-Section Amidships*	*Nails (cm)*	*Bolts (cm)*	*Treenails (cm)*
(1) Serçe Limanı	1025	15.66	5.2	2.4	1:3.01	Flat floor timbers, hard chine 72° flair outward	0.8-1.2 cm sq.	1.5-2 cm diam.	1-1.2 cm diam. repairs only
(2) Marsala A	1050s	18	5.8	2.9	1:3.1	Slight deadrise, round bilge	0.8 cm sq.	3 cm diam.	None
(3) Marsala B	1100s	8.4	2.8	1.4	1:3	Flat floor timbers, hard chine 72° flair outward	Square	None (?)	None
(4) Rhodes 4	1175-1200s	30-35				Flat floor timbers, hard chine 71-72° flair outward	Nails	Bolts	?
(5) Precenicco	1180-1300	8	1.6		1:5	Flat floor timbers, soft chine flair outward	present	None	1.8-2 cm diam.
(6) Çamaltı Burnu I	1200-1225	25	8		1:3.1	Flat floor timbers, unknown bilge	0.5 cm sq.	2 cm diam.	None
(7) Rhodes 1	1240 ± 60	20+				Flat floor timbers, round bilge	Present	Present	None (?)
(8) Culip VI	1290-1300	18.8	4.8	2.2	1:3.92	Flat floor timbers, round bilge	1 cm sq.	1.5-1.8 cm diam.	possible treenails 1.5-1.8 cm diam.
(9) Camarina	13th ca. (1301?)	30	4		1:7.5	Flat floor timbers, round bilge	Present	Present	Present
(10) Olbia Wreck 4	1323 (?)	9.5+	3+		1:3.1+	Flat floor timbers, round bilge?			
(11) Boccalama A	1300-1325	23.6	6	0.74	1:3.9	Flat floor timbers, hard chine	Square		3 cm diam.
(12) Boccalama B	1300-1325	38	5		1:7.6	Flat floor timbers, round bilge	Present	Present	None (?)
(13) Les Sorres X	1390s	9.5	1.9	0.9	1:5	Flat floor timbers, slight round bilge	1 cm sq.	None	2 cm diam.
(14) Olbia Wreck 10	1405-1440					Flat floor timbers, round bilge (?)	Square	?	Present
(15) Bacàn 2	1420s	15-16				Flat floor timbers, round bilge	0.8 cm sq.	Present	Present (Ceiling)
(16) Marinières	1420-1430	25	8.45	2.07	1:3	Flat floor timbers, round bilge	0.8-1 cm sq.	2.5 cm sq.	3-3.5 cm diam.

Table 1 Continued

Shipwreck	*Date*	*LOA (m)*	*Beam (m)*	*Depth (m)*	*Ratio*	*Cross-Section Amidships*	*Nails (cm)*	*Bolts (cm)*	*Treenails (cm)*
(17) Cavoli	1440s					Limited hull remains	1-1.5 cm sq.	Not recorded	2.5 cm diam.
(18) Bacàn 1	1450s	15-16				Flat floor timbers, round bilge	0.8 cm sq.	Present	Present (Ceiling)
(19) Contarina I	1460s	20.98	5.2	2.46	1:4.05	Flat floor timbers, round bilge	1.5 cm diam.		None
(20) Contarina II	1475s	20.5	6.3	1.67	1:3.25	Flat floor timbers, round bilge	1.4 cm diam.		None
(21) Mariposa A	1475-1525	16.8 (25)	4.5 (9)		1:4.15	Flat floor timbers, round bilge (?)	0.6-0.7 cm sq.		3-4 cm diam.
(22) Rhodes 2	1480 or 1522					Unknown	No detail	No detail	No detail
(23) Mariposa B	1500-1525	16				Slight deadrise, round bilge	Present	Present	?
(24) Lake Garda	1509	39.6	4.9		1:8.08	Flat floor timbers, round bilge	Square	Present	None
(25) Villefranche	1516	46.45	14	4.4	1:3.32	Wineglass - deadrise 35 cm	1-1.5 cm sq. & 1.2-1.6 cm diam.	3 cm diam.	
(26) Mortella III	1527	36.8	10.5	6.15	1:3.5	Half-circle - deadrise 33 cm	1-1.3 cm diam.	3 cm diam.	
(27) Sardinaux	1500-1550 (1540s?)	10-12	~1.8		1:5	Flat floor timbers, round bilge	0.4-0.8 cm sq.	None recorded	3 cm diam.
(28) Chrétienne K	1500-1550 (1540s?)	20-30				Flat floor timbers, round bilge	1 cm sq.	1.3 cm diam	
(29) West Turtle Shoals	1550-1600					Flat floor timbers, round bilge (?)	2 cm diam.	2 cm diam.	Present
(30) Yassi Ada 3	1572+	21.2	6	1.2	1:3.53	Flat floor timbers, round bilge	0.8-1 cm sq.	2.5-4 cm diam.	2.5-3 cm diam.
(31) Cadiz-Delta II	1573 (1587)	30				Wineglass?	Iron nails	Bolts	
(32) Calvi 1	1575	23.4	7.8	2.2	1:3	Wineglass - deadrise 39 cm	0.8-1 cm sq. & 0.8-1 cm diam.	2-2.5 cm diam.	2 cm diam. One on entire wreck
(33) *Kadırga*	1575-1625	39.57	5.72	1.34	1:6.92	Flat floor timbers (slight deadrise), round bilge	Square	Present	None

Table 1 Continued

Shipwreck	*Date*	*LOA (m)*	*Beam (m)*	*Depth (m)*	*Ratio*	*Cross-Section Amidships*	*Nails (cm)*	*Bolts (cm)*	*Treenails (cm)*
(34) Cap Lardier 1	1575-1600	20 ± 2				Flat floor timbers, round bilge	0.48-0.49 cm sq.	3 present	
(35) Agropoli	1575-1625	23	5.75		~ 1:4	Flat floor timbers, round bilge	Iron nails	Bolts	
(36) Sveti Pavao	1580	24	6+		1:4+	Flat floor timbers, round bilge	1.5-2 cm sq.	2-2.5 cm diam.	None
(37) Church Rocks	1582+						Present	Present	None
(38) *Trinidad Valencera*	1588					Flat floor timbers, round bilge (?)	1.3 cm sq.	2.5 cm diam.	None
(39) Ribadeo	1590 (1597)	34.48	11.78	7.76	1:4.49	Wineglass?	Iron nails	Bolts	
(40) Rodinara	1590-1620	14	4.5	2	1:3.11	Flat floor timbers, round bilge (?)	0.7 cm sq.	1.5 cm diam	
(41) Saint-Honorat 1	1637	25-30				Shallow wineglass (?)	Iron nails	bolts	Treenails (Ceiling only)

(1) Matthews and Steffy, 'The Hull Remains'; (2, 3) Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala'; (4) Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck'; (5)Capulli, 'Il Relitto di Precenicco'; (6) Günsenin, 'The construction of a monastic ship'; (7) Koutsouflakis, 'Three Medieval Shipwrecks'; (8) Rieth, 'L'Arquitectura Naval'; (9) di Stefano, 'La galea medieval di Camarina'; (10) Riccardi, 'I relitti del porto di Olbia'; (11, 12) Romanelli, *La Galea Ritrovata*; (13) Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc'; (14) Riccardi, 'I relitti del porto di Olbia'; (15) Medas, 'I relitti tardo-medievali del Bacàn'; (16) Daeffler, 'L'Epave des Marinières'; (17) Martin-Bueno, *La Nave de Cavoli*; (18) Medas, Due relitti con carichi lapidei rinvenuti al Bacàn'; (19, 20) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (21) Riccardi, 'Evidenze archeologiche di imbarcazioni'; (22) Koutsouflakis, 'Three Medieval Shipwrecks'; (23) Gavini, 'Osservazioni sulla circolazione dei manufatti ceramici'; (24) Capulli, *Le navi della Serenissima*; (25) Guérout, 'Le navire Génois de Villefranche'; (26) Cazenave de la Roche, *The Mortella III Wreck*; (27) Joncheray, 'Un navire de commerce de la fin du XVIIe siècle; (28) Lopez, Joncheray, Brandon, 'L'épave post-médiévale Chrétienne K', (29) Russo, *West Turtle Shoals Wreck (8MO142)*; (30) Labbe, 'A Preliminary Reconstruction'; (31) Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto Delta'; (32) Villié, 'L'épave Calvi 1'; (33) Arcak, 'Kadırga'; (34) Joncheray, 'L'épave dite «des ardoises», au cap Lardier'; (35) Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli'; (36) Beltrame, 'The ship'; (37) Preece, Burton, and McElvogue, 'Evidence for High Status at Sea'; (38) Martin, '*La Trinidad Valencera*'; (39) San Claudio Santa Cruz, 'Excavating a 16th-century Galleon'; (40) Villié, 'La Rondinara'; (41) L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes'

Table 2 Axial timbers measurements and characteristics

Shipwreck	*Date*	*Keel dimensions sided, molded (cm)*	*Keel Rabbet*	*Keel Scarf*	*Additional Keel sided, molded (cm)*	*Stem sided, molded (cm)*	*Sternpost sided, molded(cm)*
(1) Serçe Limanı	1025	12 x 16	Only rabbeted endposts	Flat scarfs		N/A (probably round)	10-15 x 12.5-15
(2) Marsala A	1050s	10 x 12-14	Keel Rabbet	Butted to endposts (?)		Round	
(3) Marsala B	1100s	9 x 3	None	Plank			
(4) Rhodes 4	1175-1200s	29.5 x 18	Present near sternpost	Hook scarf or half-lap (stern)			
(5) Precenicco	1180-1300	16-19 x 3-3.5	None	Plank			
(6) Çamaltı Burnu I	1200-1225	16 x 23					
(7) Rhodes 1	1240 ± 60	Keel plank	None	Plank			
(8) Culip VI	1290-1300	7 x 9	None	Butted (bow)		7.8-8.5 x 7	N/A
(9) Camarina	13th ca. (1301?)	12-14 x 16	Chamfered Keel	Unknown			
(10) Olbia Wreck 4	1323 (?)	7-15 x ?	Keel Rabbet				
(11) Boccalama A	1300-1325	Keel plank					
(12) Boccalama B	1300-1325	Rectangular	Keel Rabbet	Hook scarf (stern)			sternson present
(13) Les Sorres X	1390s	7 x 6	None	Butted at both endposts	Counter plank 10 x 2	7-8 x 13	7-8 x 11-13
(14) Olbia Wreck 10	1405-1440	11 x 6					
(15) Bacàn 2	1420s	7 x 18	Keel Rabbet				
(16) Marinières	1420-1430	26 x 11-12	Rabbet created by keel and counter-keel	Butted at both endposts	Counter keel 24 x 10		No remains of main sternpost - 77° angle Inner sternpost (22 x 28)
(17) Bacàn 1	1450s	9 x 11	Keel Rabbet				
(18) Contarina I	1460s	15 x 7	None	Butted at both endposts		13.2 x 33.4 -no rabbet	13.5 x 29.5 -no rabbets
(19) Mariposa A	1475-1525					present -flat scarf	? X 15; 82° angle
(20) Mariposa B	1500-1525				False keel at bow	26 x 29.5	19 x 24; 80° degree
(21) Lake Garda	1509	Rectangular	Keel Rabbet			Stemson - trapezoidal 8 cm wide above keel, 40-20 upper face	

Table 2 Continued

Shipwreck	*Date*	*Keel dimensions sided, molded (cm)*	*Keel Rabbet*	*Keel Scarf*	*Additional Keel sided, molded (cm)*	*Stem sided, molded (cm)*	*Sternpost sided, molded(cm)*
(22) Villefranche	1516	29-18/19 x 42-90	Keel Rabbet	Hook scarf (bow) Butted (stern)		? x 27-34	No remain - 75-78°
(23) Mortella III	1527	24-33 x 26-38 -Rising aft	Keel Rabbet	Horizontal flat scarf (bow) Butted (midship)	Rider keel 24-33 x 20-25	No remains 8.6 m entry	2.14 run 76 degrees
(24) Sardinaux	1500-1550 (1540s?)	7 x 9.8	No Rabbet - Internal Keel/Garboard plank between frames	Horizontal Flat scarf (bow)			
(25) Chrétienne K	1500-1550 (1540s?)	13 x ?	Keel Rabbet				
(26) West Turtle Shoals	1550-1600	17 x ?					15 cm sided
(27) Yassi Ada 3	1572+	20 x 20	None	No surviving evidence		apron - 13 x 15-19 cm trapezoidal section	round sternpost inner sternpost 11.5 x 20
(28) Calvi 1	1575	21 x 20-22	Keel Rabbet	Hook scarf (stern)			Sternpost, 18 x 18 - 65° inner sternpost - 26 cm wide sternpost knee reused timber
(29) *Kadırga*	1575-1625	10 x 15 (replacement) -original rockered	None (replacement)	Flat scarf (bow) Half-lap (stern)		2 sections connected with flat scarf Apron 30 cm wide, flat scarf to keelson	2 pieces connected with flat scarf
(30) Cap Lardier 1	1575-1600	9.8 x 13.3	None	Butted (bow), stopwater dowel			
(31) Agropoli	1575-1625	26 x 24	Keel Rabbet	Hook scarf (bow) Butted (aft of bow)	False keel, 7 cm thick		straight
(32) Sveti Pavao	1580	21.5 x (5?) Keel plank		Plank			
(33) Church Rocks	1582+	? x 35-55	Keel Rabbet				68.5 degrees

Table 2 Continued

Shipwreck	*Date*	*Keel dimensions sided, molded (cm)*	*Keel Rabbet*	*Keel Scarf*	*Additional Keel sided, molded (cm)*	*Stem sided, molded (cm)*	*Sternpost sided, molded(cm)*
(34) Rodinara	1590-1620	11 x 12	Keel Rabbet	Butted (bow)		Lower Stem 1.65 m long x 69 cm tall Keel end - 11 x 12 cm Upper end - 12 x 20 cm (rounded front face) Butted upper stempost	
(35) Saint-Honorat 1	1637		Chamfered Keel				

(1) Matthews and Steffy, 'The Hull Remains'; (2, 3) Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala'; (4) Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck'; (5) Capulli, 'Il Relitto di Precenicco'; (6) Günsenin, 'The construction of a monastic ship'; (7) Koutsouflakis, 'Three Medieval Shipwrecks'; (8) Rieth, 'L'Arquitectura Naval'; (9) di Stefano, 'La galea medieval di Camarina'; (10) Riccardi, 'I relitti del porto di Olbia'; (11, 12) Romanelli, *La Galea Ritrovata*; (13) Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc'; (14) Riccardi, 'I relitti del porto di Olbia'; (15) Medas, 'I relitti tardo-medievali del Bacàn'; (16) Daeffler, 'L'Epave des Marinières'; (17) Medas, Due relitti con carichi lapidei rinvenuti al Bacàn'; (18) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (19, 20) Riccardi, 'Evidenze archeologiche di imbarcazioni'; (21) Capulli, *Le navi della Serenissima*; (22) Guérout, 'Le navire Génois de Villefranche'; (23) Cazenave de la Roche, *The Mortella III Wreck*; (24) Joncheray, 'Un navire de commerce de la fin du XVIIe siècle; (25) Lopez, Joncheray, Brandon, 'L'épave post-médiévale Chrétienne K', (26) Russo, *West Turtle Shoals Wreck (8MO142)*; (27) Labbe, 'A Preliminary Reconstruction'; (28) Villié, 'L'épave Calvi 1'; (29) Arcak, 'Kadırga'; (30) Joncheray, 'L'épave dite «des ardoises», au cap Lardier'; (31) Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli'; (32) Beltrame, 'The ship'; (33) Preece, Burton, and McElvogue, 'Evidence for High Status at Sea'; (34) Villié, 'La Rondinara'; (35) L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes'

Table 3 Floor timber and futtock measurements

Shipwreck	*Date*	*Pattern*	*Nailed to Keel?*	*Floor timbers sided, molded (cm)*	*Room and Space (cm)*	*Scarf Type (cm)*	*Fastener Connection*	*Futtocks sided, molded (cm)*	*Room and Space (cm)*
(1) Serçe Limanı	1025	Alt. Long-armed floor timbers	1 Nail	12 x 16	33	Vertical Flat / Overlap / Diagonal Butt	1-2 nails	12 x 16	33
(2) Marsala A	1050s	Alt. Long-armed floor timbers	1 Nail	10-12 x 12-14	28	Vertical Flat / Overlap / Diagonal Butt	1-2 Nails	10 x 12	
(3) Marsala B	1100s	Alt. Long-armed floor timbers	1 Nail	11 x 11	25.6	Overlap / Diagonal Butt	2 Nails	11 x 11	
(4) Rhodes 4	1175-1200s	Floor timbers, futtocks	1 Nail	13-15 x ?	28-29	Overlap /Hook Scarf(?)		40 x 20	63
(5) Precenicco	1180-1300	Alt. Long-armed floor timbers	1-3 Treenails	9 x 8.5-13	27-36	Overlap	1 Nail	7 x ?	
(6) Çamaltı Burnu I	1200-1225	Alt. Long-armed floor timbers (?)		20 x 10	33-35	Overlap	1 Nail		
(7) Rhodes 1	1240 ± 60	Floor timbers, futtocks		18-20 x 18-20	38-46	Overlap	Nails		
(8) Culip VI	1290-1300	Floor timbers, futtocks	1 Nail underneath -Bow frames toenailed on inside	9-11.5 (10 avg) x 10-17	21-28 (24.5)	Hook Scarf (1.5-2 cm rebate)	4 Nails		
(9) Camarina	13th ca. (1301?)	Floor timbers, futtocks	2 Treenails	13-17 (15 avg) x 8-13	20	Overlap (?)			
(10) Olbia Wreck 4	1323 (?)			6-13 x ?	23-30	Dovetail			
(11) Boccalama A	1300-1325	floor timbers, Long-armed futtocks	Treenails	10-12 x 14	23-24	Overlap	None	12 x 14	24+
(12) Boccalama B	1300-1325	Floor timbers, futtocks		7-8 x 8-10	17-18	Overlap	Iron Nails	7-8 x 8-10	17-18
(13) Les Sorres X	1390s	Floor timbers, futtocks	-Masters nailed from inside -Remainder underneath -Stern fillers toenailed	5 x 5	15	Overlap Diagonal Butt, Occasional recessed futtocks for floor timber ends	4 Nails	5-6 x 5-6	16-24
(14) Olbia Wreck 10	1405-1440	Floor timbers, futtocks	1 Nail and 1 treenail	5.5-7.5 x 6-7					

Table 3 Continued

Shipwreck	*Date*	*Pattern*	*Nailed to Keel?*	*Floor timbers sided, molded (cm)*	*Room and Space (cm)*	*Scarf Type (cm)*	*Fastener Connection*	*Futtocks sided, molded (cm)*	*Room and Space (cm)*
(15) Bacàn 2	1420s	Floor timbers, futtocks		10 x ?	10	Overlap to keel		14 x ?	
(16) Marinières	1420-1430	Floor timbers, futtocks	Most bolted to keel, 3 Y-timbers nailed to keel, 1 Y-timber toenailed from side face	19.5-20 x 19.5	34-44 (avg. 39)	Double Dovetail (3.5-4 rebate) -Floor tenon to futtock mortise	2 Nails, either extremity 3 Treenails, Central over scarf area	19.5-20 x 19.5	35-49 (avg. 48.5)
(17) Cavoli	1440s	Floor timbers, futtocks		17-21 x 12-17	37	Overlap Possible Double Dovetail (3-4 rebate)		17-21 x 12-17	37
(18) Bacàn 1	1450s	Floor timbers, futtocks		9 x 9	14-16	Overlap to keel		9 x 9	14-16
(19) Contarina I	1460s	Floor timbers, futtocks	1 Nail -Clenched outside keel face	12 x 12	28-30	Overlap	3 Round Nails (1.3 diam)	12 x 12	28-30
(20) Contarina II	1475s	Floor timbers, futtocks					2 Round Nails (1.4 cm diam)		34
(21) Mariposa A	1475-1525	Floor timbers, futtocks							34 (avg.)
(22) Rhodes 2	1480 or 1522	Floor timbers, futtocks		12-18 x ?		Overlap		12-18 x ?	
(23) Mariposa B	1500-1525	Floor timbers, futtocks	Bolted to keel	11-16 x ?	26.5-34	Hook scarf (2.5-3 rebate) / Overlap	4 Nails -Clenched	11-14 x ?	24-34
(24) Lake Garda	1509	Floor timbers, futtocks		8 x 8.5-19	25	Overlap	3 Nails		

Table 3 Continued

Shipwreck	*Date*	*Pattern*	*Nailed to Keel?*	*Floor timbers sided, molded (cm)*	*Room and Space (cm)*	*Scarf Type (cm)*	*Fastener Connection*	*Futtocks sided, molded (cm)*	*Room and Space (cm)*
(25) Villefranche	1516	Floor timbers, futtocks	Bolted to keel, several floor timbers unfastened W70 bolted twice	19-23.5 x 32-45	38-47	Dovetail, (1-3 cm depth) Greatest width, top or bottom Upper Futtocks, half-rebate, single rebate, dovetail, double dovetail (or double rebate), or none	2 Round Nails (1.2-1.6 cm diam)	15-25 x 15-25	30-50
(26) Mortella III	1527	Floor timbers, futtocks	Bolted to keel	15-27 (avg 18) x 18-19 (avg 20)	34-35	Hook scarf, (1.5 cm rebate) Carved recess for first futtock Upper Futtocks, carved recess for overlap	2 Round Nails (1.2 cm diam) - Only master nails horizontal to framing	12.7-15.3 x 13.7-15	34-35
(27) Sardinaux	1500-1550 (1540s?)	Floor timbers, futtocks	Yes, 2-3 nails	8.6 x 6.8	32-34	Hook scarf (1.5-2 cm rebate) -Internal faces covered in pitch	3-4 square Nails	5 x 6	23
(28) Chrétienne K	1500-1550 (1540s?)	Floor timbers, futtocks	Bolted to keel	12-18 x 12	28-30	Overlap, Tapered Overlap, Recessed for Overlap	2 Round Nails (1.2-1.4 cm diam.) -Clenched	13 x 11	29-32
(29) West Turtle Shoals	1550-1600	Floor timbers, futtocks	Bolted to keel	12-18 (avg 14) x ?	28-47 (avg 39)	Hook Scarf (3-4 cm rebate)	2 Round Nails (2 cm diam.)	11-16 (avg 13) x ?	30-67 (avg 41)
(30) Yassi Ada 3	1572+	Floor timbers, futtocks	1 Nail	11-13 x 11-13	19-21	Hook Scarf, (2-2.5 rebate)	3 Nails -Double clenched	11-13 x 11-13	34
(31) Cadiz-Delta II	1573 (1587)	Floor timbers, futtocks	Y-Frames bolted to keel			Hook Scarf	2 Nails		

Table 3 Continued

Shipwreck	*Date*	*Pattern*	*Nailed to Keel?*	*Floor timbers sided, molded (cm)*	*Room and Space (cm)*	*Scarf Type (cm)*	*Fastener Connection*	*Futtocks sided, molded (cm)*	*Room and Space (cm)*
(32) Calvi 1	1575	Floor timbers, futtocks	Yes	11-17 x 23-30.5	34	Hook Scarf (2 cm rebate) Dovetail Upper Futtocks, half lapped or recess for overlap (2 cm)	1-3 Round Nails (1 cm diam)	10 x 10 (Both 11.7 avg)	26-35
(33) *Kadırga*	1575-1625	Floor timbers, futtocks		8 x 10	34	Hook Scarf, (1-2 cm rebate)	3 Nails -Double Clenched	8 x 8	34
(34) Cap Lardier 1	1575-1600	Floor timbers, futtocks	Yes	11.5-14.2 x 8.5-9.5	17-21	Overlap	3+ Nails - Clenched		18-19
(35) Agropoli	1575-1625	Floor timbers, futtocks	Nails	16 x 20	34	Overlap	Nails from both sides		
(36) Sveti Pavao	1580	Floor timbers, futtocks		12.5-15 x 16	24-25	Hook Scarf (1 cm rebate)	2 Nails	12-15 x 14.5	
(37) Church Rocks	1582+	Floor timbers, futtocks							
(38) *Trinidad Valencera*	1588	Floor timbers, futtocks		20 x 19-20		Hook Scarf (1-2 cm rebate)	3 Nails		
(39) Ribadeo	1590 (1597)	Floor timbers, futtocks						25-26 x 20-21	47
(40) Rodinara	1590-1620	Floor timbers, futtocks	Yes, V-frames nailed	11-13 x 11	26-29				
(41) Saint-Honorat 1	1637	Floor timbers, futtocks		25 x 25	45-55		Not Recorded		

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Table 4 Internal longitudinal assembly

Shipwreck	*Date*	*Keelson Dimensions sided x molded (cm)*	*Keelson Notched?*	*Bolted Between or through floor timbers to keel?*	*Stringers sided, molded (cm)*	*Ceiling width, thick (cm)*
(1) Serçe Limanı	1025	20 x 18, 2 sister-keelsons	Yes	Between, 2 cm bolts	9-14.4 x 8-10	Transversal
(2) Marsala A	1050s	30 x 25, 2 sister-keelsons	Yes	Between, 3 cm bolts	11 x ?	Longitudinal ? X 3.5-4
(3) Marsala B	1100s		Yes	Between, square nails		Longitudinal
(4) Rhodes 4	1175-1200s	28 x 19.5-23.5, 2 sister-keelsons	Yes	Between(?)	16 x 26 Notched	Transversal, 25 x ?
(5) Precenicco	1180-1300	Mast Step	Yes	Through	5 x ?	None
(6) Çamaltı Burnu I	1200-1225			Between		
(7) Rhodes 1	1240 ± 60			Between, some possibly through		
(8) Culip VI	1290-1300	13.5 x 7-10	Yes	Between, Nailed to floor timbers in alternating edges	Present, No remains	Longitudinal 2 strakes each side, did not survive
(9) Camarina	13th ca. (1301?)	? X 18	Yes	Between, every other (bow), or every 3rd (midship)	14 x 8 -Notched	Transversal Keelson has notch for boards
(10) Boccalama B	1300-1325		Yes			Longitudinal
(11) Les Sorres X	1390s	6 x 9-12	Yes	Between, -Treenail "bolts"	5 x 8-11	Longitudinal
(12) Olbia Wreck 10	1405-1440			Through, -Treenail "bolt"		
(13) Bacàn 2	1420s					Longitudinal ? x 3
(14) Marinières	1420-1430	? x 10+ cm No remains, thickness based on fasteners	Missing	Through, - Most floor timbers bolted -Floor timbers 15, 20 22, 25 and 39 no connection to keel	Present, No remains	Not Recorded
(15) Cavoli	1440s					Fragments
(16) Bacàn 1	1450s		Yes	Through (7-8 bolts, 1 nail)	Present	Longitudinal ? x 2

Table 4 Continued

Shipwreck	*Date*	*Keelson Dimensions sided x molded (cm)*	*Keelson Notched?*	*Bolted Between or through floor timbers to keel?*	*Stringers sided, molded (cm)*	*Ceiling width, thick (cm)*
(17) Contarina I	1460s	14.5 x 10	Yes - Central section	No bolt	30-40 x ?	Longitudinal
(18) Contarina II	1475s				5-10 x 8.5-10 -Notched	Longitudinal
(19) Mariposa A	1475-1525				11-13.5 x ?	
(20) Mariposa B	1500-1525	20 x 9+	Yes	Through	Present	Longitudinal
(21) Lake Garda	1509	14 x 9.5-12	Yes	Through (bolts), scarfs Bow-Mid 2 nail Mid-stern 1 nails	20 x 7 -Notched	Longitudinal ? x 3
(22) Villefranche	1516	24-28 x 17-25	Yes -Central section	Through, all midships except W59 Through, every other floor toward bow	15.5-17 x 14-15 - Notched	Longitudinal 3.5-6 x 13-26.5 -live works 12 cm thick
(23) Mortella III	1527	20 x 14	Yes	Through	21-24 x 10 One, 16-19 x 10 One, 11 x 15 -Round Nails -Notched Sill, 30 x 6 -crenulated	Transversal ? x 3 - Longitudinal strake between lower stringers
(24) Sardinaux	1500-1550 (1540s?)	15 x ? -Notches on floor timbers for mast step	Unknown	Between, Either for keelson or mast step - 1 treenail at bow between floors		None Detected
(25) Chrétienne K	1500-1550 (1540s?)			Through most		
(26) West Turtle Shoals	1550-1600	20-23 x 14	Unknown	Through	13 x ?	Unknown
(27) Yassi Ada 3	1572+	? X 19 .5 cm		Through, every 3rd floor timber bolted; Between, treenailed between every other floor timber	20-25 x ?	

Table 4 Continued

Shipwreck	*Date*	*Keelson Dimensions sided x molded (cm)*	*Keelson Notched?*	*Bolted Between or through floor timbers to keel?*	*Stringers sided, molded (cm)*	*Ceiling width, thick (cm)*
(28) Cadiz-Delta II	1573 (1587)	Present 2 Jupiter scarfs				Transversal - 20 cm wide boards - Also longitudinal ceiling at turn of bilge
(29) Calvi 1	1575	15 x 18	Yes -Central section	Through, every other floor (the other floor its nailed to the frame)	Four, 15 x 13.5 One, 13 cm diam. One, 10 cm diam. - Notched Sill, 17 x 5.5 -crenulated shelf clamp support 20 x 6	Longitudinal - Limber boards 3-3.8 cm thick
(30) *Kadırga*	1575-1625	12 x 11, (replacement)	No, (replacement)		19 x 11 -Notched	None
(31) Cap Lardier 1	1575-1600	No Remains		Through, 3 bolts for whole hull		None Detected
(32) Agropoli	1575-1625	Missing		Through with nails		
(33) Sveti Pavao	1580	18 x 13	Yes	Through, every other floor		Transversal (?)
(34) Ribadeo	1590 (1597)				footwale - 17 x 17 Shelf clamp support -17 x 24	Transversal ? x 13-15
(35) Rodinara	1590-1620	No Remains		Through, V-frames bolted		
(36) Saint-Honorat 1	1637	15 x 15	Yes		Present	Transversal 5-6 x 26-28

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Table 5 Outer hull

Shipwreck	*Date*	*Bilge Keel Sided, Molded (cm)*	*Plank Dimensions thick, width (cm)*	*Plank Fastener Ratio Iron:Wood*	*Wales Width, thick (cm)*	*Caulking*
(1) Serçe Limanı	1025		4 x 22-27 -Z-scarfs present	4-6 : 0	16 x 10	Seams, Internal/External pitch
(2) Marsala A	1050s	10 x 12 -Notched	3.5-4 x 28 (filler pieces under planks)	2-3 : 0		Seams, veg. fiber
(3) Marsala B	1100s		3 x 16	2 : 0		
(4) Rhodes 4	1175-1200s		2.5 x 17	2 : 0	? X 12	
(5) Precenicco	1180-1300		3-3.5 x 18-24	0 : 1-3		Fibers
(6) Çamaltı Burnu I	1200-1225		2.7 x 18	2-3 : 0	?	
(7) Rhodes 1	1240 ± 60					
(8) Culip VI	1290-1300	12 x ? -Notched -Treenailed between floors	2 x ? Garboard: 2 x 24-26 -Nailed to floors only	3-5 : 0	? X 4 trapezoidal	Painted with tallow Internal/External pitched (1 cm thick)
(9) Olbia Wreck 4	1323 (?)		? x 12-28 Garboard: ? x 20-23			
(10) Camarina	13th ca. (1301?)	Present, - Notched	5 x widths vary			Seams
(11) Boccalama B	1300-1325		-Flat scarf and hook scarf together		Notched	
(12) Les Sorres X	1390s	7-8 x 8-9	2 x ? Garboard: 2 x 40 -Nailed to floors only	2-3 : 0		Seams, Internal/External pitched
(13) Olbia Wreck 10	1405-1440		2.5 x 16-18			
(14) Bacàn 2	1420s		2.5 x ?			
(15) Marinières	1420-1430		5.5 x 34 Garboard: 2 nail : 2 treenails	2-3 : 1		Seams, veg. fibers External pitched (6-6.5 cm thick) Lead strips between Garboard joint
(16) Cavoli	1440s		5 x 22-67 -Clenched nailing	2(?) : 1		Nail heads covered in lead
(17) Bacàn 1	1450s		2.2-2.5 x ?	1+ : 0		

Table 5 Continued

Shipwreck	*Date*	*Bilge Keel Sided, Molded (cm)*	*Plank Dimensions thick, width (cm)*	*Plank Fastener Ratio Iron:Wood*	*Wales Width, thick (cm)*	*Caulking*
(18) Contarina I	1460s	17.5 x 7	4 x ? -Square nails	4 : 0	30-40 x ?	
(19) Contarina II	1475s		4 (Upper), 5 (Lower) x 26 -Square nails		10-14 cm x 6-7	
(20) Mariposa A	1475-1525		3-3.5 x 24		half log 10 diam	
(21) Rhodes 2	1480 or 1522		8.5 x 35 Planks Z-scarfed together			
(22) Mariposa B	1500-1525	Massane	3-3.5 x 24	1 : 1-2	10 diam half logs	
(23) Lake Garda	1509		2.9 x ?		Notched	
(24) Villefranche	1516		12 (lower strakes) 10 (upper strakes) 4-5 (deadworks) x 18-34 -Part of Garboard round nailed	2-3 : 0	Two, 21 x 12 One, 21 x 19	Internal/External pitched Brown mastic covering inside on keel and counter keel Vegetable tow Lead sheathing present
(25) Mortella III	1527		8-10 X 16-20 -Clenched nailing -Round Nails	2 : 0		Internal/External pitched (pitch, pine resin, animal fat) 2-3 mm thick
(26) Sardinaux	1500-1550 (1540s?)	Triangular 6.2 x 14.2 to Parallelogram 9.6 x 5.6	3.7 ± 0.2 x ? -Garboards 16.5-17.5 cm wide	2-3 : 0		No seam, Internal/External pitched
(27) Chrétienne K	1500-1550 (1540s?)			2-3 : 0		
(28) West Turtle Shoals	1550-1600		5 x 10-31.5 (avg. 13)		14-15 x ?	
(29) Yassi Ada 3	1572+		5-6 x 20	2-3 : 0	? X 9-11	Internal/External pitch
(30) Cadiz-Delta II	1573 (1587)		6 x 20	Iron nails		Lead sheathed, entire hull

Table 5 Continued

Shipwreck	*Date*	*Bilge Keel Sided, Molded (cm)*	*Plank Dimensions thick, width (cm)*	*Plank Fastener Ratio Iron:Wood*	*Wales Width, thick (cm)*	*Caulking*
(31) Calvi 1	1575	Massane - 17 x 10-14 - Disappears after C20 to ordinary strake	4.5-7 x ? - Every other strake thicker - Clenched nailing - Round Nails	2 : 0	One, 9 x 17 - Clenched nails One, 9 x 21 - bolted to shelf clamp	Internal/External pitched Lead sheathed, keel/garboard
(32) *Kadırga*	1575-1625	Massane only in stern transitions to planking forward	3.5 x 25		10 x 13	
(33) Cap Lardier 1	1575-1600		4.2 X 9-25 (21 avg)	2-3 : 0 -2-10 groupings		External pitch
(34) Agropoli	1575-1625		8 x 32-34 -Garboard staggered to sternpost			Lead sheathed below waterline
(35) Sveti Pavao	1580		Inner 7.8 x 19 Outer 5 x 19	2-4 : 0		Double planking
(36) Church Rocks	1582+		? x 18-29	2-3:0		No caulking identified in seams
(37) *Trinidad Valencera*	1588		10 x 36	2:0	14 x 18	Internal/External pitch
(38) Ribadeo	1590 (1597)		15 X 23-26	2-3:0	20 x 20	Seams, lead sheath strips
(39) Rodinara	1590-1620		3 x 15	2 : 0	8-15 x 6.6-7.6	
(40) Saint-Honorat 1	1637		-Garboard 10 cm thick			

(1) Matthews and Steffy, 'The Hull Remains'; (2, 3) Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala'; (4) Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck'; (5)Capulli, 'Il Relitto di Precenicco'; (6) Günsenin, 'The construction of a monastic ship'; (7) Koutsouflakis, 'Three Medieval Shipwrecks'; (8) Rieth, 'L'Arquitectura Naval'; (9) di Stefano, 'La galea medieval di Camarina'; (10) Riccardi, 'I relitti del porto di Olbia'; (11) Romanelli, *La Galea Ritrovata*; (12) Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc'; (13) Riccardi, 'I relitti del porto di Olbia'; (14) Medas, 'I relitti tardo-medievali del Bacàn'; (15) Daeffler, 'L'Epave des Marinières'; (16) Martin-Bueno, *La Nave de Cavoli*; (17) Medas, Due relitti con carichi lapidei rinvenuti al Bacàn'; (18, 19) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (20) Riccardi, 'Evidenze archeologiche di imbarcazioni'; (21) Koutsouflakis, 'Three Medieval Shipwrecks'; (22) Gavini, 'Osservazioni sulla circolazione dei manufatti ceramici'; (23) Capulli, *Le navi della Serenissima*; (24) Guérout, 'Le navire Génois de Villefranche'; (25) Cazenave de la Roche, *The Mortella III Wreck*; (26) Joncheray, 'Un navire de commerce de la fin du XVIIe siècle; (27) Lopez, Joncheray, Brandon, 'L'épave post-médiévale Chrétienne K', (28) Russo, *West Turtle Shoals Wreck (8MO142)*; (29) Labbe, 'A Preliminary Reconstruction'; (30) Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto Delta'; (31) Villié, 'L'épave Calvi 1'; (32) Arcak, 'Kadırga'; (33) Joncheray, 'L'épave dite «des ardoises», au cap Lardier'; (34) Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli'; (35) Beltrame, 'The ship'; (36) Preece, Burton, and McElvogue, 'Evidence for High Status at Sea'; (37) Martin, '*La Trinidad Valencera*'; (38) San Claudio Santa Cruz, 'Excavating a 16th-century Galleon'; (39) Villié, 'La Rondinara'; (40) L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes'

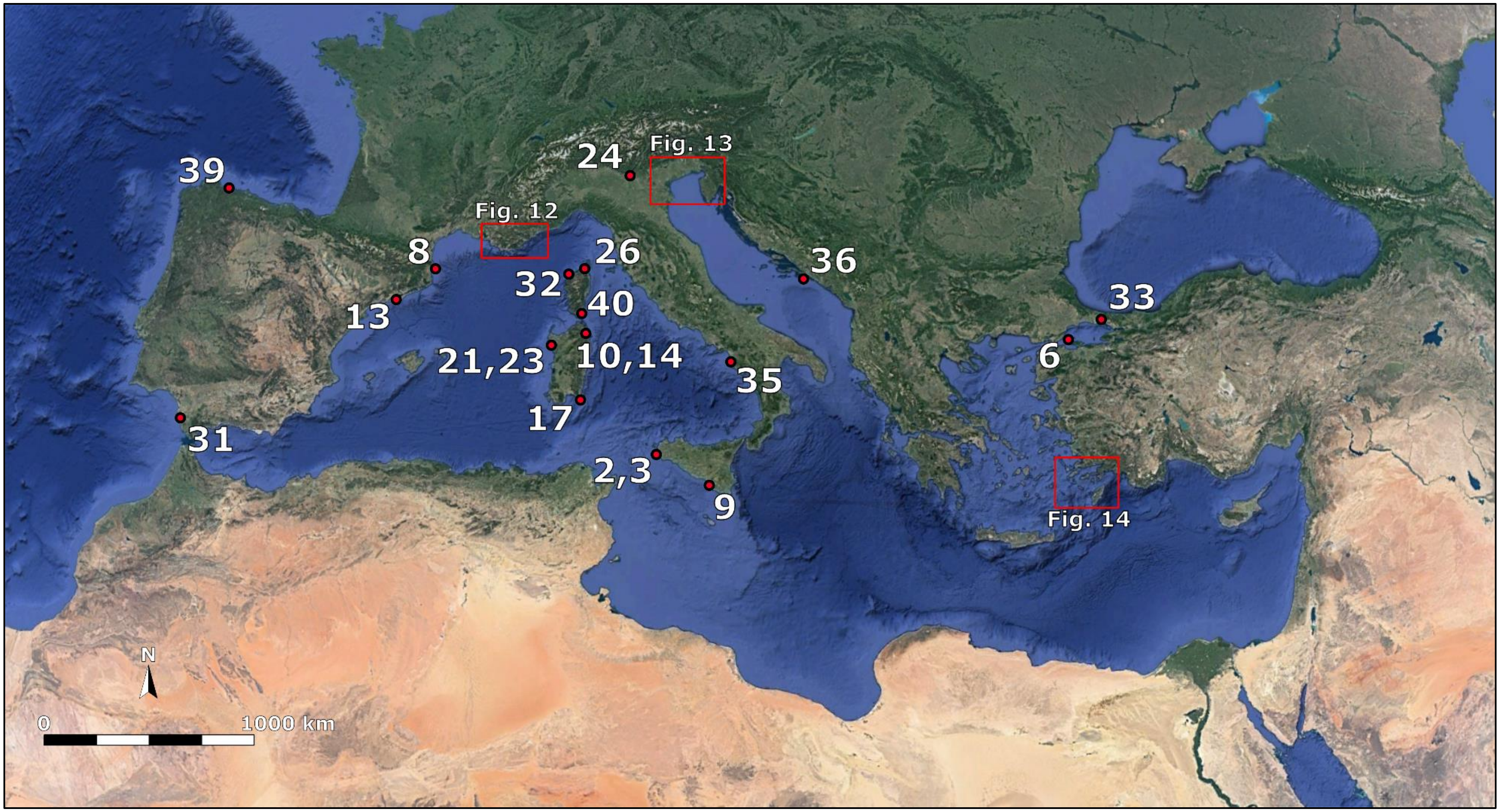

Figure 11 Location of shipwrecks in the Mediterranean. (2) Marsala A; (3) Marsala B; (6) Çamaltı Burnu I; (8) Culip VI; (9) Camarina; (10) Olbia Wreck 4; (13) Les Sorres X; (14) Olbia Wreck 10; (17) Cavoli; (21) Mariposa A; (23) Mariposa B; (24) Lake Garda; (26) Mortella III; (31) Cadiz-Delta II; (32) Calvi 1; (33) Kadirga; (35) Agropoli; (36) Sveti Pavao; (39) Ribadeo; (40) Rodinara. (After Google Earth, 2020)

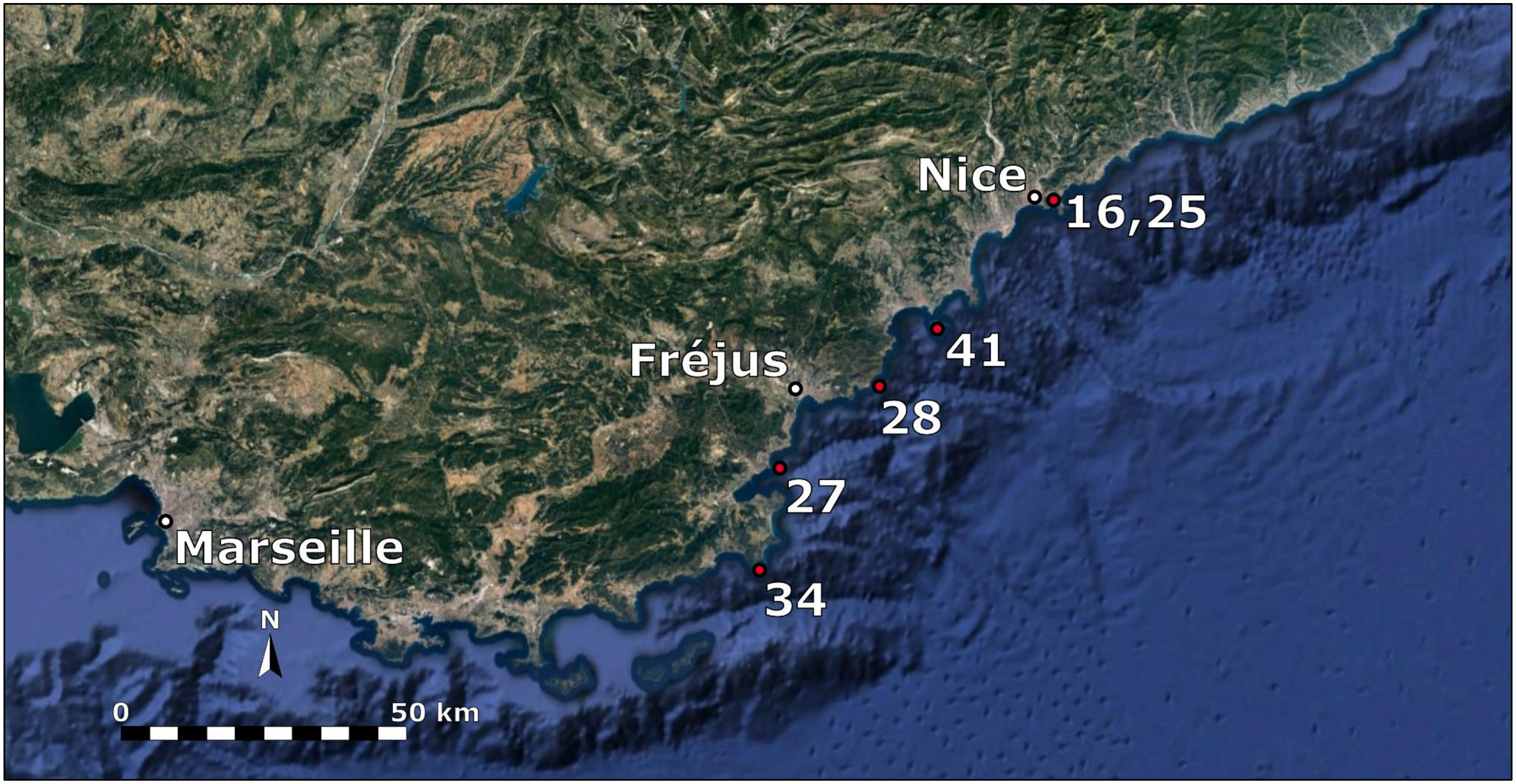

Figure 12 French Riviera map of shipwreck sites. (16) Marinières; (25) Villefranche; (27) Sardinaux (28); Chrétienne K; (34) Cap Lardier 1; (41) Saint-Honorat 1. (After Google Earth, 2020)

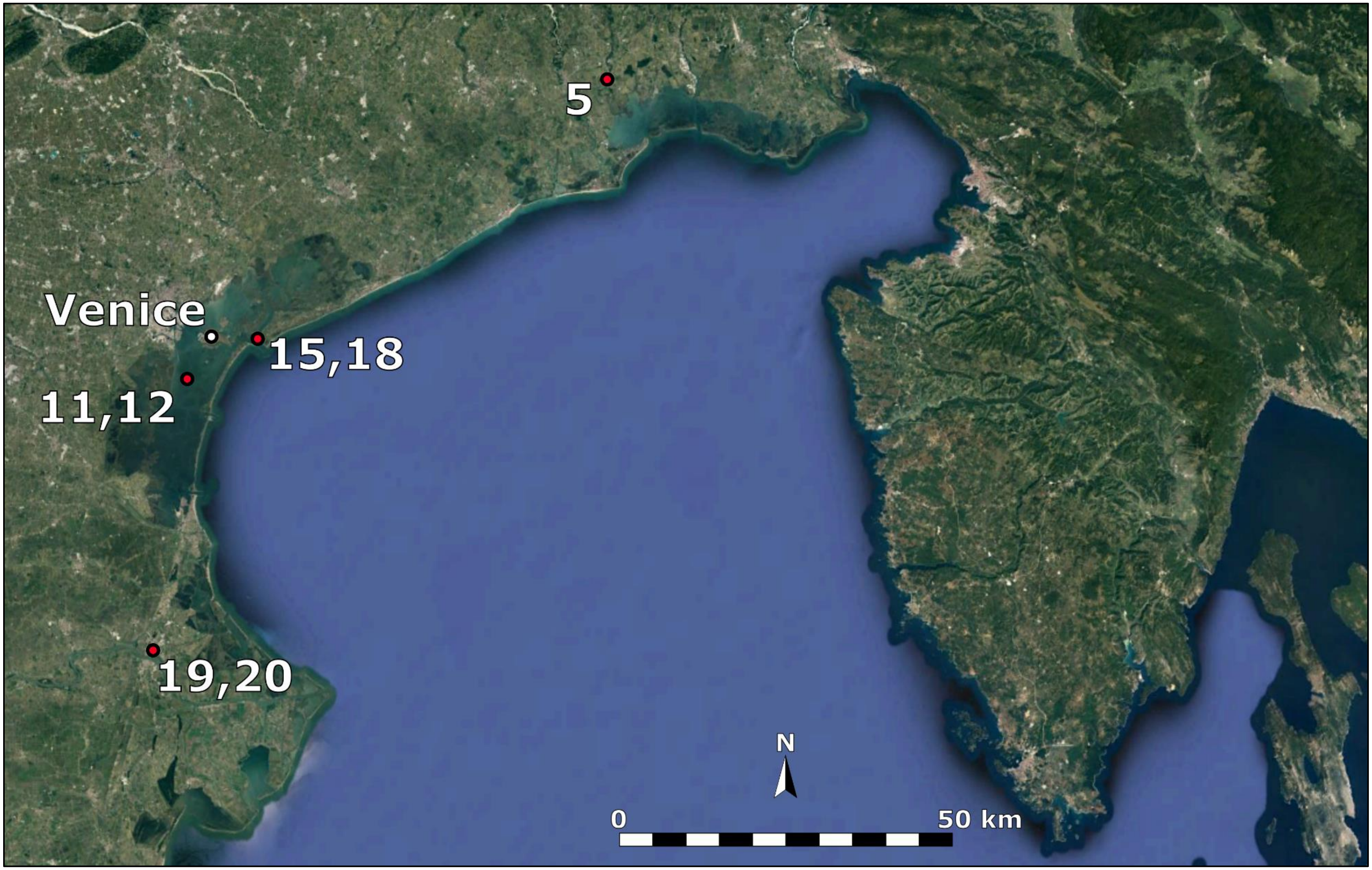

Figure 13   Northern Adriatic location map of shipwreck sites. (5) Precenicco; (11) Boccalama A; (12) Boccalama B; (15) Bacàn 2; (18) Bacàn 1; (19) Contarina I; (20) Contarina II. (After Google Earth, 2020)

Figure 14 Southwestern Turkey and Rhodes location map of shipwreck sites. (1) Serçe Limanı; (4) Rhodes 4; (7) Rhodes 1; (22) Rhodes 2; (30) Yassi Ada 3. (After Google Earth, 2020)

Figure 15 Detailed map of shipwrecks in northwestern Europe. (37) Church Rocks; (38) Trinidad Valencera. (After Google Earth, 2020)

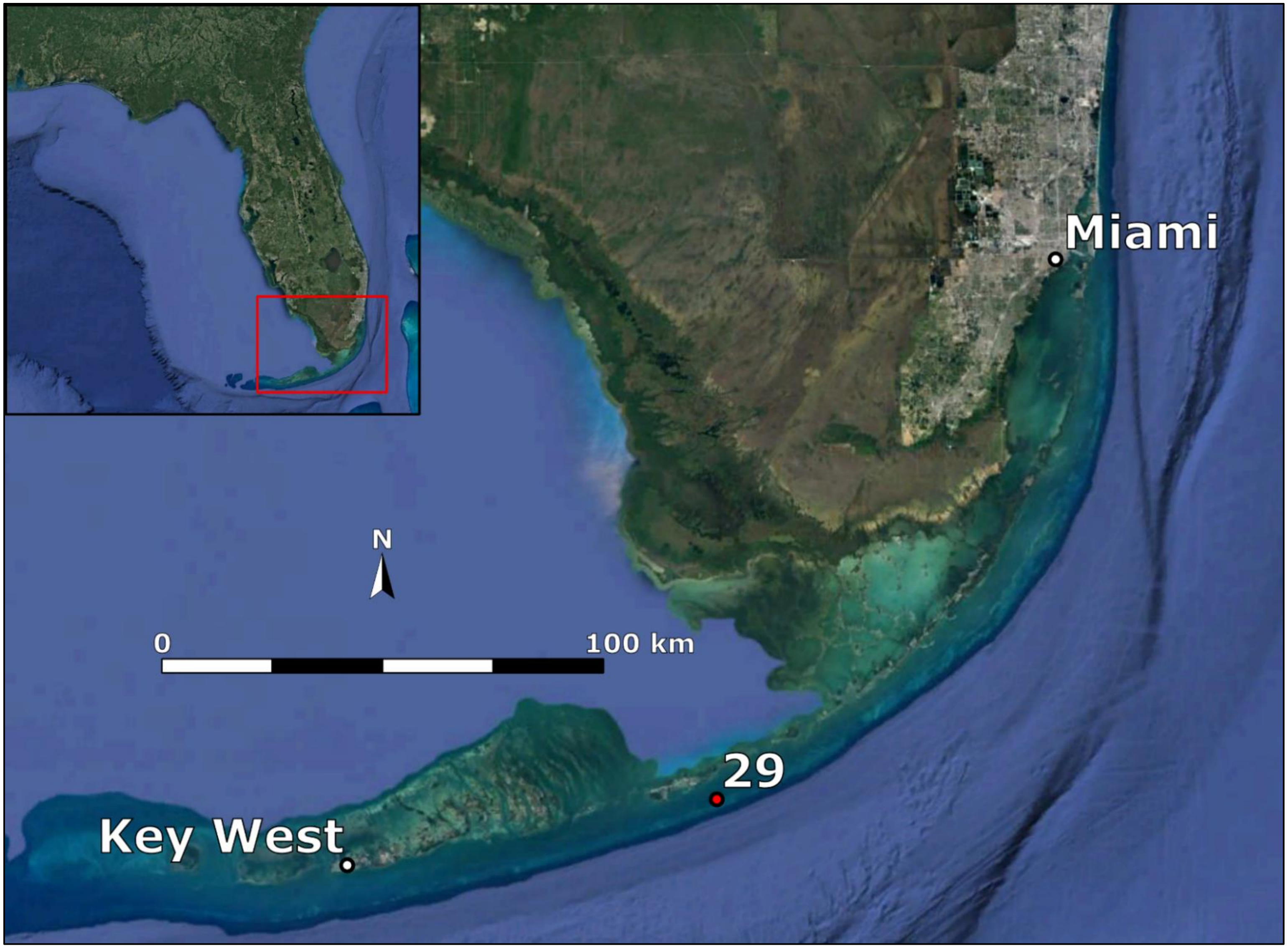

Figure 16 Detailed map of a shipwreck in the Americas. (29) West Turtle Shoals. (After Google Earth, 2020)

of geometric formulas, or roman numerals etched onto the framing, will be discussed in Chapter 5 and are omitted below. Published measurements for most of the hull structure is provided in Tables 1-5 for convenient cross-referencing, while the subsections on each shipwreck are primarily descriptive. Figures 11-16 provide several maps with the original location for each archaeological site.

Serçe Limanı

During a shipwreck survey in 1973 along the southwestern Turkish coast, archaeologists from the Institute of Nautical Archaeology hired local retired sponge diver Mehmet Aşkin of Bozburun to help locate possible sites for future investigations. Aşkin led the team to the small bay called Serçe Limanı (Sparrow Harbor), and a shipwreck noted for scattered broken glass.[105] Initial dives revealed an intact amphora that was later dated to the eleventh century. Although the massive glass cargo was intriguing, the eventual decision to excavate the site was due to the thoroughly buried mound, suggesting a high level of preservation of the original hull and its tentative date to a period less known archaeologically. Political turmoil in the eastern Mediterranean and the subsequent Turkish invasion of Cyprus stalled any initial work. Excavations eventually began in 1977 and conducted in until 1979 with the removal of the artifacts and remaining hull structure (figure 17).[106]

Researchers subsequently concluded that the remains were from a small merchant ship that sailed into the bay around AD 1025, possibly seeking shelter before continuing its voyage. Evidence from the site suggests that the crew were Hellenized Bulgarians transporting a cargo of

[105] Bass and van Doorninck Jr., 'Discovery, Excavation, and Conservation', 51-2.
[106] Bass, Steffy, and van Doorninck Jr., 'Excavation of an 11th-Century Shipwreck at Serce Limani, Turkey', 161-4

Figure 17 Serçe Limanı site plan. Image: George Bass and Fred van Doorninck. © Institute of Nautical Archaeology.

glass cullet, glassware, Islamic ceramics, copper cauldrons and buckets, sumac, raisins, and other trade goods.[107] Either a storm or an unexpected wind channeled into the bay, broke the main anchor, and drove the small vessel against the nearby jagged shoreline. Serçe Limanı's artifacts represent an important transition for the Byzantine world into the late medieval period. The collection of glass recovered from the wreck remains one of the largest ever to be archaeologically recovered. For nautical archaeologists, the ship also represents one of the earliest examples of exclusively frame-based construction in the Mediterranean.[108]

Serçe Limanı's keel is rectangular with its greater dimension extending away from the hull. There are no rabbets on the keel and each end presumably included a flat scarf connected to the endposts. The stem did not survive, while a small fragment from the rounded sternpost and the associated assembly suggests the ship was double ended.[109] Framing for the ship relied on alternating L-shaped floor timbers, along with two pairs of half-frames acting as tail frames near either end of the vessel. Most floor timbers and futtocks overlap, while dual master frames at the center of the ship include vertical flat scarfs connected with one or two nails. Elements of its construction suggest the ship was built using the Byzantine foot (31.23 cm) as the proportional measurement. Other frame stations do not present this same level of detail to scarf or nail the overlapping ends of the floor timbers and futtocks. Most floor timbers and futtocks are thicker than their width, while the former were also nailed to the keel.[110] There is a rebated keelson that runs along the centerline of the ship and was bolted between the floor timbers to the keel. Fastened to the frames on either side of the keelson was a pair of square sister-keelsons.

[107] Delgado, ed., *Encyclopedia of Underwater and Maritime Archaeology*, 367-9.
[108] Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 245.
[109] Steffy, 'The Reconstruction of the 11th Century Serçe Liman Vessel: A Preliminary Report', 20-1
[110] Matthews and Steffy, 'The Hull Remains', 88-98.

Further out from the sister-keelsons a pair of stringers was observed as equal distance from the keelson to the turn of the bilge. There is also a second pair of stringers that rest directly over the turn of the bilge. Both pairs of stringers are of different dimensions and are chamfered, the bilge stringers are rebated for ceiling planks that rest on top of the sister-keelsons. Instead of attaching the ceiling directly to the framing, as seen on many later ships, this earlier example indicates a raised platform above the bilge.[111] Evidence suggests that the planking was installed in two different stages, the first from the garboard to the turn of the bilge. The upper strakes were then assembled, and the planking intended for the turn of the bilge was installed last. More nails were used at each frame station than was the case on later archaeological examples, with each station including four to six iron nails.

Remains of two wales were also found, suggesting a thicker main wale closer to the waterline and a smaller version above separated by a single strake. Both wales were also chamfered along their upper edges in a manner similar to the stringers.[112] Nails had square shanks, bolts round shanks, and the few treenails present are round in section. Treenails present in the planking are few and inconsistent, suggesting these are from repairs and not original construction.[113] There is also evidence for caulking between the seams and the entire hull was covered in pitch inside and out. The overall transverse shape of the hull presents a flat floor with a slight deadrise and a hard chine that flairs outward at 72°.[114]

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[111] Steffy, 'The Reconstruction of the 11th Century Serçe Liman Vessel: A Preliminary Report', 25
[112] Steffy, *Wooden Ship Building and the Interpretation of Shipwrecks*, 89-91.
[113] Matthews and Steffy, 'Serçe Limanı', 107, 162.
[114] Steffy, *Wooden Ship Building and the Interpretation of Shipwrecks*, 91; Matthews and Steffy, 'Serçe Limanı', 156.

Marsala A and B

After an intense storm off Sicily in 1983, reports of archaeological material exposed along the seabed south of modern Marsala, Italy prompted swift rescue operations to prevent looting. The source of the uncovered artifacts was a shipwreck located sunk beneath 40 m of water near Lido Signorino. Observations suggested that the Marsala A wreck was a rich collection of materials with surviving hull remains often covered by shifting sand (figure 18). Storms the following years kept exposing the hull, but these same environmental effects would later bury the area in 2 m of sand.[115] Interest from the Baglio Anselmi Archaeological Museum led to fieldwork to record and recover the shipwreck for display. The museum was already home to an earlier Punic wreck and officials were keen on expanding their collection to other periods of Marsala's history. The hope was that the museum would become a regional center for archaeological and conservation expertise.

Investigations on Marsala A during the 1985 field season also led to the discovery of a second smaller wreck site nearby (figure 19). This smaller vessel, dubbed Marsala B, was added to the original plans for recording and recovering Marsala A. Between the 1985 and 1986 field seasons, Marsala B was recorded, its contents recovered, and the hull remains collected. Excavation on Marsala A followed a similar format, but unfortunately, the hull remains were not retrieved. The smaller size of Marsala B and its fewer wooden remains made it easier to recover and funding dried up before the same could be accomplished on Marsala A.[116] Original dating and provenience of the ceramic assemblages found on both wrecks suggested that the ships were

[115] Purpura, 'Un relitto di età normanna a Marsala', 129-30
[116] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 286

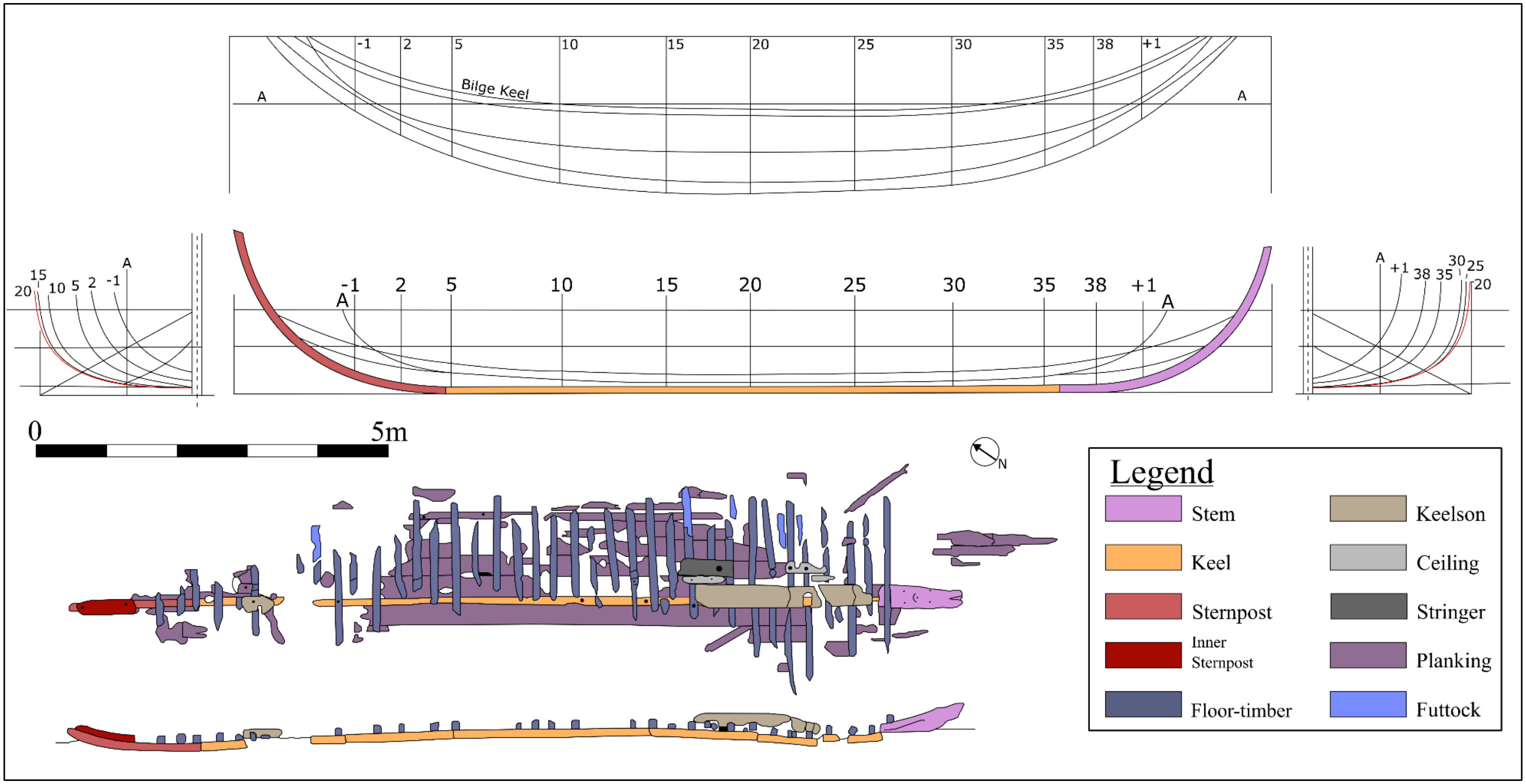

Figure 18 Site plan and ship lines for Marsala A. (after Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala', 298 and Bonino, 'Appunti sul Relitto Medieoevale', 184)

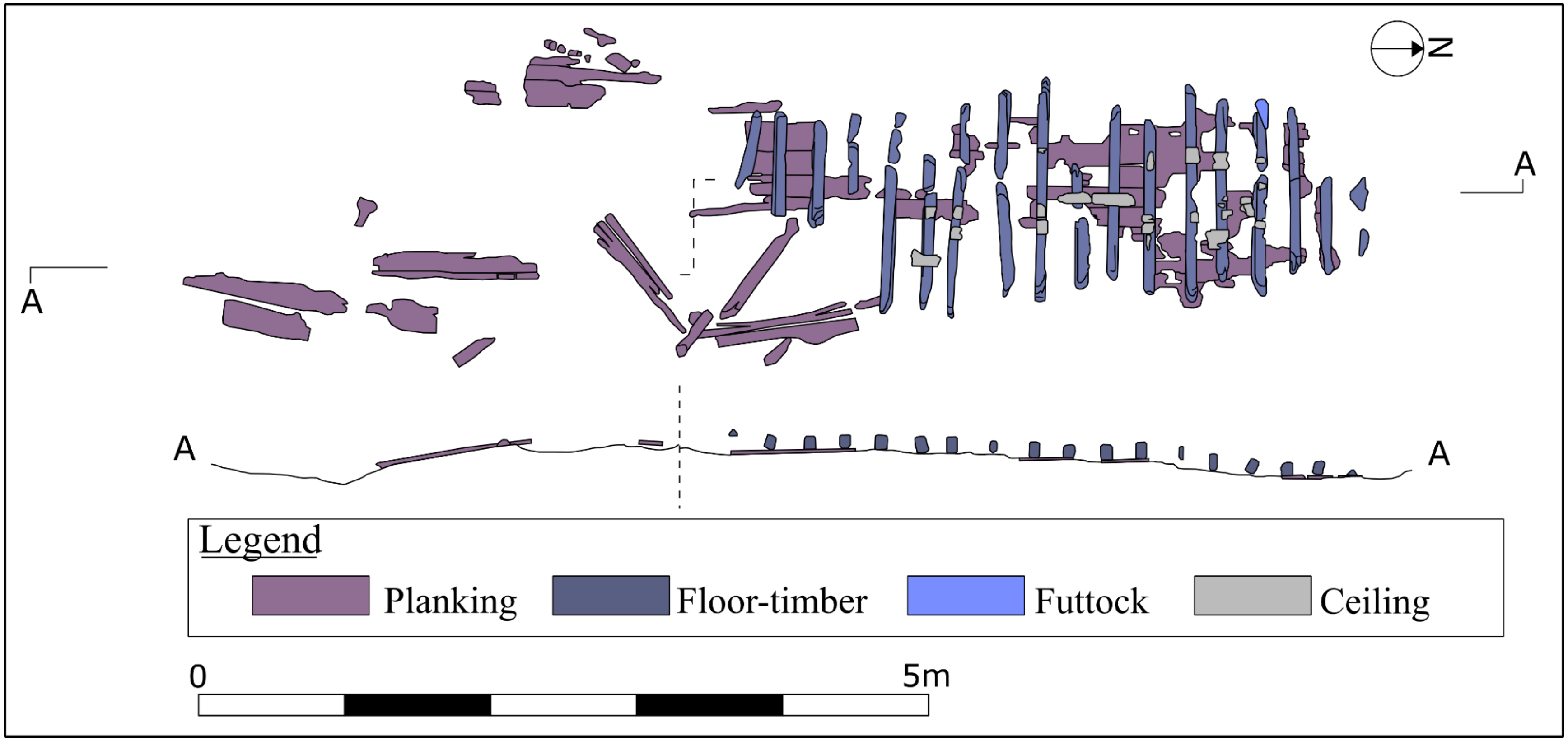

Figure 19 Site plan for Marsala B. (after Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala', 29)

from the late eleventh to early twelfth centuries associated with western Sicily and North Africa. Recent reanalysis of the assemblages emphasizes two ships lost at different times and by coincidence in the same area. Both ships were presumed to be built in Sicily, with Marsala A lost around AD 1050 and Marsala B at the beginning of the following century.[117]

Marsala A is an axial timber-built ship with a rectangular rabbeted keel rabbeted. Not enough evidence survives to know whether the keel was scarfed to the endposts or simply butted. The in-situ side profile for the wreck suggests the latter, although these might also represent breaks along the keel that were created due to site formation processes. Lower surviving ends of the rounded endposts suggest that Marsala A was double ended like Serçe Limanı. Frames are composed of alternating L-shaped floor timbers overlapped with short futtocks. Limited evidence suggests vertical flat scarfs with iron nails connect pieces together, otherwise they simply diagonally butted. Each frame is nailed to the keel and their dimensions remained relatively square throughout the hull.[118] Elements suggesting a rectangular rebated keelson positioned along the centerline of the hull are based on surviving wood fragments and the presence of bolts positioned between the floor timbers to connect with the keel. A pair of sister keelsons are adjacent the keelson, along with a mast-step partner to hold the stanchion for the mast partner beam. Fastener holes at the turn of the bilge suggest the existence of a bilge stringer at this location. Few nail holes were noted on the upper surfaces of the floor timbers, which might infer transverse ceiling resting on the sister keelsons and bilge stringers.[119]

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[117] Tisseyre, 'The Medieval Shipwrecks of Western Sicily', 147; Pisciotta and Garnier, 'Nuovi dati sulle anfore di fine X-XI secolo dal relitto "A" di Lido Signorino (Marsala)', 169.
[118] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 297-300
[119] Ibid., 301-2.

On the outside face, at the turn of the bilge, are square bilge keels rebated into the framing. Planking has similar dimensions to Serçe Limanı, which appears to be based on the overall dimensions of the ship. Strakes are attached at each frame station with two or three nails. Little evidence survives regarding the wales that would extend around the upper sides of the hull. Nails are square shanked, while iron bolts are round.[120] There is no mention of treenails used anywhere in the hull construction or repairs. Sections of the starboard keel rabbet shows that planking seams were caulked with vegetable fiber. [121] The overall shape of the hull was originally suggested based on Serçe Limanı's reconstruction. Reevaluation of the original data suggests the hull had a flat floor with a slight deadrise and a round bilge.[122]

Marsala B is a bottom-based vessel that relies on a plank keel the same thickness as the other strakes. The poor state of preservation prevents any further understanding on how the plank keel was attached to endposts or whether these were present. Framing is composed of alternating L-shaped floor timbers with shorter accompanying futtocks. These two elements overlap without clear evidence if scarfs were used, besides an indication on several that two nails were part of the connection. Both the floor timbers and futtocks are square in dimension.[123] Floor timbers are connected to the keel plank with nails and evidence from a surviving fragments of the rebated keelson indicates this timber was also bolted to the keel plank between frames. Limited evidence survives to indicate whether stringers were present at the turn of the bilge. Planking was installed with square iron nails, two per frame station, without any use of treenails. Preliminary

[120] Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 185-6
[121] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 298-300, fig. 14
[122] Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 184, fig. 4
[123] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 292-4

reconstruction for Marsala B suggests a similar profile as Serçe Limanı, except without the deadrise.[124]

Rhodes 1, 2, and 4

The island of Rhodes includes Mandraki harbor, one of the oldest continually used ports in the eastern Mediterranean. Occupied by numerous groups throughout the centuries, Rhodes became an important waystation for travel, trade, and the occasional haven from regional politics. Over the past century, the small island tailored itself as a tourist destination, due to its rich history and continued human occupation over the last 25 centuries.[125] Today, Rhodes includes three adjacent harbors for different services, with the Central and Akandia Ports used mainly for cruise ships and other international vessels that either dock or anchor throughout the year. These ships leave detrimental effects for shipwrecks lost within the harbor interior. Surveys by the Hellenic Ephorate of Underwater Antiquities in 2007/8 located the remains of three shipwrecks within the boundaries of the Central harbor.[126]

Rhodes 1 was discovered in October 2007, 80 m west of the Pier of Angels within the confines of the Central Port. Radiocarbon dating places the hull in the middle of the thirteenth century. This period is part of a turbulent history for Rhodes, when the island changed hands between Latin (Genoese) and Byzantine rulers.[127] The ship is noted as a relatively long and narrow bottom-based vessel that relied on a keel plank. Approximately three-fifths of the hull survives, while one fragmentary end resembles that of the early fourteenth-century barge

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[124] Ibid., 296-7.
[125] Georgiadis, *Kos in the Neolithic and Early Bronze Age: The Halasarna Finds and the Aegean Settlement Pattern* 192.
[126] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 1.
[127] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 479, 482.

(Boccalama A) found in the Venetian lagoon. Floor timbers are generally square shaped, but their thickness differed throughout the hull. Each frame station includes a floor timber nailed to an overlapping futtock without any scarf connection. Surviving evidence of the central keelson indicates that this timber was bolted to the keel plank between floor timbers. The overall shape is described as flat floored with round bilges, suggesting that the ship could operate easily in a littoral zone and was not limited to harbor travel. Despite the comparisons made about the barge-like qualities of Rhodes 1, the investigators also highlight that the narrowed and rounded shape suggests a rowing vessel similar to contemporary longships.[128]

A local diver directed the survey team to the wreck of Rhodes 2 in March 2008 west of the Pier of Angels. Its radiocarbon dates place it between the latter half of the fifteenth or the early sixteenth century, while the presence of charred wood and the position at the entrance to the harbor suggests it was lost during a siege. Ottoman forces besieged the island on two occasions within this period, the first in 1480 by Mesih Pasha (1499-1501), and 1522 by Sultan Suleiman I (1520-66), when the Knights Hospitaller were forced to surrender and leave.[129] Compared to Rhodes 1, the remains from Rhodes 2 were extremely fragmentary and little survives of the hull. Several strakes of planking show continued use of the Z-shaped scarf rather than simply butting the ends at frame stations. The surviving framing also shows a significant overlap that was interpreted as the assembly between the floor timbers and futtocks from the lower hull. Scantlings for the surviving planking are unusually large when compared to contemporary vessels in the eastern Mediterranean. The average 35 cm width for the strakes is quite wide, and the 8.5 cm thickness suggests a ship of a much larger size than what survived.

[128] Ibid., 480-1.
[129] Ibid., 483.

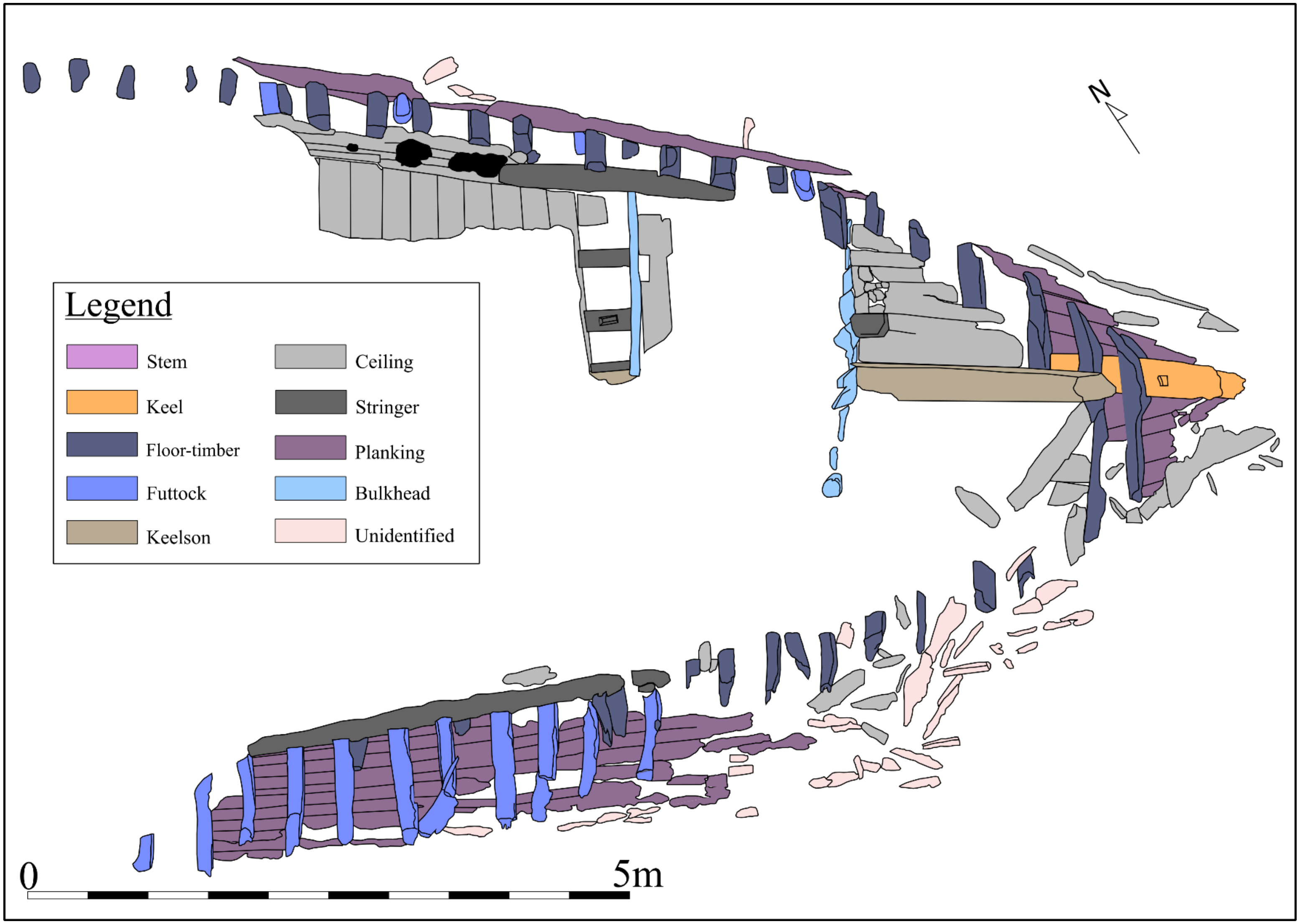

Figure 20   Site plan for the Rhodes 4 shipwreck. (after Koutsouflakis, 'Three Medieval Shipwrecks',486)

Further work on either Rhodes 1 or 2 will not be possible, as both wrecks were destroyed by harbor activity after their initial recording.[130]

Surveying in the same area of the commercial port in April 2008, archaeologists located Rhodes 4 almost entirely covered, except for exposed broken tips of framing (figure 20). Finding Rhodes 4 coincided with the last few days of the survey and only a preliminary trench was opened to evaluate the preservation and artifact potential. Significant hull structure and an entire assemblage of amphoras pointed to exceptional preservation. Amphora typology placed the wreck between the twelfth and thirteenth centuries, while the calibrated radiocarbon date of AD 1020-1155 from a wood sample suggested an earlier deposit.[131] Revisiting the wreck in 2013, excavators opened the stern section and the earlier survey trench near amidships. Further analysis of the artifact assemblage, including datable tableware, indicated the ship was lost sometime in the last quarter of the twelfth century. The after section of the ship shows indications of a fire that consumed this area before the vessel sank. There was no clear evidence to indicate whether the fire was an accident or if it was part of military or naval action in the harbor. This period coincides with the weaker rule of the Angeloi Byzantine emperors (1185-1204) at Constantinople and the rise of an independent state at Rhodes under Leo Gabalas (ca. 1204 – 40).[132]

The limited excavations on Rhodes 4 in 2013 revealed a round ship of significant size with an almost homogeneous amphora cargo. The amount of broken ceramics that filled and protected the underlying hull impeded the recording of structural elements. Nevertheless, the

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[130] Ibid., 482.
[131] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 2.
[132] Macrides, *George Akropolites: The History - Introduction, Translation and Commentary*, 50, 100-1.

excavation team was able to determine that it was a frame-based hull. The exposed after section of the keel indicates a massive timber (29.5 by 18+ cm) that is one of the most robust examples seen in this dissertation. Rabbets are present on the keel, and it is assumed these continued to the missing sternpost. The keel's after end abruptly terminates in a scarf that connected it to the curved sternpost.[133] Not enough of the scarf survives to know whether it was a hook or half-lap connection, but there is evidence for a bolt driven vertically through it.

Framing is composed of floor timbers that overlap with futtocks. Every futtock uncovered was specifically placed overlapping the next floor timber's after face. Both framing elements appear thicker than their width, while the floor timbers are proportionally spaced in a 1:1 ratio (every floor timber has roughly same amount of space between them). The project team refrained from disassembling the hull and it is unclear whether the overlap between the floor timbers and futtocks was achieved with fastenings or scarfs. Exposure of a futtock outboard of a bilge stringer on the portside (F101W) suggests a possible hook scarf, however, further excavation is required to provide definitive proof.[134]

The recorded floor timbers are nailed to the keel, while the recessed keelson likely connected to the keel between the frame stations. Sister keelsons are present over the frames, but these do not sit adjacent to the keelson. Further from the centerline of the hull, there is a middle stringer and a separate bilge stringer. The sister keelsons and stringers support transversal ceiling above the framing and bilge in a manner similar Serçe Limanı. Differences in ceiling

[133] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 4, 7-8.
[134] Rieth et al., 'The Rhodes 4 Shipwreck: Final report', 18-19.

construction on Rhodes 4 include a rebate cut into the upper edges of the keelson to provide a lip for each ceiling plank to rest upon since the sister keelsons are not directly adjacent.[135]

Although the scantling dimensions for the axial timbers suggest a large heavily-built vessel, the frames are generally smaller than what would be assumed. Planking follows a similar pattern, as the thickness (2.5 cm) is much thinner than seen on smaller ships from other periods. Attachment of planks to frames remains the same with two nails per frame station without any evidence for treenails as part of the fastening pattern.[136] The overall shape for after section of Rhodes 4 suggests a flat floor with a hard chine that causes the futtocks to flair outward at 71-72°. Limited excavations on the wreck do not provide definitive proof for this shape and perhaps future work on site may show a flat floor with round bilge more typical of later round ship examples.

Precenicco

Out of the many river networks between the Alps and the Adriatic coastline, the Stella River holds a prominent place. The groundwater-fed river provides a constant flow throughout the year that empties into the Marano Lagoon. This navigable waterway allowed human occupation along its shores for centuries with archaeological finds originating as far back as the Neolithic.[137] Construction in 2012 for a removable flood barrier on the Stella near Precenicco by the Consorzio di Bonifica Bassa Friulana uncovered the remains of a medieval wooden boat during the archaeological survey prescribed by the Superintendence for Archaeological Heritage

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[135] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 495.
[136] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 9; Rieth et al., 'The Rhodes 4 Shipwreck: Final report', 20.
[137] Capulli, 'Il relitto di Precenicco (XI-XIII d.C.): Lettura dello scafo e osservazioni sull'uso dei madieri asimmetrici alternati', 83.

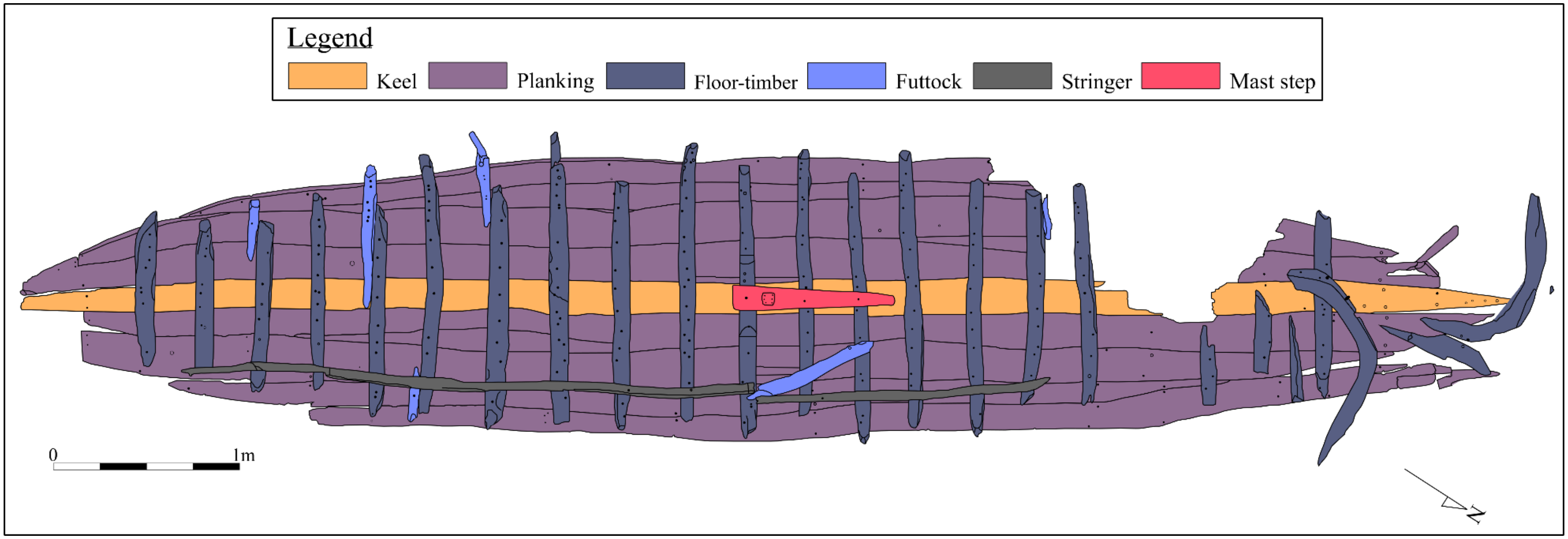

Figure 21 Site plan for the Precenicco boat. (after Capulli, 'The Precenicco shipwreck', 134)

of Friuli Venezia Giulia (figure 21). After two years of deliberation, the Consorzio and Superintendence agreed to retrieve the boat for conservation. Contract archaeologists from Archeolab returned to the site in 2014 to conduct a full-scale excavation that eventually led to the recovery of the surviving hull structure. The wooden remains were kept intact in a custom-built metal cradle and shipped to the salt warehouses of Villa Ottelio (owned by the Venezia Giulia Region), where it is still immersed in water awaiting treatment. [138]

Samples collected from the Precenicco wreck by C-14 date the ship to the twelfth or beginning of the thirteenth century.[139] The boat is bottom-based with a central keel plank matching the same thickness as the rest of the strakes. No evidence for endposts survive, instead the keel plank is shaped into a point on either end that accompanying garboards and upper strakes are tapered to match. Fastener holes in the planking suggests that the framing continued until the very end points of the boat.[140] An interesting element on Precenicco is the use of alternating long-armed floor timbers that overlap and are nailed to short-armed futtocks. Floor timbers are mainly square and there is a clear narrowing progression from a single master frame to either end with limited rising. Frame stations are widely spaced with double or triple the space compared to the dimension of floor timbers.[141] The remains of a short mast step positioned over the center of the overall hull length are connected to the floor timbers rather than bolted between them.[142] There is a bilge stringer on either side positioned at the overlap between the floor timbers and futtocks. Iron nails are rare on this boat and were only used to connect the floor

[138] Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 131.
[139] Capulli, 'Il relitto di Precenicco', 117, note 38.
[140] Capulli, 'Il relitto di Precenicco (XI-XIII d.C.): Lettura dello scafo e osservazioni sull'uso dei madieri asimmetrici alternati', 79.
[141] Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 132.
[142] Capulli, 'Il relitto di Precenicco', 115.

timbers and futtocks. Most other fastening are treenails, with one to three used per plank at each frame station.[143] The boat's flat floor and round bilge is unusual for an exclusive riverine craft (which typically includes a hard chine instead) and suggests that the vessel could operate in the Marano Lagoon or be used for coastal travel.

Çamaltı Burnu I

Around the beginning of the thirteenth century, a Byzantine wine-carrying merchantman sailed the Sea of Marmara in northwestern Turkey. The ship may have recently departed Marmara island with a mixed cargo that included three different sizes of wine amphoras from the local monasteries, ceramic containers holding other commodities, and over 30 broken anchors that were intended for repair or scrap. A storm or some other disaster befell the ship while it was traveling near Çamaltı Burnu, along the northwestern coast of the island.[144] Archaeological surveys around Marmara during the 1990s by Nergis Günsenin and Istanbul University located the remains of the wreck. Since few shipwrecks from this period were known throughout the Mediterranean and the ship's cargo represented the last amphora type used for maritime trade, authorities approved a full-scale excavation. Fieldwork began in 1998 and continued until 2004 when the fragmented wooden hull remains were retrieved from the seabed.[145] Along with the aforementioned cargo, the small amount of tableware found on the site suggested an affluent lifestyle for some on board, while the absence of any carpentry tools or defensive weaponry hints the ship was making a short-distance voyage.[146]

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[143] Capulli, 'Il relitto di Precenicco (XI-XIII d.C.): Lettura dello scafo e osservazioni sull'uso dei madieri asimmetrici alternati', 79, 81.
[144] Günsenin, 'L'epave de Çamaltı Burnu I (Ile de Marmara, Proconnese): Resultats des campagnes 1998-2000', 117-20
[145] Bass, ed., *Beneath the Seven Seas: Adventures with the Institute of Nautical Archaeology*, 118-9.
[146] Günsenin, 'L'Epave de Çamaltı Burnu I (Ile de Marmara, Proconnese): Resultats des Campagnes 2001-2002', 376

Compared to many other ships presented in this chapter, the wooden remains from the Çamaltı Burnu I are poorly preserved. Perhaps due to the amount of cargo and the weight of the broken anchors, there was relatively little ballast to protect the bottom of the hull on the seafloor over the previous centuries. Estimates for the preservation of the hull suggest only 3 percent remains, mostly in the form of scatter bits of planking, concretions of iron nails, and a few framing pieces.[147] Only 1.2 m of the ship's keel was found, which had a rectangular shape that is thicker than its width. No rabbet is included, and the surviving section has no indication of a scarf at either end. Neither endpost survived, so their original shape is not clear their original shape, although it is assumed that the vessel was double ended. A portion of a surviving floor timber suggests this element curved upward and was nailed to an overlapping futtock. Floor timbers were greater in height than width and were spaced twice the distance between each frame station.

No keelson timber survives, but the preservation of the bolts connecting this timber to the keel suggests they were located between frames. Elements from the planking show that the strakes were similar in thickness and width to those found on the much larger Rhodes 4 shipwreck. Each strake was fastened to the hull with two or three nails per frame station. Sections of a lower wale survive, suggesting a log cut in half with the sapwood removed. [148] Surviving concretions show the use of iron nails and bolts, but none of the scant wood remains indicate the use of treenails. Based on the surviving timbers, the ship presumably had flat floors, but it is unclear whether the turn of the bilge was hard chined or rounded.

[147] Bass, ed., *Beneath the Seven Seas: Adventures with the Institute of Nautical Archaeology*, 122-3.
[148] Günsenin, 'The construction of a monastic ship (?) in the Sea of Marmara: Çamaltı Burnu I wreck', 152.

Culip VI

Archaeologists from the Girona Archaeological Research Center (Centre D'Investigacions Arqueològiues de Girona) worked throughout the 1980s at Cala Culip along the northeastern coast of Spain. Cala Culip is a rocky inlet along the northern shore of the Cap de Creus peninsula. Ships traveling along the western coastline of the Mediterranean frequently visited the small bay since antiquity. In fact, archaeologists working in this bay uncovered several ships from antiquity during their initial surveys. While working on Culip IV, an AD first century shipwreck, excavators kept uncovering medieval ceramic sherds that eventually led them to conclude another wreck might be in the vicinity.[149] Following this lead at the end of their normal field season on Culip IV in 1987, the team opened test units in the surrounding area to uncover elements from Culip VI's hull. Archaeologists returned the following year to conduct a more thorough investigation and to plan for subsequent fieldwork.[150]

Full excavation and recording of the surviving hull structure commenced in 1990. The team was able to uncover a cargo of ceramics associated either with southern Andalusia (within the confines of the Kingdom of Granada) or North Africa. Other remains include dried fruits, nuts (including apricot and peach pits suggesting a late summer sailing season), animal remains possibly related to victualing the crew, along with possible tableware. Analysis of the non-Islamic pottery indicates an assortment originating from either Catalonia, Spain or Languedoc, France.[151] The artifact assemblage implies the ship could be dated to the end of the thirteenth century. Based on the finds, the reconstructed sailing course proposes the ship was sailing north

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[149] Nieto Prieto, 'El jaciment arqueològic Culip VI', 261-2.
[150] Nieto Prieto, 'Metodologia de treball - Introducció', 25-6.
[151] Palou, 'El carregament', 41-3, 78-9, 100.

when it sank. It is unclear whether the vessel departed North Africa sailing directly along the Iberian coast or if it stopped in Majorca along its journey.[152]

Investigators believe the ship was heading for Roussillon or Languedoc and presumably stopped at Cala Culip to seek a protective anchorage from winds in almost every direction except north beneath the high rocky mountain sides surrounding the inlet. Surviving hull remains suggest that a storm or strong wind from the north and created an intense wave action that eventually smashed the hull against submerged boulders. The ship sank a short distance away with most of the bottom of the hull quickly covered due to the vessel's sand and pebble ballast, along with the active formation processes in the small submerged gulley. These same processes were also destructive for the upper hull and the artifacts, which were largely broken and scattered on the seabed with few intact examples. [153]

Culip VI is often cited in nautical archaeological analyses due to its high level of hull preservation compared to the little found on many other contemporary shipwrecks (see figure 22).[154] The lower half of the stem and much of the central portion of the ship survives. This preservation extends slightly past the dual master frames at amidships. Scantlings suggest a lightly built round ship with a rectangular keel that is thicker than its width. There is no evidence for rabbets cut into either side of the keel, except near the front end where the lower hood ends of the garboards connect to the rabbet present on the stem. No scarf is present between the front end of the keel or the stem, instead these two timbers simply butt against each other. The lower surviving section of the stem suggest that it curved upward, and reconstructions of the ship

[152] Palou, 'El darrer viatge del Culip VI', 226.
[153] Nieto Prieto, 'El Derelicte Culip VI', 15-17.
[154] Rieth, 'First Archaeological Evidence of the Mediterranean Moulding Ship Design Method, The Example of the Culip VI Wreck. Spain, XIIth-XIVth c.', 9; Pujol i Hamelink, *La construcció naval a la Corona d'Aragó, Catalunya (segles XIII-XV)*, 29.

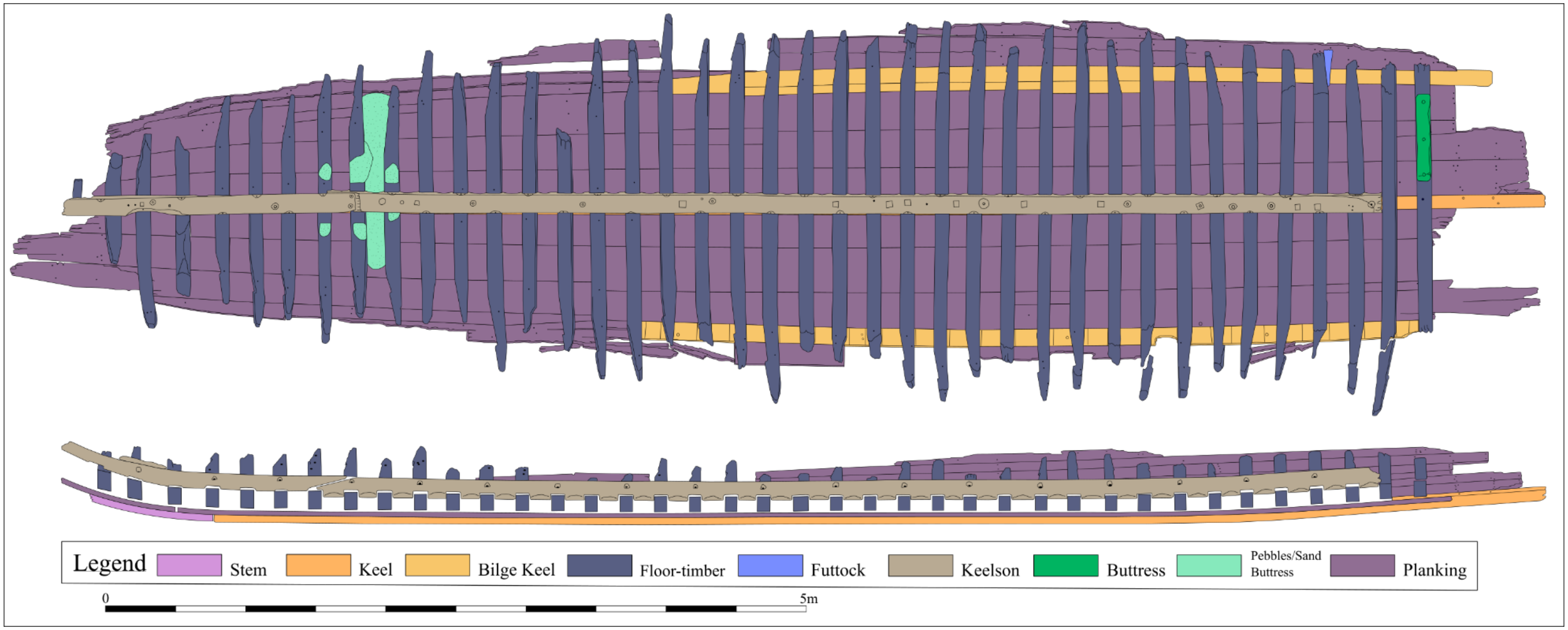

Figure 22   Site plan of Culip VI. (after Rieth, 'L'Arquitectura Naval', 140)

hypothesize a double ended vessel.[155]

Each frame station is composed of a floor timber hook scarfed to a futtock and fastened together with four nails. Scantlings for the floor timbers are roughly the same width as the keel, while their thickness varied based on the rising occurring toward the front end of the hull.[156] Floor timbers are nailed to the keel from underneath or outside the hull, while the three filling frames at the bow are toenailed from inside. Two sections of the keelson are flat scarfed together along the central axis and bolted to the keel between frame stations. Additional nailing in an alternating pattern across the top of the keelson provided a connection to the floor timbers.[157] Evidence for two mast steps survive, one placed toward the front of the hull and another closer to amidships. Mast steps were built over the keelson and were composed of several independent knees or buttresses fastened to the floor timbers. Two upright planks acted as mast step partners, while a pair of chocks fastened to the top of the keelson on either end of the mast step partners completed the mast mortise. Repairs during the life of the vessel included several of the forward buttresses being replaced with a primitive cement mixture of sand and pebbles.[158]

No remains of the bilge stringers survive, but their presence is indicated by the fastening pattern and indentations found on the top faces of the floor timbers and futtocks at the turn of the bilge. The stringers were iron nailed to the framing, while it is also suggested that treenails were used to connect this element to the bilge keels running along the outside of the hull.[159] Two strakes of longitudinal ceiling are also present between the keelson and the stringers. External

[155] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 118-20.
[156] Rieth, 'L'épave du caboteur de Culip VI (Catalogne, Espagne)', 209-10
[157] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 287-8
[158] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 127-30.
[159] Ibid., 134-5.

bilge keels running parallel to the internal stringers are rebated to fit over the outside faces of the frames. Planking is fastened to the frames with three to five iron nails per station without any evidence for the use of treenails. Fragments from a lower wale were also recorded that showed a trapezoidal cross-section. Further examination of the hull revealed that it was painted with tallow and that afterward a thick layer of pitch was applied both on the inside and outside of the ship.[160] Limited hull remains above the floor timbers and a few pieces of lower futtock arms suggest the vessel's original shape featured a flat floor with a round bilge. The smaller dimensions of the keel suggest a ship intended to operate closer to shore rather than a deep-water merchantman.

Camarina

In 1989, winter storms along the coast near Camarina, Italy uncovered the remains of a longship 40 m from shore in less than 5 m of water. Personnel from the Superintendence for Cultural and Environmental Heritage of Ragusa (Soprintendenza ai Beni Culturali ed Ambientali di Ragusa) investigated the wreck site the following year. The remains stretch over a 40 m by 9 m area with the hull broken into two separate sections corresponding to the bow and amidships area.[161] The entire site was overlain by sand with scattered pebbles that are believed to be part of the original ballast. The recovered artifact assemblage was mostly iron concretions representing a collection of helmets, fragments from breastplates, and tools for a farrier. Remnants of an anvil, pliers, hammers, chisels, files, saws, and mule shoes were included in the concretions. Faunal remains found within the hull were identified as horses that were probably being transported on the ship. The few ceramics found with the assemblage point to a date between the eleventh and fourteenth centuries.

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[160] Ibid., 151-2.
[161] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87

Due to the type of ship and the artifact assemblage, the investigators believe the Camarina shipwreck was a type of auxillary transport for larger ships. Based on a review of contemporary records, the survey report suggests a *tarida* or *tafurrea*, a flat-stern longship intended to transport horses and also offloaded them on shore.[162]

Recent research suggests the ship was part of a war fleet led by Duke Robert of Anjou (1296-1309) in 1301 and lost (along with 22 others) in a storm prior to landing to invade the southern Sicilian hinterland.[163] In 1282, riots broke out across Sicily that led to the entire island rejecting French Angevin rule and offering themselves to the Aragonese. Angevin rulers refused to accept the loss and continued fighting to reassert control of the island until initially abandoning this effort with the Peace of Caltabellotta (1302).[164]

The keel of the Camarina wreck is rectangular and much thicker than it is wide (figure 23). No rabbet is cut into the keel, instead, the ship carpenters chamfered the upper edges and corresponding inboard edges of the garboards. No mention is included about whether there are any surviving scarfs connecting the keel with the stem. Each frame station includes a relatively square floor timber overlapping its futtocks, with no scarf connection observed. The frame stations on Camarina indicate a 1:2 ratio for space between floor timbers. Each floor- timber is connected to the keel with two treenails, while the keelson is bolted between every other frame at the bow or every third frame amidships. Bilge stringers are present at the turn of the bilge covering the overlap between the floor timbers and futtocks. Both stringers on either side of the hull are also recessed like the keelson to fit over the frames.[165]

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[162] Ibid., 88-92.
[163] Distefano, 'La galea di Kamarina'.
[164] Stanton, *Roger of Lauria (c. 1250-1305) 'Admiral of Admirals'*, 299-300.
[165] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87

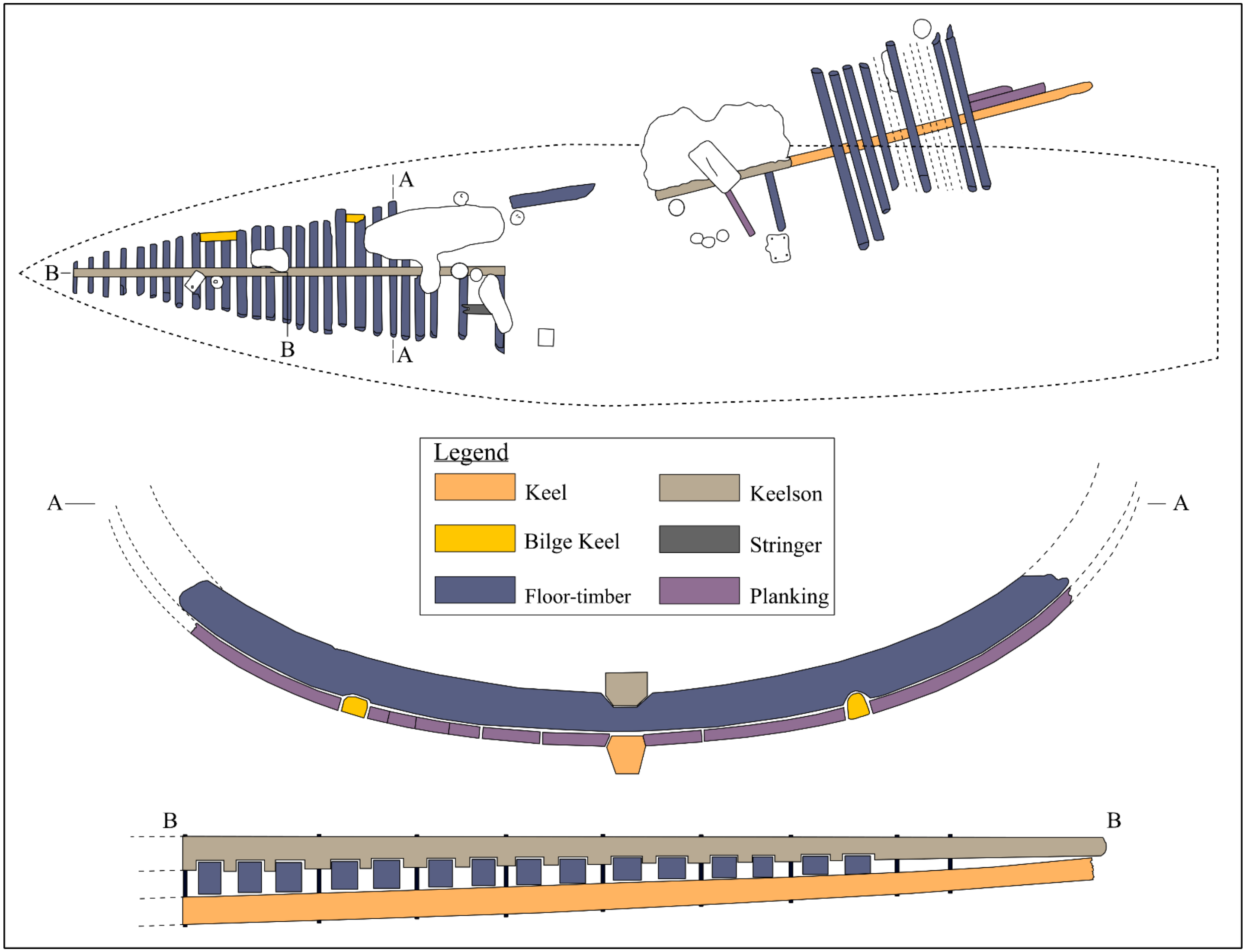

Figure 23   Site plan and profile sections from the Camarina shipwreck (No scale). (after Stefano, 'La galea medieval di Camarina', 89-90)

Ceiling is raised above the frames like earlier eastern vessels. In this case, the keelson is rebated to provide a lip for the transverse boards that presumably had their outboard ends fit into corresponding rebates in the stringers. Bilge keels rebated to fit over the outside of the frames were located adjacent the bilge stringers. Planking is relatively thick (5 cm) for a longship and there is no clarifying information on whether each strake was fastened with iron nails exclusively. Caulking is reported in the seams between the planking, although there is no mention if a sealant was used to cover the entire hull.[166] The only profile provided for the ship is forward from amidship, but descriptions suggest a flat floor and rounded bilges. Camarina represents the earliest frame-based longship currently known from the late medieval period. Earlier examples uncovered at Yenikapı in Istanbul, Turkey are associated with shell-based construction.[167]

Olbia Wrecks 4 and 10

The construction of a tunnel along the waterfront in downtown Olbia, Sardinia uncovered 24 ancient wrecks in 1999. Archaeological excavations over the following two years recorded and dismantled the surviving hulls for preservation.[168] Most of the wrecks belong to three different periods: 2 from the AD first century, 11 assumed lost during a Vandal raid in the 5th century, 3 abandoned as reclamation fill between the eleventh and twelfth centuries, and 3 ships dating to the eleventh, fourteenth, and fifteenth centuries respectively (assumed to be accidental losses). Five other hull remains were significantly damaged and dated to the 5th century with a small boat not dated.[169] The tunnel excavation also uncovered various tools and wooden objects

[166] Ibid., 88.
[167] Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 262-7; Kocabaş and Özsait Kocabaş, 'Technological and construction features of Yenikapı shipwrecks: A preliminary evaluation', 176-82.
[168] D'Oriano, 'Relitti di storia: Lo scavo del porto di Olbia', 1249-50.
[169] D'Oriano and Riccardi, 'I relitti del porto di Olbia. Dallo scavo al museo', 189-90.

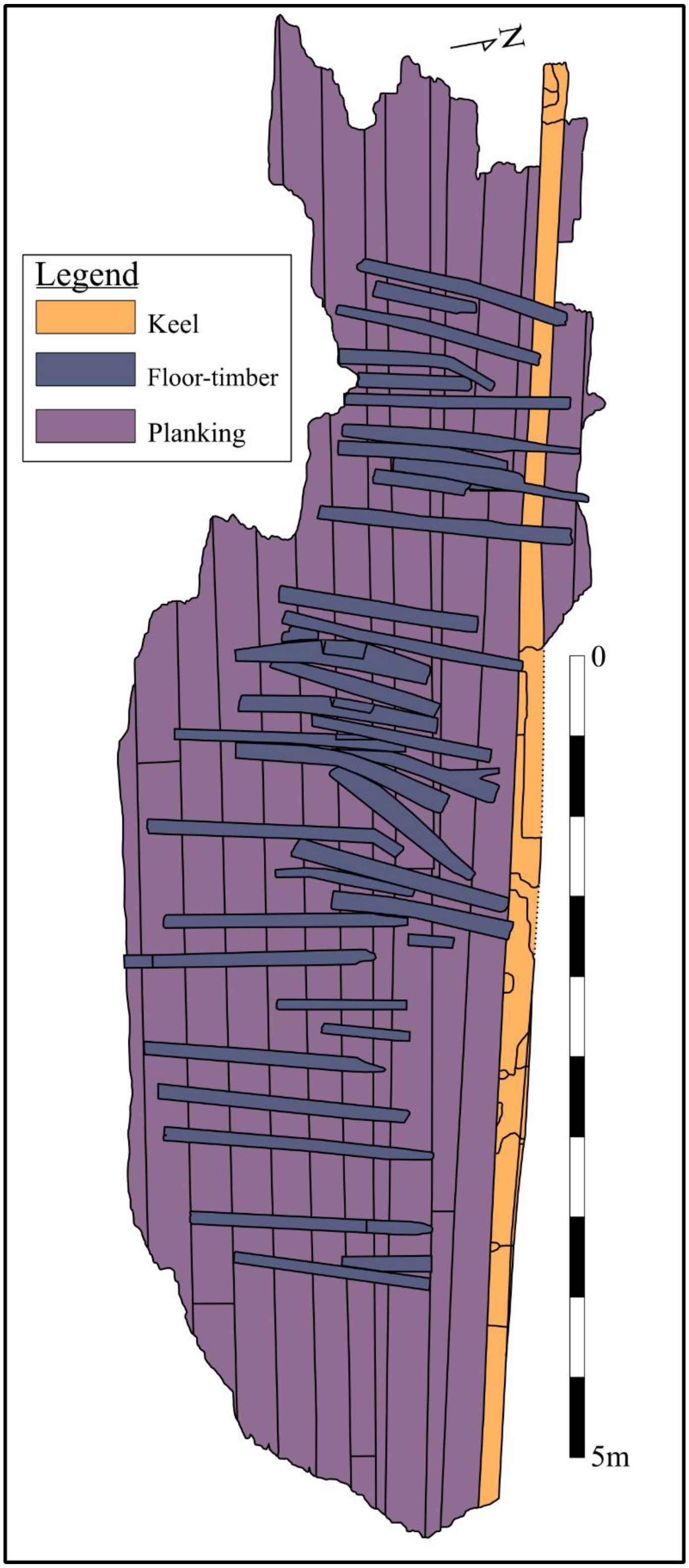

Figure 24 Site plan of Olbia 4 shipwreck. (after Riccardi, 'Medieval boats from the Port of Olbia', 313)

in the process of being converted into naval supplies. This latter collection of material is assumed to be lost and not recovered due to flooding of a local shipyard. Most publications about this collection focus on the earlier vessels with less information reported about the medieval shipwrecks.[170]

Surviving evidence from Olbia Wreck 4 (figure 24) suggests the ship caught fire and sank based on radiocarbon dating between AD 1165-1265. Associated ceramics in the area provide a wide date range from the twelfth to fourteenth centuries. After disassembly of the hull, excavators uncovered a stone ball from a catapult that they believe was used during the siege of Olbia by the Aragonese in 1323. Limited information reported Wreck 4 states that the keel has a shallow rabbet and most of the frames were jumbled. Several frames are also reported with dovetail joints connecting the floor timbers to futtocks.[171]

Olbia Wreck 10 was found embedded into the side of the tunnel and only preliminary observations were recorded. Radiocarbon dating suggests the ship was in service some time between 1405-40. It has a shallow keel that is rounded on the lower face, possibly suggesting minimal transformation of the original log beyond removing the sapwood or continual wear during its operation in shallow waters. The floor timber recorded on the hull is fastened to the keel with an iron nail and a treenail. Along with the other three visible frames, their overall dimensions were rectangular. Planking is thinner and the strakes that survived appear to be made from smaller trees.[172]

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[170] For example: Riccardi, 'I relitti del porto di Olbia' ; D'Oriano and Riccardi, 'A lost fleet of ships in the port of Olbia'
[171] Riccardi, 'Medieval boats from the Port of Olbia, Sardinia, Italy', 313.
[172] Ibid., 314.

Boccalama A and B

Throughout the Venetian lagoon evidence of earlier human occupation can be found not only in the central islands that make up the modern metropolis, but also the surrounding isolated island archipelagoes. On the now-submerged island known as San Marco in Boccalama, an oratory was founded in AD 1013. By the fourteenth century, a monastery was erected with a small collection of monks living in isolation from the rest of the lagoon. Concerned that subsidence and erosion were slowly destroying their home, the prior of the monastery was granted permission for a reclamation project.[173] Hulls from a *rascona* (Boccalama A), a barge-like vessel that mainly operated within the lagoon and local riverways, and a thin galley (Boccalama B) were brought to the island. Wooden piles were driven into the seafloor surrounding both ships and their interiors were filled with soil extending the island further into the lagoon.[174] This attempt at preventing further erosion was unsuccessful, as the monastery was abandoned after 1328. The island remained deserted until 1348, when Venetian officials used it as a burial site for the black plague victims. Documents from the sixteenth century continue to mention the island, but it appears to have already been submerged for quite some time.[175]

The first revisits to the site for archaeological purposes began in 1966 with research directed at understanding the surviving structure of the former monastery.[176] Major construction projects within the lagoon over the proceeding decades led to a concern by the local water authorities about the preservation of the island’s archaeological sites. As a result, a group of

[173] Romanelli, *La galea ritrovata: Origine delle cose di Venezia*, 90-3.
[174] Ibid., 22.
[175] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 13-14
[176] Canal, 'Localizzazione nella laguna veneta dell'isola di San Marco in Bocca Lama e rilevamento di fondazioni di antichi edifici', 168-72

divers and archaeologists were assembled to mount a large-scale archaeological monitoring project. This project included revisiting San Marco in Boccalama in 1996, which led to the discovery of the first of the two wrecks.[177] Preliminary findings reported a well-preserved wreck and it was decided that protection using driven poles around the site would prevent the local clam fishery from damaging the site. Fishing continued inside the pilings and the subsequent discovery of the second wreck while a monitoring expedition was attempting to relocate the original find led to further concerns about preservation. Suggestions for additional pilings and boards fastened between them to cut off access to the area were unsuccessful in preventing reported damage by unauthorized visits to the area.[178] Due to the constant threats and skepticism about the importance of both wrecks, a full excavation project was launched in 2001.

Pilings surrounding the island's location were replaced with full metal sheeting locked into the seafloor, cutting off the internal area from the rest of the lagoon. Excavation followed in two stages, the first to excavate both wrecks while they were submerged to limit potential damage. Once the removal of any artifacts and the majority of the sediment was completed, the inside of the coffer dam was drained so that a photogrammetric survey could be completed.[179] Publication of the results a year after the investigations provides only a summary report about either wreck; a full report about the hull assembly is still awaited.

Boccalama A was assembled in a bottom-based methodology utilizing a plank keel the same thickness as remainder of the planking. The greater width of the ship (6 m) required both the accompanying garboard and first strakes beyond to lay flat. What survives of the ends of the

[177] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 3
[178] Romanelli, *La galea ritrovata*, 25-8.
[179] McManamon, D'Agostino, and Medas, 'Excavation and Recording of the Medieval Hulls at San Marco in Boccalama (Venice)', 23-4

ship suggest that the keel plank may have ended in a point that was complemented by the curved ends of the garboard and other bottom strakes.[180] Framing is composed of square floor timbers that overlap with short-armed futtocks creating a hard chine at the turn of the bilge. No scarf is present between the frame elements and neither were fastened together. There is clear evidence on the interior faces of the short-armed sections of futtocks of two treenails driven from inside the hull. These may relate to the installation of now missing bilge stringers.[181] A recessed keelson is suggested by impressions it left over the central section of the floor timbers and two pairs of buttresses treenailed and iron fastened to the hull near the bow. As an exclusive riverine or lagoon vessel, Boccalama A has a low freeboard only 74 cm in height that is accentuated by the flat bottom and hard chine.[182]

The construction of the longship (Boccalama B) is based on an axial timber system with a rectangular keel. Toward the stern, there is a hook scarf that connects the keel to sternpost and both elements include a rabbet. Above the scarf there is a sternson that reinforces the keel-sternpost and covers the seam of the scarf. Floor timbers overlap and are nailed to the futtocks without a scarf. Scantlings for the framing are relatively light compared to those of round ships, presumably to keep the ship agile and lessen hogging. A rebated keelson runs along the centerline of the vessel and a recessed stringer at the turn of the bilge clamps the framing in place.[183] Ceiling runs longitudinally between the keelson and the stringers on either side of the hull.

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[180] Romanelli, *La galea ritrovata*, 44-7.
[181] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 10-11
[182] Romanelli, *La galea ritrovata*, 45.
[183] Ibid., 62-5.

A mast step assembly toward the bow includes seven tall buttresses per side that provide lateral support for mast step partners rebated over the frames and adjacent to the keelson. The buttresses are placed further away from each other near the ends of the mast step. Two long chocks rest over the keelson, which are combined with the mast step partners create the mast mortise. Wear patterns show that the mortise saw continual use during the vessels' working life. While the aft section includes a large adjustable chock and an upper lip to sit over the accompanying mast step partners.[184]

Several transverse keelson riders are present dividing the hold into separate sections. Vertical planking in front of the mast step clearly shows a partition for a storeroom. Hull planking includes the use of flat or hook scarfs that are simply connected to the frame stations with nails and not to each other.[185] The ship's overall cross-section includes a flat floor with a round bilge.

Les Sorres X

Barcelona in the Catalonia region of Spain was chosen in 1986 to host the 1992 Olympic summer games. Infrastructure construction before the event included an artificial canal (Canal Olímpic de Catalunya) near Castelldefels intended for canoe sprinting competitions.[186] During work on the canal in September 1990 a bulldozer uncovered the remains a medieval boat. Recording and recovery of the find (now known as Les Sorres X), was undertaken by the Department of Culture and the Center for Underwater Archaeology of Catalonia (Centre d'Arqueologia Subaquatica de Catalunya - CASC).[187]

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[184] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 67
[185] Romanelli, *La galea ritrovata*, 65.
[186] Garrido, 'El canal olímpic de rem', 9-10.
[187] Ibid., 11-12.

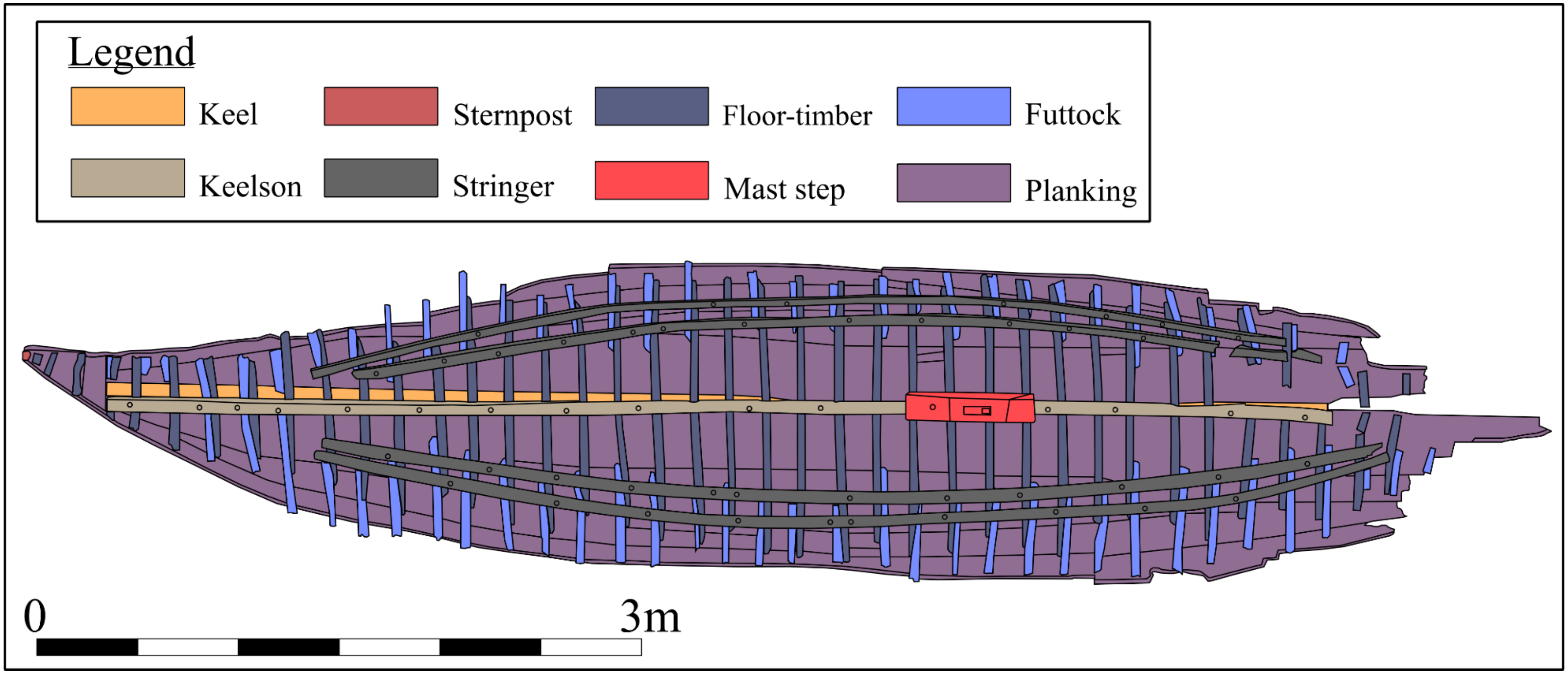

Figure 25 Site plan of Les Sorres X. (after Pujol i Hamelink, 'Medieval Shipbuilding in Catalonia, Spain', 289)

Temporary measures to continually drain the surrounding sand where the wreck was found allowed archaeologists to document the site in situ. Due to the pressing nature of the canal project, the team worked around the clock and dismantled the wreck rather than remove it as a single object. This decision was mainly due to many fractures found across the hull. The ship was also documented with 1:1 scale drawings of each timber as it was removed from the hull (figure 25). Conservation plans included building a vat at the CASC where the boat would be preserved using polyethylene glycol and await a final exhibit space.[188] In 2011, the hull remains were shipped to the Maritime Museum of Barcelona (Museu Marítim de Barcelona), where the staff began renewed preservation work in 2015 with a final exhibit unveiled four years later.[189]

Artifacts found originally within the boat included approximately 10 ceramic jars divided between the bow and stern to transport salted fish. Each jar was also protected with esparto grass either wrapped around the ceramics or woven into a matt protecting it from sudden jolts against the hull. The style of the jars and of the tableware found in the hull suggest the ship was lost in the latter half of the fourteenth century.[190] Limited finds near amidships suggest that whatever cargo was originally in this area was salvaged. Both the Olympic canal and Les Sorres X rest on fluvial deposits from the Llobregat river, although the river itself currently discharges into the Mediterranean further north. The landscape of the surrounding area includes urban sprawl, rich agriculture plots, and the Barcelona-El Prat airport. The earliest cartographic representation of the area from 1590 depicts a coastline similar to that seen today. Earlier documents suggest, however, that this floodplain silted up and expanded outward throughout the medieval period due

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[188] Martín, 'Desenvolupament de l'excavació', 27-8.
[189] Les Sorres X Exhibition: A medieval vessel, accessed 9 Sept. 2020, https://www.mmb.cat/en/exhibitions/les-sorres-x/.
[190] Raurich, 'El carregament del jaciment les Sorres X', 50-2.

to significant soil run off as local forests and were transferred into farming zones, Les Sorres X's location fits within the shallow Murtra lake that once existed and was slowly silted up to the point that only its original entrance to the sea continues to exist as a water run off for the surrounding area. [191]

Les Sorres X is built with a relatively square keel that butted against similarly sized endposts. Les Sorres X has the earliest known example (outside antiquity) of a counter keel installed as part of its construction. In this example, the counter keel is a keel plank that sits directly over the keel.[192] Both endposts are rebated on their lower ends to accommodate the counter plank keel extending beyond the keel. Connections between the endposts, counter plank keel, and keel appear to mimic a scarf without the labor involved to create this overlap. Frames are composed of square floor timbers that overlap, and are nailed to, the futtocks. Several overlaps are diagonal butts, while the ship carpenter occasionally spent time cutting out a recess in a futtock to accommodate the wronghead of an accompanying floor timber. Dual master frames positioned amidships are nailed from the inside to the keel, while the remainder of the central frames were all fastened from underneath the hull. Several surviving filler frames found on the sternpost indicate these were toenailed in place from the inside.[193]

The keelson along the centerline is composed of two pieces flat scarfed together with a wooden block mast step covering the connection. Instead of iron fasteners, the keelson is connected to the keel with a series of treenails between frames. Two pairs of bilge stringers are fitted on either side of the hull at the turn of the bilge. Lower stringers are treenailed between

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[191] Izquierdo, 'El medi geogràfic: Aproximació a l'evolució del paisatge', 14.
[192] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 289-90
[193] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 36-7.

frames to rebated bilge keels. During disassembly of the hull, archaeologists noted that the upper stringer was possibly treenailed to a ribband, which was later removed once the planking was installed.[194] Ceiling runs longitudinally and appears in irregular shapes to fill the space between the keelson and stringers. The sternpost includes a rabbet, while the keel has none (this is clearly because of the presence of the counter keel plank that rests against the frames). Planking runs adjacent the counter keel plank and fastened with two or three iron nails per frame station. Garboard strakes are extremely wide (40 cm), while the remainder of the planking is much narrower.[195] Several smaller rectangular cuts suggest repairs during the life of the vessel. Evidence of caulking was identified in the seams between strakes and both the inside and outside of the hull was covered in pitch. Les Sorres X also represents one of the earliest Mediterranean-built vessels with evidence of a stern rudder instead of the traditional quarter rudders seen on all previous ships.[196]

Bacàn 1 and 2

Two wrecks were uncovered near the inlet to the Venetian lagoon during the course of archaeological monitoring in conjunction with the canal management system. Under the auspices of the Magistrate of the New Venice Water Consortium (Magistrato alle Acque-Consorzio Venezia Nuova), further inspection of the two sites was conducted between 2004 and 2010 with direction by the Superintendence for Veneto Archaeological Heritage.[197] Bacàn 1 was discovered in 2004 as a pile of large stone slabs near the island Sant'Erasmo and originally believed to be

[194] Pujol i Hamelink, *La construcció naval a la Corona d'Aragó, Catalunya (segles XIII-XV)*, 218-9.
[195] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 39.
[196] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 289
[197] Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 78; Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 115-7

associated with a former lighthouse, known as Faro della Pissotta. Further investigations revealed that the stone was the cargo from a wooden vessel pinned underneath. The position of the wreck suggests that the ship was lost along the edge of an ancient channel that led into the port beyond Sant'Erasmo. This port area was closed several times throughout the fourteenth and fifteenth century until it later sealed permanently to encourage the development of San Nicolò.[198]

Monitoring continued for the next several years until a preliminary excavation campaign was launched in 2006 for site recording and identifying any surviving artifacts. In the same year, Bacàn 2 was identified with another stone cargo and the second shipwreck became part of the same monitoring and subsequent excavation project between 2009/10. Most of the planning focused on Bacàn 1 and its stone cargo was retrieved during the 2009 fieldwork. During the following year, investigators revisited Bacàn 1 to collect further information about the surviving hull structure. Only in this last campaign season did archaeologist also conduct limited excavations on Bacàn 2.[199] After recording the surviving hull remains, both wrecks were covered with geotextiles, electro welded mesh, and permanent sandbags to be left in situ.

Due to the cross current affecting both sites from the canal projects and jetty system installed between the 19th and 20th centuries, no surviving stratigraphy was present on site. Few artifacts were found around the hull of either vessel that could be confidently attributed to the original wrecking event. Modern trash and debris were also found beneath the stone slabs and the hull itself, indicating that the wrecks were prone to significant scour and reburial. Wood samples from both wrecks suggest that they were lost at different dates in the fifteenth century.[200] Investigators suggest the ships were originally *marani* or *marrani*, known as flat cargo carriers

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[198] Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 82-3.
[199] Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 117-8
[200] Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 79, 82.

with two lateen sails that operated in the Venetian lagoon and the Adriatic coastal trade routes. The belief is that both vessels were heavily loaded with stone cargoes and sank when attempting to enter the canal during a dangerous moment with heavy wave action.[201]

Radiocarbon dating from Bacàn 1 suggests the ship was lost in the 1450s. The keel is rectangular in cross section with rabbets along its length. Preservation of the hull was dependent on what survived beneath the stone cargo, so no information is available about any keel scarfs or the endposts. Framing relies on square floor timbers that overlap without a scarf to similarly sized futtocks. Instead of having a limited overlap between the framing elements, futtocks on either side butted against each other over the keel. Spacing between the frames is slightly less than the width of the frames themselves. Both the limited space between frame stations and the significant overlap between floor timbers and futtocks suggest the hull was reinforced to carry heavier loads.[202] Evidence also survives for a rebated keelson that ran along the centerline of the hull with an expanded mast step as part of the same timber. The keelson is attached to the keel with seven or eight bolts that extend through floor timbers. A a single iron nail in the keelson might be associated with a scarf connection. Ceiling runs longitudinally and was installed with treenails, while the planking is fastened exclusively with iron nails. [203] Planking remains are thin based on the general size of the ship. The transverse profile of the hull suggests a flat floor with a round bilge.

Less is recorded for Bacàn 2, but what has survived suggests a construction arrangement similar to Bacàn 1. Radiocarbon dating for Bacàn 2 places the wreck in the 1420s. The keel is

[201] Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 124
[202] Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 79-80.
[203] Stefano Medas, pers. comm.

also rectangular, although it is much thicker than the example from the other wreck.[204] Rabbets for the garboards are also present on Bacàn 2. Not enough of the ends of the ship survives to know anything about the endposts. Framing is also the same as Bacàn 1, with floor timbers the same size, except the futtocks are slightly larger. The futtocks also act as half-frames that butt against each other directly over the keel.[205] Surviving elements from the planking suggest a similar thickness as described for Bacàn 1 and a similar profile for the overall shape.

Marinières I

Many places along the coastlines of the medieval-era Mediterranean remained deserted outside of major coastal metropolises. Rural peasantry often sought refuge in villages and towns situated further away from the coast on the margins of mountain ranges. Pirates and corsairs sailed unimpeded throughout the Mediterranean waters, capturing inhabitants to sell into slavery or to pillage the communities.[206] In 1295, Charles II of Anjou (1285-1309) ordered for the foundation of a port settlement at the bay of Olivula directly east of Nice. The bay was the perfect natural harbor and Charles planned to build up the area as part of his maritime kingdom between Provence and southern Italy.[207]

Villefranche-sur-mer quickly took shape with the surrounding population given incentives (such as establishing the new settlement as a "free port") to move to the coast with privileges and compensation. After the death of Angevin Queen Joan I (1343-82), the inheritance of the domains was hotly contested. The County of Provence divided between the majority to the west who sided with Louis I of Anjou (1339-84), while eastern territories (including the area of

[204] Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 122
[205] Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 81-2.
[206] Sayous, 'Le commerce de Nice avec l'intérieur: D'Après des actes inédits de notoires niçois (1272-1284)', 47
[207] Durante, *Histoire de Nice depuis sa fondation jusqu'à l'année 1792*, 247-8, 250.

Villefranche-sur-mer) chose to side with Charles III of Naples (1345-86), and later his son Ladislaus of Naples (1377-1414).[208] Louis I managed to hold onto most of the defecting areas, except those along the eastern fringe and Nice, which chose in 1388 to defect to the Red Count of Savoy, Amadeus VII (1360-91), for protection against the Anjous and their allies. Definitive possession of these lands were finalized by 1419 as exclusively under Savoy control.[209] Villefranche-sur-mer then became the exclusive military port for Savoy, although it remained without any harbor facilities or shipyards until the sixteenth century.

In the meantime, directly after Savoy took full control of the area, a ship was lost or abandoned in the harbor in less than 5 m water along the Marinières beach. Its discovery in 1985 prompted two excavation seasons in 1992/3 led by Jean-Marie Gassend and Alain Visquis. Ceramics recovered during this first investigation dated the wreck to around 1500.[210] In 1996, Michel L'Hour resumed work on the site and it was eventually decided to disassemble the well-preserved hull in a manner similar to the work of Parks Canada on the sixteenth-century 24M Red Bay, Labrador Basque whaler.[211] Michel Daeffler took over recording the hull structure after its disassembly in the late 1990s (figure 26).[212] Dendrochronology carried out by Frederic Guibal on the timbers provided a felling date between 1420 and 1430 with synchronization compared to references in southwest Germany, Paris, Franche-Comté, and Cluny (Saône et Loire). No

[208] Venturini, 'Vérité refusée, vérité cachée: Du sort de quelques nouvelles avant et pendant la Guerre d'Union d'Aix (1382-1388)', 182-3, 187.
[209] Ripart, 'La « Dédition » de Nice à la Maison de Savoie: Analyse critique d'un concept historiographique', 21-2, 26
[210] Daeffler, 'L'épave des Marinières: Un témoin des mutations technologiques dans les chantiers navals du XV^{e} siècle', 9; Daeffler, 'Villefranche-sur-Mer (Alpes Maritimes), épave des Marinières', 330.
[211] For more detail on this disassembly methodology, see Waddell, 'Disassembly of Hull Structure', 134; Waddell, 'The disassmebly of a 16th century galleon', 142-4
[212] Daeffler, 'L'épave des Marinières', 14-15.

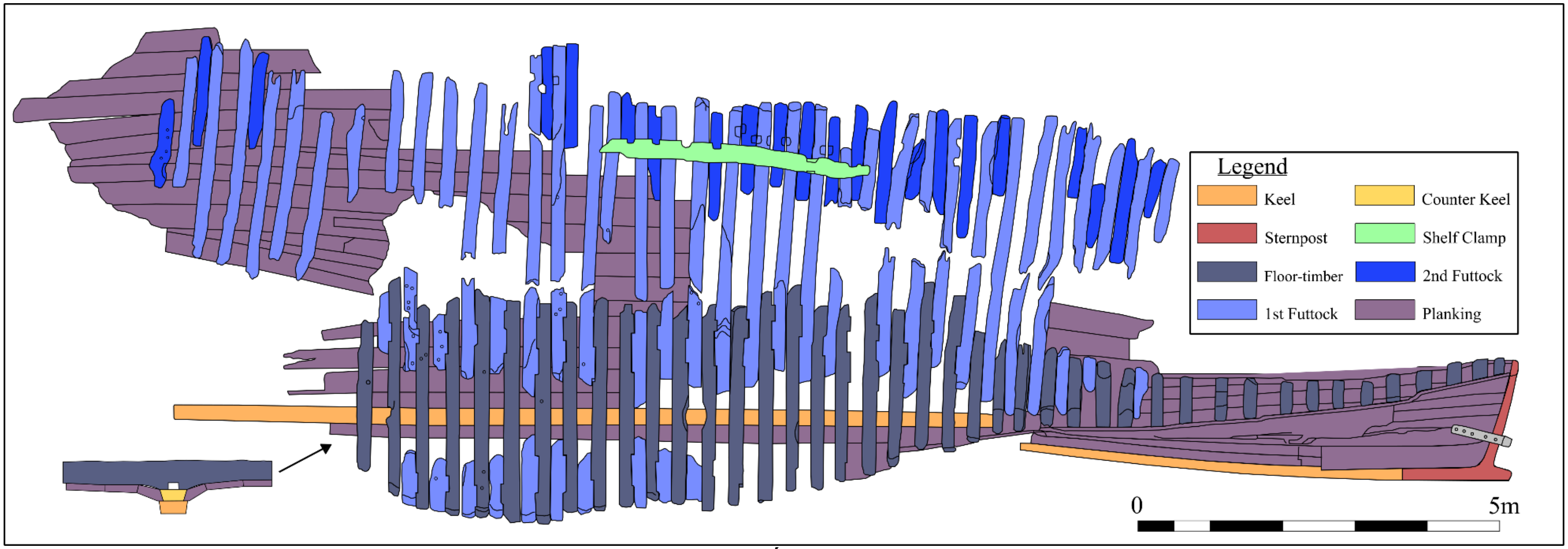

Figure 26 Site plan of Marinières shipwreck. (after Daeffler, 'L'Épave des Marinières, 39)

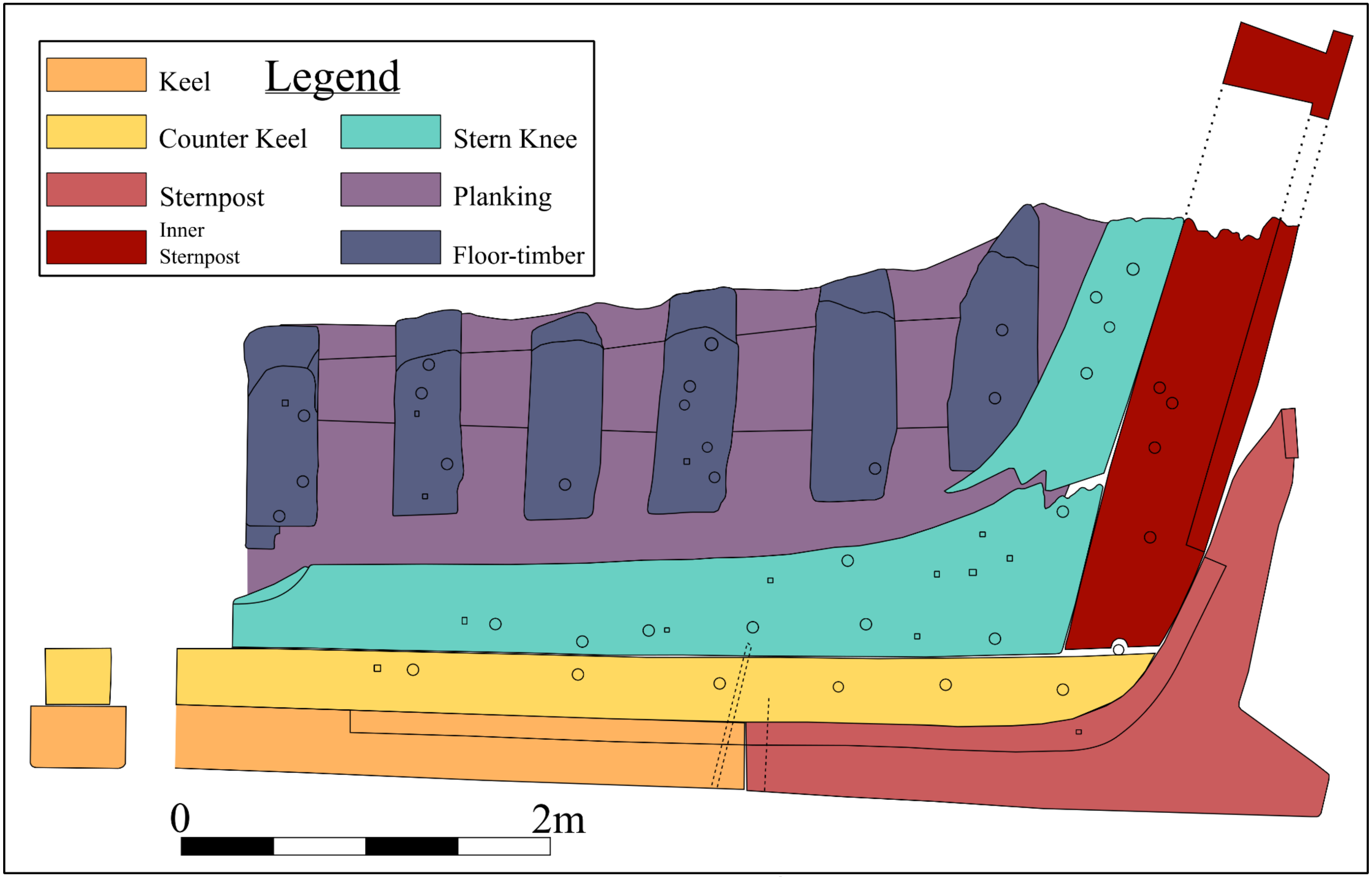

Figure 27   Stern assembly of the Marinières shipwreck. (after Daeffler, 'L'Épave des Marinières, 44)

available correlation gradient exactly fits the Marinières wreck samples, preventing a precise geographical origin determination.[213]

Construction of the original Marinières wreck began with a wide rectangular keel. The keel is supplemented with a smaller counter keel and both elements were connected by sculpted garboards fastened using iron nails and treenails. Neither the keel nor counter keel have a rabbet, the original shipbuilders chose to have the keel wider than the counter keel, creating a lip for the garboard to rest on. The after end of the keel butts against a heel timber without any scarf and the upper section of the latter also butts with a stopwater to a missing upper sternpost at 77° (figure 27). Forward of the heel timber is an inner sternpost that is also butted to the top of the counter keel using another stopwater. While the heel timber has a rabbet for the after end of the garboard, only the inner sternpost includes the rabbet to accommodate the hood ends for the remaining planking. The stern knee rests on top of the counter keel and its upper arm rests against the inner sternpost. [214]

Framing is relatively square with floor timbers that overlap futtocks. Evidence suggests the ship was built with dual master frames and tailframes toward either end. There is a single or double dovetail scarf connecting the lower framing elements together using three treenails and two nails. The nails appear to set the correct overlap position, while the treenails were installed afterward. Average spacing between floor timbers is roughly the same width as each frame. Most floor timbers are bolted to the keel, while three Y-timbers are nailed to the counter keel and a fourth example is toenailed on the side.[215] No remains of the keelson were found, but surviving evidence suggests it was bolted through the floor timbers and recessed over the frames. Half-

[213] Michel Daeffler, pers. comm.
[214] Daeffler, 'L'épave des Marinières', 19-20.
[215] Ibid., 20-2.

round cuts into two floor timbers slightly abaft of amidships, and directly over the keel, suggest a pump sump was cut through the center of the keelson. Bilge stringers were also missing, but the pattern of surviving treenails on the top faces of the frames at the turn of the bilge suggest their original presence.[216] Planking thickness generally follows the same seen on contemporary ships found in the western Mediterranean. Each strake is fastened with two nails and one treenail, with three nails used exclusively at the ends of strakes. Seams were caulked with vegetable fiber and the outside of the hull heavily covered in thick layer of pitch. Lead strips were also found between the garboard joints.[217] The reconstruction of the ship suggests a flat floor with a round bilge. Daeffler asserts that the ship was built in Portugal before its loss at Villefranche-sur-mer.[218]

Cavoli

Along the southeastern coast of Sardinia, along the coastal perimeter of Capo Carbonara, 42 divers associated with the British Royal Air Force in Germany participated in a 1971 underwater survey. Between Capo Boi and Punta Molentis, the team was unable to locate any ancient harbors, but were successful with isolated finds and two amphora piles associated with wreck deposits dated between the AD second to fourth centuries. The most significant find from this survey was a collection of artifacts found near the southern coastline of the nearby island of Cavoli that were dated between the sixteenth or seventeenth century.[219] Subsequent visits to the site over the next three years included groups of British military divers retrieving artifacts as souvenirs and illegally exporting them from Italy. The whereabouts of this collection is

[216] Ibid., 22, 39, fig. 6.
[217] Ibid., 18.
[218] Ibid., 31.
[219] Martin-Bueno and Amare Tafalla, 'Remains of a Fifteenth-Century Spanish Ship Found in Sardinia', 85-6.

unknown, although the preliminary report on the findings includes a photo of significant material.[220]

Italian divers in 1986 relocated the site, obtaining permission and financing by the Province of Cagliari in collaboration with the Archaeological Superintendency of Cagliari and Oristano (Soprintendenza Archaeologica de Cagliari e Oristano) to retrieve artifacts. The initial salvage efforts by the British divers overlooked other objects associated with the wreck, and Italian archaeologists were able to locate wrought iron cannons with their associated breech blocks, ceramic sherds, lead seals associated with cotton bales from Mallorca, and a cargo of colorful tile.[221] After retrieval, many of the artifacts were apparently not conserved and their treatment neglected until the 1990s. Conclusions from the research carried out by the Italian team suggest the ship was carrying a cargo from the Spanish-Mediterranean coastline that wrecked on an eastward voyage.[222]

Efforts to revisit the site in conjunction with the quincentennial of Spain's voyages to the Americas brought further interest to the Cavoli shipwreck to better understand ships built in this period. Between 1990 and 1991, a team from the University of Zaragoza working with the Archaeological Superintendency of Cagliari return to the site to conduct a more rigorous investigation. This group conducted pre-disturbance surveys, collected sediment samples, and organized conservation facilities prior to the beginning of excavation.[223] Further artillery were uncovered, increasing the armament finds to 20 wrought iron cannons with their associated breech blocks. Compared to the number of cannons found on board, there was significantly less

[220] Fennel, 'Sardinia: Capo Carbonara', 331, fig. 1
[221] Martin-Bueno, 'Cavoli: A 15th century shipwreck off Sardinia', 31, 33-6.
[222] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 39-41.
[223] Martin-Bueno and Amare Tafalla, 'Remains of a Fifteenth-Century Spanish Ship Found in Sardinia', 86-8.

ammunition, which led researchers to conclude that the ordnance was the main cargo. Broken ceramics littered the site and connected two separate areas that earlier investigators suggested were from two separate wrecks lost together. Further analysis determined that the ceramics were from the same collection and that it was only a single wreck.[224]

The most significant find was the collection of colorful tiles with heraldic devices belonging to the Beccadelli family. This noble family served the Aragonese Crown throughout the fifteenth century and was later given the right to place their own coat of arms alongside the royal insignia. The tiles included only the Beccadelli family crest and signified a terminus ante quem before 1450.[225] Documents that mention the hiring of a master-tiler for the royal palaces in southern Italy and dating of other ceramics suggest the ship was lost in the 1440s. Together, these clues suggested the ship departed Valencia, Spain with its cargo of cannons and tiles, stopped in Mallorca to pick up a consignment of cotton, then sailed to Sardinia when it was lost in a storm against the rocks of Cavoli.[226]

This site yielded a significant artifact collection, but the remains from the hull were sparse (figure 28). Out of the entire 12 square meter area that covered the main deposit, only a small segment from the bottom after section of the ship survives. This section comprises the overlap between the floor timbers and futtocks without clear evidence about a transverse connection.[227] Most of the framing does not include scarf connections, only two possible floor timbers include potential dovetail scarfs. The accompanying futtock to one of these floor timbers

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[224] Martin-Bueno, 'Cavoli: A 15th century shipwreck off Sardinia', 32.
[225] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 80-2.
[226] Martin-Bueno and Amare Tafalla, 'Remains of a Fifteenth-Century Spanish Ship Found in Sardinia', 90-1.
[227] Martin-Bueno, 'Cavoli: A 15th century shipwreck off Sardinia', 32-3.

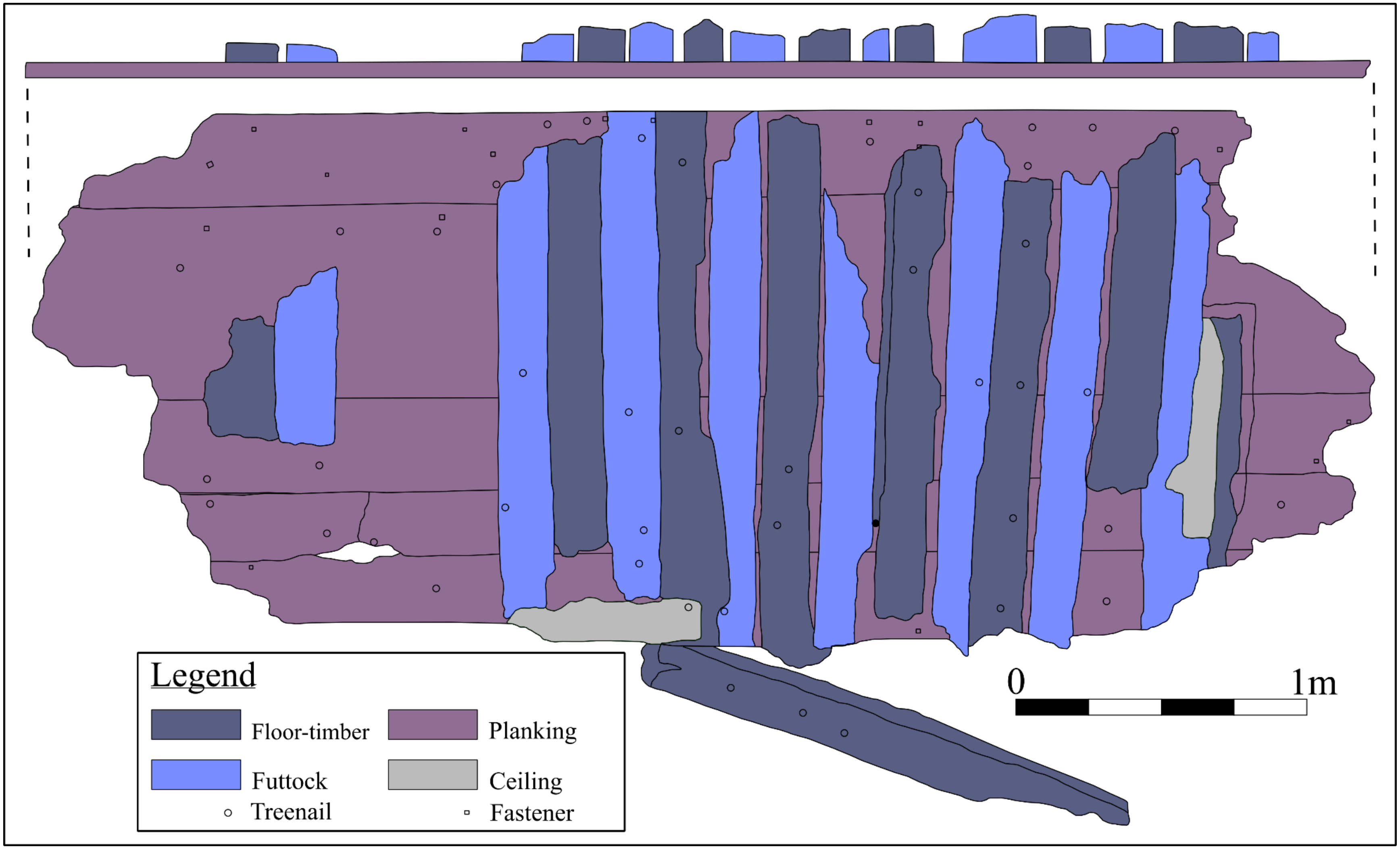

Figure 28 Hull remains from the Cavoli shipwreck. (after Martin-Bueno, La Nave de Cavoli, 64)

is recessed to accommodate half of this scarf, while the other shows no associated scarf (it was possibly a replacement). Framing is rectangular in section (thicker than wider), while the space appears to be the average width of each floor timber. Fragments from the ceiling suggest the planks ran longitudinally and were treenailed to the frames. Planking is an average thickness (5 cm) when compared to other vessels in this analysis, while it is fastened at each frame station using one or two nails and one treenail.[228] Each nail was clenched on the inside of the hull and the outside heads were covered with molten lead for protection. Dendrochronological analysis of wood samples indicated that the timbers came from a Spanish Mediterranean forest.[229]

Contarina I and II

Flooding of the Po river valley on Italy's Adriatic coast in 1882 emphasized the inadequacies of the canal network that was supposed to channel overflow away from cultivated areas. As a result, a consortium was formed for new reclamation works in the Polesano territory and to build new canals as part of this project. The main canal was to be built between the Fossa Polesella and Canalbianco and Po di Levante to channel water away from this area. The consortium hired the Trezza Company to carry out the canal excavations.[230] During construction of the canal in 1898, laborers working near Contarina, Italy uncovered the remains of two ships. Remains from both vessels were in surprisingly good condition with the first ship consisting of the hull below the waterline, while the second vessel consisted of a section from the side of the vessel and part of a deck. The significance of the ships prompted officials to suggest documenting the wrecks as part of the maritime history of the area.[231] Both ships were

[228] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 63-4.
[229] Martin-Bueno, 'Cavoli: A 15th century shipwreck off Sardinia', 33.
[230] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 12-13.
[231] Ibid., 14.

photographed in situ, disassembled, and to be transported to Venice for further study. It is unclear what happened to the original timbers, but accurate scale models of the hull structure were made and are now housed at the Naval Museum of Venice.[232]

Marco Bonino reviewed this information in 1978, suggesting that the coastline had undergone significant silting up of the Po river delta over the centuries. He speculated that, based on the few finds associated with the two wrecks as well as its construction features, Contarina I was lost around 1300 and the second Contarina wreck was from the middle of the sixteenth century.[233] Bonino's dates for both wrecks were accepted in nautical archaeological circles for several decades, due to the dearth of comparative archaeological material. In 2009, Carlo Beltrame (with advice from Mauro Bondioli) revisited the same data that Bonino reviewed and agreed that the siltation of the Po River delta was extensive, but the buildup did not transpire as quickly as Bonino claimed. Ceramic sherds, a fork, shears, and a hook-chainplate for a lateen rig associated with the second ship were reexamined and dated to the second half of the fifteenth or the early sixteenth century.[234] This dating falls within the same estimate originally proposed by Occioni-Bonaffons, who wrote the original report on both wrecks in 1901.[235] Contarina II was discovered closer to the Adriatic than the first vessel with 290 m separating the two sites. Since Contarina I was found further inshore without associated artifacts, Beltrame suggests that the wreck was probably lost a few years earlier.[236]

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[232] Ibid., 20-2.
[233] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 13, 8
[234] Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 412
[235] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 44-5.
[236] Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 415

Contarina I has a rectangular shallow keel (figure 29). Neither the keel nor the endposts include rabbets. All of the axial timbers simply butt against each other without any scarfs. The ship is double ended with rounded stem and sternpost, both include a thicker section at the junction between the flat floor and upward turn.[237] Framing consists of floor timbers that overlap without any scarf to the futtocks. A single master frame with dual futtocks was placed amidships. All of the framing elements were square with roughly the same space between each frame station. Floor timbers are fastened with three round nails to the futtocks. There is no mention of any bolts securing the floor timbers, instead bolts driven through the keelson are clinched on the outside keel face.[238] The keelson was only rebated over the central section of the hull, this feature disappeared at the extremities.[239] Two mast steps were created over the keelson, one near the bow and another further aft. Floor timbers associated with the two mast steps were originally molded with additional thickness creating a tooth-like profile or built-in buttresses that supported lateral mast-step partners and chocks that sat over the keel creating the mortise.[240]

The overlap between floor timbers and futtocks was reinforced by a single bilge stringer and fragments visible in the original photos indicate longitudinal ceiling.[241] Presence of bilge keels suggests this vessel operated in shallow water environments that required offloading near shore. Planking thickness reflects the general medium size of the vessel, and each frame station included four iron nails without any use of treenails. Overall, the ship had a flat floors with a round bilge.

[237] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 24-6.
[238] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 13-15
[239] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 27.
[240] Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 413
[241] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 13, fig. 3

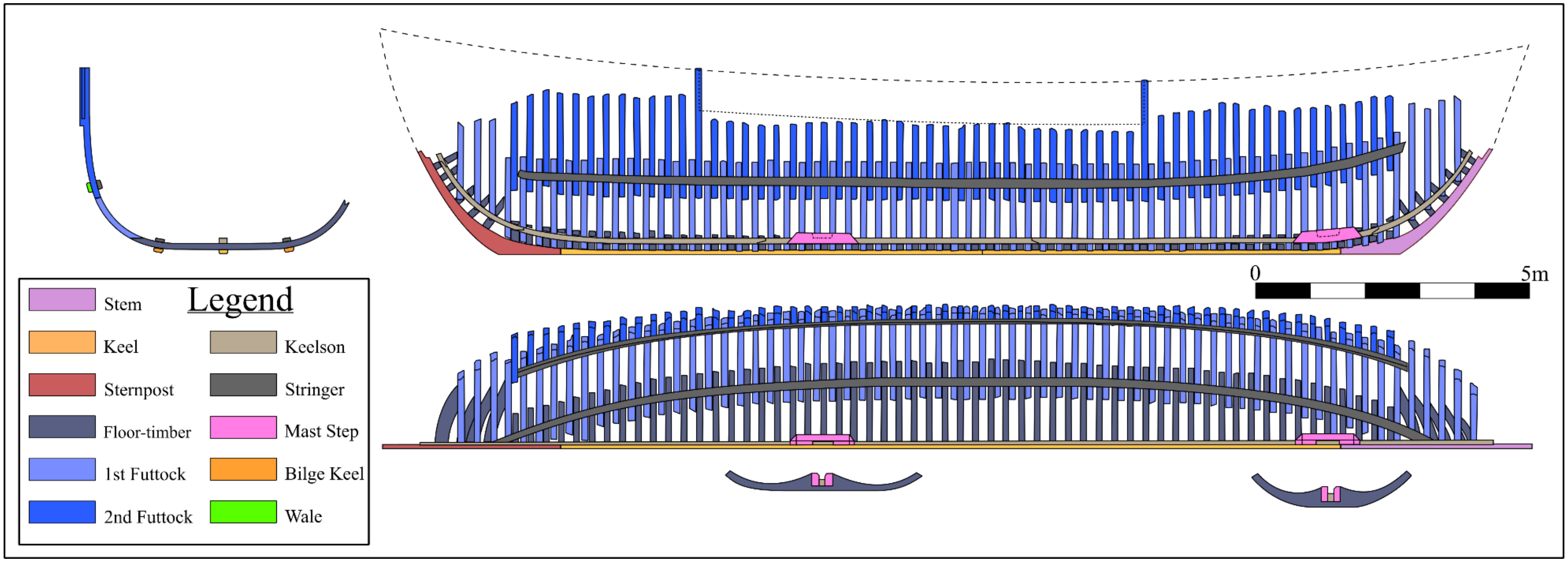

Figure 29   Site plan for the Contarina I shipwreck. (after Bonino, 'Lateen-rigged medieval ships', 14)

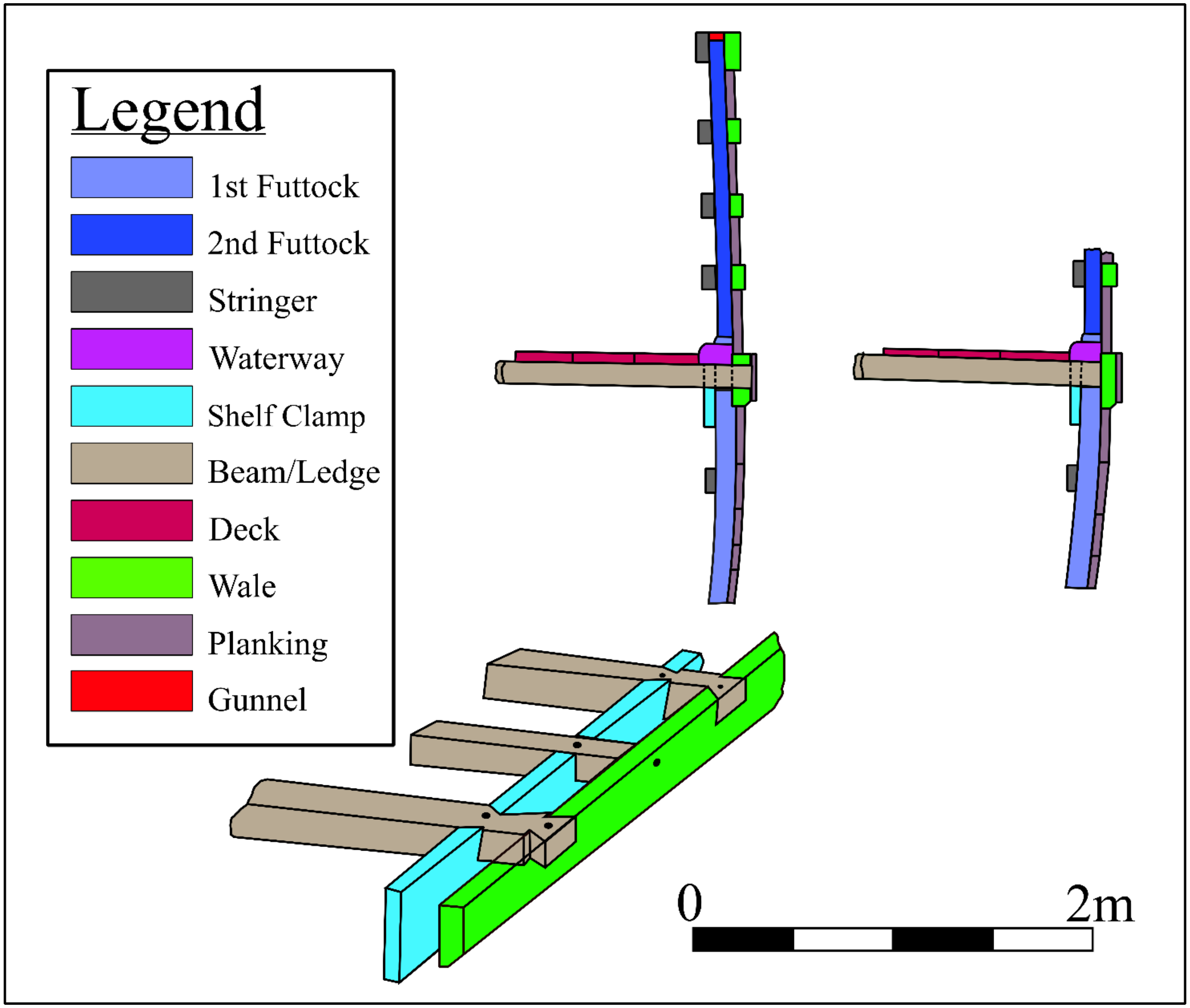

Figure 30 Profiles from Contarina II showing the different connection between the beams and ledges with the shelf clamp and lower wale. (after Bonino, 'Lateen-rigged medieval ships', 18)

For most ships in this dissertation the archaeological evidence consists of the lower hull structure, while Contarina II is a rare example from the upper section (figure 30). Surviving elements from floor timbers and futtocks suggest a non-scarfed overlap fastened together with two round iron fasteners.[242] The framing is square and slightly lighter when compare to Contarina I. Spacing between the upper futtocks is twice the sided dimension (10 cm) for each timber. Several stringers are present, one below the shelf clamp and four above. Several vertical hook scarfs were identified connecting adjacent elements of the stringers together. Planking thickness is mixed with thicker strakes (5 cm) used below the waterline and slightly thinner (4 cm) examples above.[243]

At least two wale strakes were identified that were positioned outboard of the internal stringers. The surviving deck included a thin (4 cm) shelf clamp fastened with two nails per frame station and bolted to an outside wale. Between every third futtock was a beam that fit into a rebate on the shelf clamp and dovetailed into the outside wale. Iron nails fastened the beam to the shelf clamp and wale from above.[244] Ledges are rebated into the shelf clamp, but butted the outside wale, while their opposite internal end is dovetailed into the carlings. Similar to the beams, the ledges are fastened vertically to the shelf clamp and nailed horizontally from the outside. A waterway fit above the shelf clamp and there does not seem to be a sill or filler pieces inserted between futtocks. Ends of the lower futtocks appear to extend beyond the deck and are exposed without bulwark planking covering this area. Deck planking is a similar thickness to the

[242] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 35-6.
[243] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 18, fig. 7
[244] Ibid., 20.

shelf clamp and upper strakes that comprised the outside of the hull.[245] Based on the surviving images of Contarina II, the ship presumably had a flat floor and round bilge.

Mariposa A and B

Anthropogenic changes along northwestern coast of Sardinia near Alghero, Italy revealed the remains of a shipwreck in 1988. The wreck was situated a few meters from shore in 2 m depth along the beachfront known as “La Mariposa”. Initial investigations suggested a significant amount of the hull survived and a collaboration between the Archeosub Sassari-Alghero Research Center and the Superintendency for Archaeological Heritage in Sassari and Nuoro resulted in a two-year excavation.[246] Over the course of the first field season (begun in the same year of the wreck’s discovery), investigators found that the preserved hull contained organic objects with significant preservation. Sections of rope, several wooden barrels carrying sardines, a limited amounts of ceramics, and other objects like whetstones and leather shoes were retrieved.[247] During a violent spring storm the following year, the shifting sea bottom revealed two other wrecks in the same area.

Much of the first season on what became known as Mariposa A focused on the bow and amidships area (figure 31). The second season excavated the stern, while the remainder of the fieldwork also focused on briefly surveying the other uncovered remains (known as Mariposa B and C respectively). The artifact collection from Mariposa A suggests the ship was lost toward the end of the fifteenth or early sixteenth century.[248] From the location and construction of the hull, it appears the ship was anchored in shallow water away from Alghero and was lost in a

[245] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 36-7.
[246] Riccardi, 'Evidenze archeologiche di imbarcazioni dell’età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 279-80
[247] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 134.
[248] Rovina, 'Interventi di archeologia postmedievale nella Sardegna centro-settentrionale', 260.

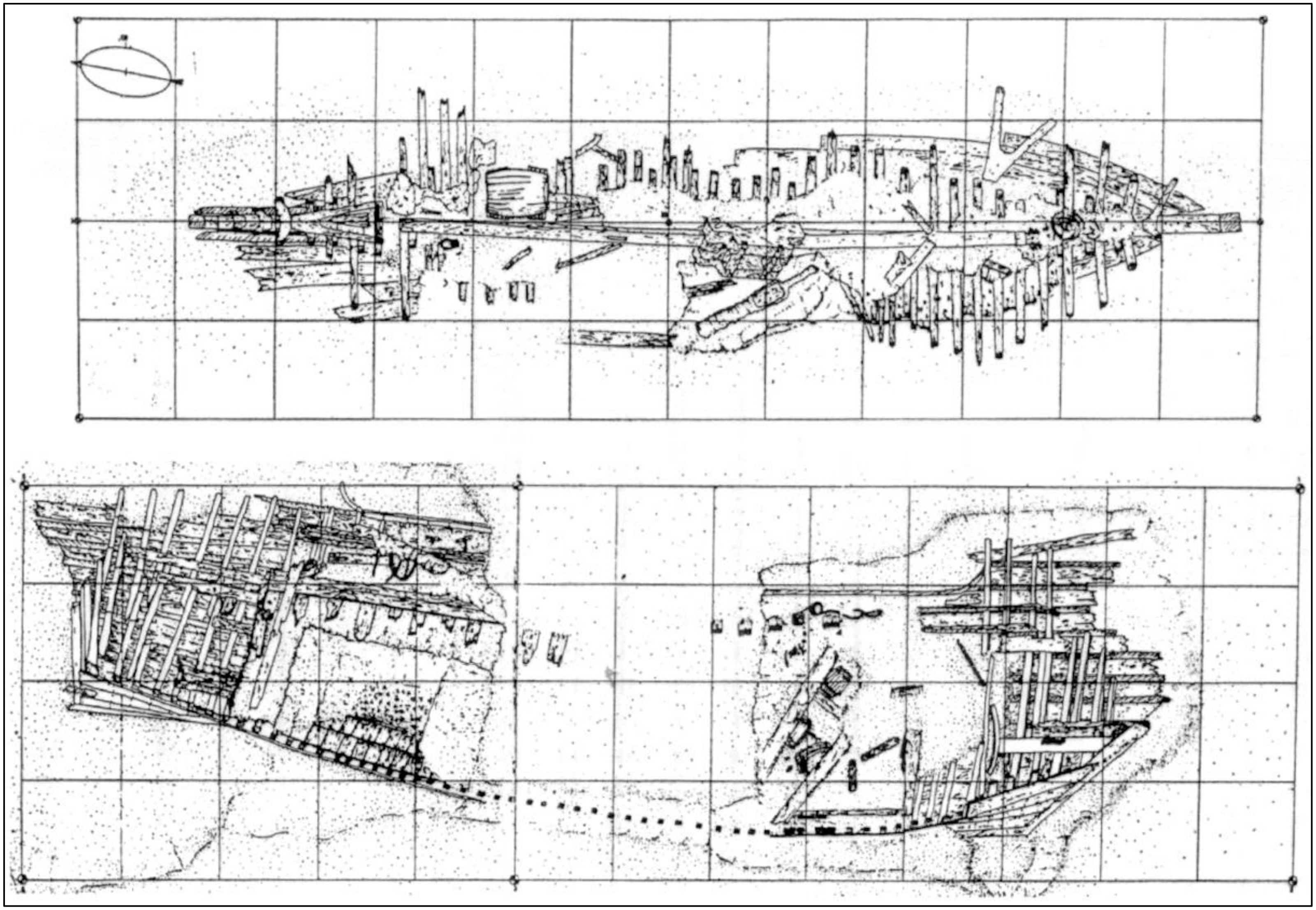

Figure 31 Site plans for Mariposa wrecks B (above) and A (below). (after Beltrame, 'Investigating Processes of Wreck Formation', 385)

storm that quickly buried the remains. The portside, largely consisting of hull, is a modest sized ship that included two types of steering methods. Surviving elements of a gudgeon were found on the lower sternpost and a quarter rudder was also located still tied in its original position.[249] Several tools found amidst the wreck suggest there were attempts to recover the ship or its cargo before it was abandoned. One of the planks had a bas-relief arch motif ending with an apotropaic eye originally covered in pitch. Based on the construction, investigators suggest Mariposa A was a round ship called a carrack or *nao*.[250]

Mariposa B is located 60 m from the first wreck and its own preliminary excavation to collect artifacts for dating purposes began in 1990 with a systematic uncovering of over 100 square meters. Archaeologists recovered ceramics exhibiting various levels of workmanship, significant quantities of rope, unidentified leather pieces, and two bronze compasses located in the stern. Other items included a thin fishing net, pieces of a sail, and the remains of several firearms.[251] Earlier plans to conduct a full excavation of Mariposa A were cancelled due to the high amount of organic material that overwhelmed the conservation lab. Instead, a total excavation of Mariposa B began in 1994 with plans for the possible recovery of the hull afterward.[252] Mariposa B sank almost with a level keel on the seafloor, providing hull remains from both sides past the turn of the bilge.

Ceramics found on both wrecks suggest Ligurian and Pisan origins, including Po-Emilian products represented by graffiti mugs found on Mariposa A. Surviving elements from an

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[249] Gavini, 'Osservazioni sulla circolazione dei manufatti ceramici in periodo medievale e postmedievale da una analisi dei relitti di Alghero', 76.
[250] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 280
[251] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 134.
[252] Gavini, 'Osservazioni sulla circolazione dei manufatti ceramici in periodo medievale e postmedievale da una analisi dei relitti di Alghero', 77.

achromatic pitcher found on Mariposa B are known throughout Spain as a type used for carrying water that is cooled by evaporation from the porosity of the ceramic. This particular pitcher originates from the southern Spanish coast in the areas of Córdoba and Málaga.[253] Initial assessments suggested Mariposa B was slightly later than Mariposa A, but more recent publications conclude these ships may have sailed together.[254] Origins of ceramic production do not necessarily indicate where the ships were built, but it may suggest sailing destinations or the migratory nature of the ships and their sailors.

Due to the significant degree of preservation found on Mariposa A, only the bow and stern structure were extensively recorded, and a detailed report is still awaiting future publication. The ship relied on axial timbers incorporating a keel, round stem, and straight sternpost.[255] Framing includes floor timbers that overlap with futtocks. The upper ends of the first futtocks overlap with surviving elements of the second futtocks. Elements from a bilge stringer are present over the floor timber and first futtock connection with ceiling on either side. The outside of the hull had thin planking (3-3.5 cm) from the keel to the top of the sternpost, before alternating with half-log wales between each strake. Planks are connected to the hull using a combination of iron fasteners and treenails.[256] The modest size of the ship suggests it had a single deck; evidence of the weather deck was recorded above the unexcavated remains of barrels and other organic cargo. Since the ship ended up on its portside and was quickly buried, segments of the gunnel remain intact, including important curved sections indicating the ship had

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[253] Ibid., 79.
[254] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 282
[255] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 131-2.
[256] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 280-1

castles at either end. The aft planking also provides evidence of the height of the missing stern panel and the counters that extended the sterncastle over the sternpost.[257]

Mariposa B was also axial based with a keel, round stem, and straight sternpost that extended from the keel at an 80° angle. A section of false keel was noted toward the bow following the same sweeping curve of the stem. Framing includes dual master floor timbers that overlapped, and were hook scarfed to the futtocks. This overlap was strengthened with four iron nails driven through the frames with the tips clenched on the opposite side.[258] Floor timbers are relatively square, except at either end, where there is clear use of a rising tablet to create the entry and runs. Space between frame stations suggest double or triple the width of the average floor timber. The recessed keelson was bolted through the floor timbers to the keel. There is a mast step atop the keelson amidships with two rebated mast partners on either side connected with dovetailed tenons.[259] Wedge shaped chocks rest on top of the keelson created the mortise for the mast. No clear evidence for buttressing the mast step is seen on the site plan or excavation photos. This mast step is different from others described in this chapter, due to its square shape that is similar to the purported *Woolwich*.[260]

Bilge stringers on either side of the hull covered the lower framing overlap, and ceiling ran longitudinally between this timber and the keelson. Planking was similar to Mariposa A, with the same thickness and the alternating upper half-log wales and plank strakes.[261] Toward the stern, there is clear evidence for a lower wale (often called a *massane*) that extends from the

[257] For best published image of site plans for either wreck, see: Beltrame, 'Investigating Processes of Wreck Formation: Wrecks on the Beach Environment in the Mediterranean Sea', 385, fig. 6.
[258] Virgilio Gavini, pers. comm.
[259] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 134, 136, fig. 9.
[260] Salisbury, 'The Woolwich Ship', 85-6, fig. 1; Philip and Garrod, 'The Woolwich Ship', 88-90, fig. 1
[261] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 281

sternpost amidships. Planking was fastened to the hull using a single iron nail and one or two treenails per frame station. Remains of a gudgeon concreted to the sternpost suggest a stern mounted rudder was the preferred steering mechanism.[262]

An unusual element to this ship is the presence of a circular hole through the hull several meters forward of the sternpost. It appears that a log with a hole cut through the center was laid horizontally between the after Y-timbers. Planking was fashioned on either side to accommodate the log, while the hole drilled through is covered in pitch. Two wooden plugs were inserted on both ends of the hole and caulked so that they sealed any access.[263] Initial analysis of this construction suggested that it was related to the quarter rudders that were abandoned at a later stage in the ship’s life for the stern rudder. The overall shape of the ship, with a flat floor and round bilge, is altered at the stern with the Y-frames presenting an abrupt widening of the futtocks directly above the hollowed-out log and would prevent a quarter rudder connection. A similar system is also present on the eighteenth-century Dramont H shipwreck, although the excavators were also unsure as to the use of this element.[264] The positioning of the hole on both wrecks is presumably associated with removing the vessels onto shore, either for maintenance or during the winter season. This might explain why the hole is always placed toward the front end of the deadwood, as this is a highly reinforced area for pulling directly aft. On the other hand, drilling a hole through the keel would presumably make this operation much easier and was used on earlier Yenikapı vessels.[265]

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[262] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 135, fig. 8.
[263] Gavini and Silvetti, 'Alghero-La Mariposa: Relitto “B”. Nuovi elementi costruttivi sui resti di una nave della fine del XV secolo', 154-5
[264] Joncheray et al., 'L'épave Dramont H. Un naufrage de la seconde moitié du XVIII[e] siécle', 50
[265] Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 262.

Lake Garda

Over most of its initial existence, Venice operated as thalassocracy focused almost exclusively on controlling the Adriatic and the eastern maritime trade routes. In the fourteenth century, the Serenissima began involving itself in northern Italian politics and acquired extensive territorial control of that region. Venetian nobles took advantage of these conquests by diverting family funds into land holdings rather than new maritime pursuits.[266] Although Venice never abandoned its maritime trade, the expansion of its territorial holdings changed the character of the nobility to focus more on agricultural production than overseas trade. At the same time, Venice also played into the Italian mindset that no major power in the peninsula should build up enough control to dominate the rest.[267] As a result, the Venetians sought to break other coalitions aiming to undermine its territorial hegemony. By the beginning of the sixteenth century, Venice found itself in a major conflict, as Pope Julius II (1503-13) orchestrated the League of Cambrai. The league was initially composed of France, the Holy Roman Empire, Spain, and the Duchy of Ferrara to regain control of territory lost by the Papal States.[268] This conflict was one of many that took place during the half-century long Italian Wars (1494-1559), where various groups fought for control of the Italian Peninsula.

In 1508, the Venetian Senate ordered Zaccaria Loredan to the Lazise arsenal along the southeastern coastline of Lake Garda. The arsenal is believed to have existed since the beginning of the fourteenth century, as documents described it as the location for vessels belonging to the

[266] Lane, *Venice: A Maritime Republic*, 226-7.
[267] Fubini, 'The Italian League and the Policy of the Balance of Power at the Accession of Lorenzo de' Medici', 183, 193-94
[268] Finlay, 'Fabius Maximus in Venice: Doge Andrea Gritti, the War of Cambrai, and the Rise of Habsburg Hegemony, 1509-1530', 990

Scala of Verona.[269] Loredan, reported that only a single galley and two *fustas* (foist) were present at the Lazise arsenal. His attempts to secure Lake Garda against the League were only nominally successful, as the associated land forces were unable to defend the surrounding cities. The Senate eventually decided that the Lake Garda position was untenable and instructed Loredan to destroy the ships and return to Venice. He carried out the instructions on 31 May 1509, filling up the galley and one of the two *fustas* with ballast and lighting them on fire several hundred meters from Lazise.[270]

For the citizens of Lazise, the knowledge of where the ships were burned never faded from their memories. Fishermen noted the location of at least one vessel to avoid entangling their fishnets. Count Vittorio Cavazzocca Mazzanti wrote an article in 1931, possibly relying on notes first written down by Francesco Fontana on markers along the shoreline describing the location of the ships.[271] Over the first half of the 20th century, various groups visited the site of a wreck that was assumed to be the galley that Loredan burned. Francesco Zorzi, associated with the Civic Museum of Natural History of Verona, presented research about Lake Garda in 1957.[272] He worked alongside Enrico Candurra, a diver who reportedly located a shipwreck in 1962, to retrieve artifacts and to plan the lifting of the entire hull for display.

Other than clearing sediment covering the surviving hull and retrieving several artifacts, the project was abandoned by 1968 because of disagreements on who would house the hull remains.[273] Beginning in 1990, the shipwreck was revisited by archaeologists with additional fieldwork taking place in 1996, 1998, and 2003. Artifacts retrieved during the excavations

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[269] Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 10.
[270] Capulli and Fozzati, 'Le navi della Serenissima, archeologia e restauro (XIII-XVI sec.)', 241.
[271] Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 23.
[272] Ibid., 25.
[273] Ibid., 28, 32.

included a small collection of ceramics, a hook chainplate (indicating the use of a lateen sail), and various fasteners found strewn about the hull.[274] When compared to contemporary documents, the overall length of the vessel indicated that it was not a galley and was instead the *fusta* burned at the same time by Loredan.

The archaeological work on the wreck yielded significant information about its construction, but the wreck was not disassembled, which limited access to the keel (figure 32). This element is rabbeted over its length and its shape is rectangular. The forward end of the keel curves upward to meet the missing stem. A stemson is bolted directly above this section.[275] There was even less preservation at the stern, which was missing the sternpost. A single master frame, composed of a floor timber and dual futtocks on either side, is placed on the center of the keel. Framing is composed of floor timbers that overlap with the futtocks without a scarf joint. This overlap is secured with three iron fasteners driven horizontally between the framing elements. Dimensions for the floor timbers suggest a lighter build and are square in dimension at amidships.[276] There is a rebated keelson along the centerline of the ship that is bolted to the keel through the floor timbers. Archaeologists also note that there is a difference in the nailing pattern used to secure the keelson scarfs. From the bow to amidships, these scarfs are secured with two fasteners, while the remainder uses only a single nail.[277]

Bilge stringers recessed to fit over the frames are situated at the turn of the bilge at the overlap of the floor timbers and futtocks. Ceiling is composed of irregular longitudinal strakes between the keelson and the bilge stringer.[278] The mast step is positioned toward the center of the

[274] Ibid., 69-75.
[275] Ibid., 109-14.
[276] Ibid., 106-9.
[277] Ibid., 101-3.
[278] Ibid., 35.

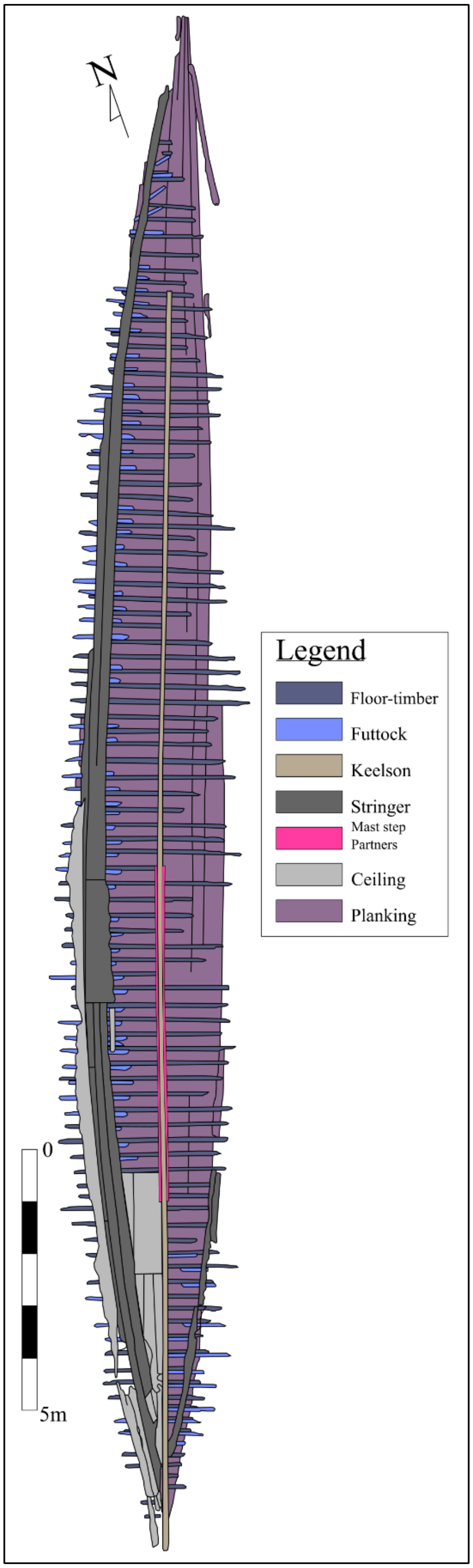

Figure 32   Site plan of the Lake Garda wreck. (after Capulli, Le navi della Serenissima, 35)

ship and is created with two long trapezoidal mast partners rebated over the frames on either side of the keelson. Each mast step partner is supported by buttresses affixed to underlying floor timbers. Two long chocks are positioned over the keelson to create the central mortise where the heel of the mast was inserted.[279] Planking is thinner than seen on other ships and might be related to the overall dimensions of the hull. Isometric reconstructions of a typical late fifteenth-century longship suggest that wales positioned near the waterline were recessed over the futtocks to reinforce the futtocks, although it remains unclear whether physical evidence was found on the Lake Garda hull.[280] This recessed system was presumably part of an overall support strategy to prevent hogging of the long narrow hull.

Villefranche

Villefranche-sur-mer became the French Mediterranean port of call for foreign ships in the nineteenth century. The dredging of the port to accomodate the increase in maritime traffic likely destroyed many early wrecks. Fortunately, not all of them were lost. In 1979, diver Alain Visquis stumbled across the remains from a shipwreck near the center of the harbor.[281] Archaeologists began excavation in 1982 and continued over the next nine years to systematically remove the overburden, uncovering a significant assemblage of artifacts and hull structure. Coins and Nuremburg tokens provided an initial 1503 terminus post quem for the site. This observation was supplemented by ceramic sherds from a majolica cup attributed to a Montelupo workshop in Tuscany; similar surviving examples of this cup portray an image of

[279] Ibid., 109.
[280] Ibid., 87.
[281] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 38.

Pope Julius II, pushing the date further forward to 1509.[282] Fish spawning pits on the wreck also suggested that it was lost in late summer.

Between a combination of ceramics, finding an overlapping growth of tree species from the same area identified in the hull components, geologic studies of the ballast, and chemical analysis of brucite (magnesium hydroxide) from a cannon, investigators found the origins of most of these components concentrated around Genoa.[283] Both a majolica fragment and a surviving section of an arquebus butt also displayed the Genoese Fregoso family crest. Delving into the Genoese archive, researchers were able to find several accounts about a ship lost in 1516 while anchored in Villefranche.

In that year, the Genoese round ship *Lomellina* entered Villefranche-sur-mer. As mentioned above regarding the Marinières shipwreck, this port and Nice were the Duke of Savoy's main connection to the Mediterranean at beginning of the sixteenth century.[284] The former continued to grow in importance during the Italian Wars (1494-1546) for shipbuilding, careening, and as a good location for offloading French or Spanish armies and military supplies that utilized the Ligurian coastal road network into Italy.[285] On 15 September 1516, a fierce storm arose that damaged multiple buildings surrounding the Villefranche harbor and the nearby fortified walls of Nice.[286] Several ships anchored in Villefranche were also reported damaged from the storm and contemporary accounts listed the *Lomellina* among those that sank. Local salvors immediately descended upon the wreckage to recover anything of value. Roughly a week

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[282] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 127
[283] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 40-1; Guérout, 'Epave de la Lomellina (1516) - La soute à poudre', 4-6.
[284] Braudel, *The Mediterranean and the Mediterranean World in the Age of Phillip II*, 573.
[285] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 133
[286] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 41.

after the disaster, the Genoese ruling council was informed of the *Lomellina's* loss and illegal salvage. Letters were written to the rulers of Nice condemning the looting and arrangements were made for a sanctioned recovery of the artillery that the ship was carrying.[287] A visitor to the harbor two years later mentioned that the masts from the wreck still extended slightly above the waterline. Additional salvage work by locals in 1531 suggests the original recovery was incomplete; the materials from this latest attempt were ultimately confiscated by local authorities.[288]

Since its archaeological investigation throughout the 1980s and early 1990s, *Lomellina* remains one of the best archaeological studies of Renaissance-era Mediterranean shipbuilding (figure 33). The keel elements attached to the surviving hull structure remain intact and show a tall, rectangular profile. Between the main hull structure and the stern there is a missing section of the hull, but what has survived indicates that the keel is rabbeted throughout.[289] Toward the bow, the keel is hook scarfed to the stem, while it butted the heel timber. Only a short fragment of the stem survives and shows a rounding curve on its forward end with dimensions similar to those of the keel.[290] The heel timber that survives increases the molded dimension of the keel toward the end of this component (figure 34).

Part of the main sternpost survived and the only evidence of it is on the heel timber, where the back end is rebated at 75-78° as half of a scarf.[291] The bottom half of the scarf rests over the skeg built into the heel timber. Remnants of a stern rudder provide evidence for the steerage system. The rabbet terminates forward of the upper arm of the heel timber. Rebated into

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[287] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 137-9
[288] Ibid., 139, 143-45.
[289] Ibid., 23.
[290] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 41.
[291] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 28-9

the top face of the heel timber is the bottom of the stern knee. On the forward end of the stern knee is half of a hook scarf, suggesting this timber continued forward covering the butt seam between the heel timber and keel.

Framing consists of floor timbers dovetail scarfed to futtocks and upper futtocks also scarfed together (figure 35). Lower scarfs were cut with the widest part of the dovetail shape either on the inboard or outboard faces of the frames, depending on the frame station. Upper futtock scarfs are not consistent, as archaeologists record half, single, dovetail, double dovetail, or no scarf. These connections are all secured with two round iron nails. Except for the master frame with dual futtocks on each wronghead, all futtocks are attached on the floor timber face toward the center of the ship (most other archaeological examples are the opposite).[292] Scantlings emphasize a rectangular shape for all frames, specifically because the ship has a wineglass form with deadrise at the master frame. Space between frame stations varies between two to three times the width of the widest floor timber. Every other floor timber is bolted to the keel, except the frame stations surrounding amidships and the placement of the mast step, which are all fastened. Frame station W70 toward the stern, one of the last surviving lower hull assemblies, is bolted to the keel twice.[293]

The keelson is recessed over the frames only in the center of the hull and not at the ends. The garboard for the *Lomellina* is a much thicker plank that was carved to fit once it was placed in position. At least one section of the garboard is fastened to the keel and counter keel with round nails. Investigators question whether the keel and garboards were assembled together prior to adding any frames to the axial timbers.[294] Lower strakes are slightly thicker (12 cm) than those

[292] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 43.
[293] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 42
[294] Ibid., 62-3.

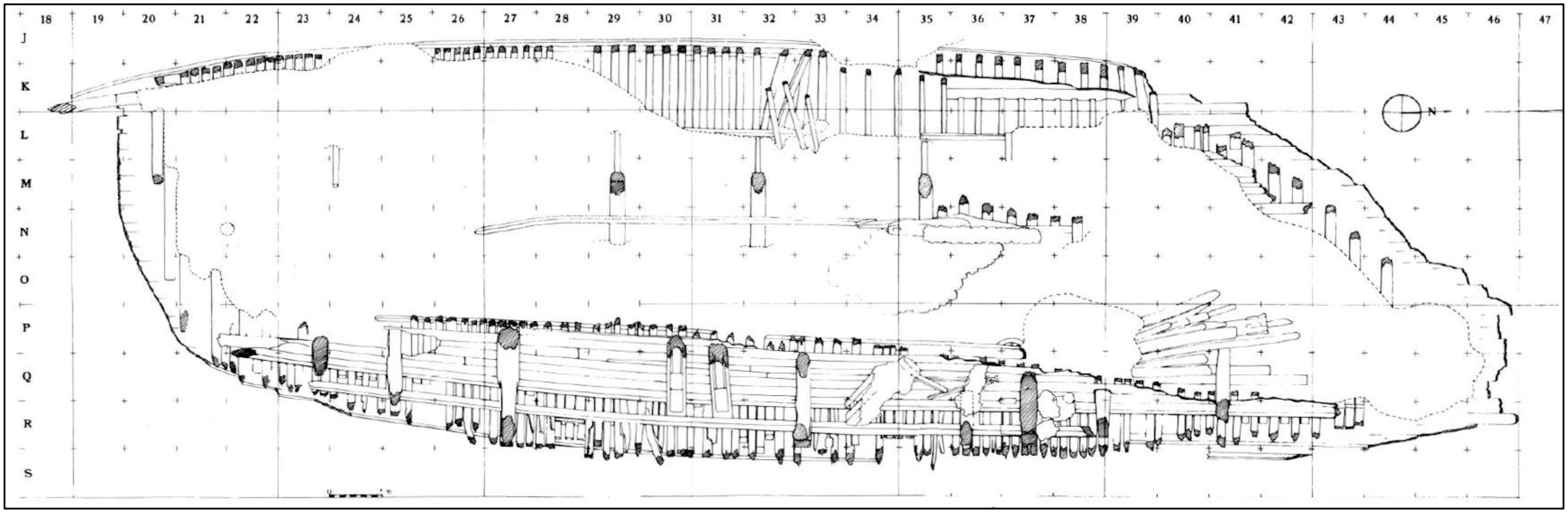

Figure 33 Site plan of the Villefranche shipwreck. (after Guèrout et al., 'Le navire Génois de Villefranche', 20)

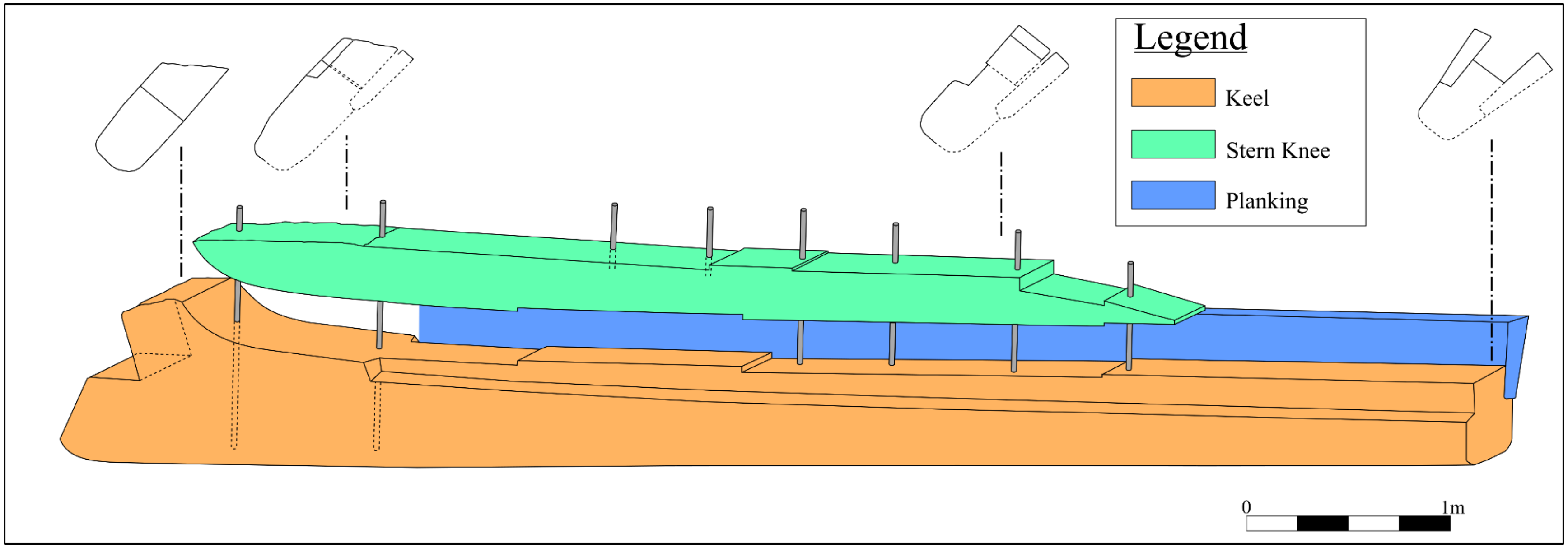

Figure 34   Stern assembly of the Villefranche shipwreck. (after Guèrout et al., 'Le navire Génois de Villefranche', 24)

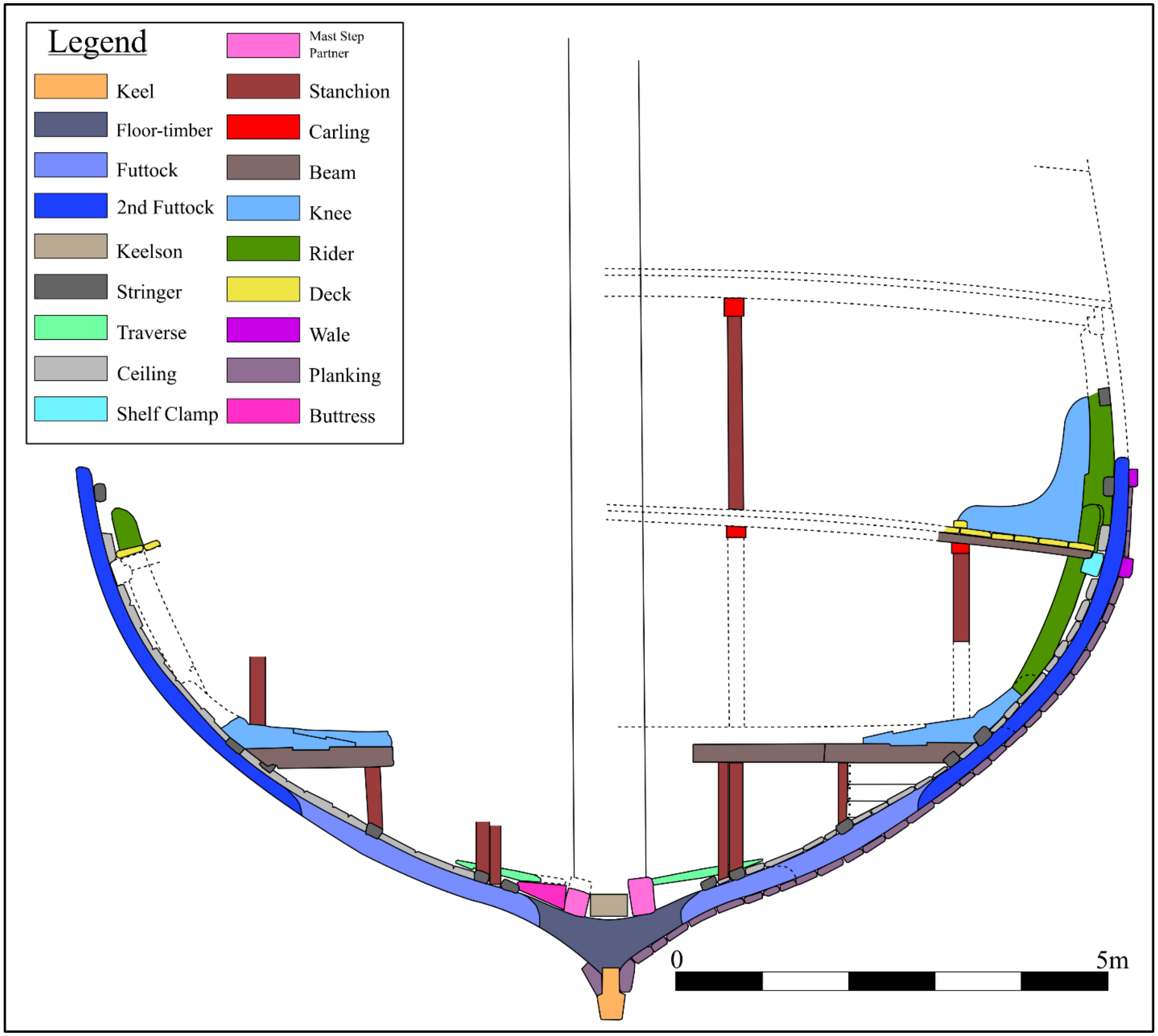

Figure 35 Profile of frame station W 70 toward the stern from the Villefranche shipwreck. (after Guèrout et al., 'Le navire Génois de Villefranche', 93)

closer to the waterline (10 cm), while the deadworks consists of planks half their thickness (4-5 cm).[295] Each strake is attached to the frames using two or three iron nails and there is no evidence of treenails. Both the interior and exterior of the hull were covered in pitch, while the keel and garboards were also covered in a brown mastic material and vegetable tow. Lead sheathing is also present protecting the keel and garboards.[296]

Due to the excellent preservation, which includes most of the portside of the hull, several consecutive stringers survive. The pattern for stringers is that two cover the overlap either between the floor timber to first futtock or the crossing of upper futtocks. Near the center of each set of futtocks is a single stringer for reinforcement. All stringers are rebated like the keelson to increase longitudinal support.[297] Longitudinally oriented ceiling is spiked to the frames between the stringers from the keelson up to the main deck. The mainmast step consists of two mast step partners resting on either side of the keelson without any recesses to fit over the frames. The top face includes two dovetail rebates for keys to connect the mast step partners together. A series of rebates are also present for riders and ledges to cover this area and create a raised platform with longitudinal planking. Eight mast-step buttresses sit over accompanying floor timbers with their outboard ends supported by the lowest stringer and the opposite rest against the faces of the mast step partners. The mortise for the mast is created with the space between the two keys and the installation of a chock to fill the gap left over after the mast was installed.[298] A pump well

[295] Ibid., 63-7.
[296] Guérout, 'Epave de la Lomellina (1516) - Doublage de la coque', 3-5.
[297] Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 43.
[298] Rieth, 'L'emplanture du grand mât de l'épave du début du XVIème siècle de Villefranche-sur-Mer: Un exemple d'emplanture de tradition méditerranéenne', 180-1; Guérout, 'Epave de la Lomellina (1516) - L'emplanture du grand-mât', 11-12.

surrounds this area for protection, along with a similar enclosed area further aft to protect the pumps.

Based on the surviving remains, it is believed that *Lomellina* had three decks with the orlop consisting of only heavy beams rebated into shelf clamps. Several beams also had an additional standing knee resting above that was hook scarfed into a secondary beam that crossed the hull. The knee included a longer arm that ran over the ceiling up the side of the hull. The orlop deck does not appear to be planked, as some of the stowed cannons were tied to the exposed beams.[299] An internal reinforcing castle rider covered the ceiling and overlapped with the upper arms of the orlop knees. The castle riders went through the next deck and are only found at the bow and aft of midship. Lower castle riders were then replaced with another set of robust knees situated on the main deck.[300] The main deck consists of beams and ledges, dovetailed into shelf clamps covered with longitudinal planking. Whereas the orlop deck beams were simply fitted between the two lower stringers, the main deck consists of the shelf clamp and a waterway covering the dovetail connection.[301] Since the ceiling continues from the keelson up to what remains of the main deck, it is unclear if any sill or filler pieces were inserted between futtocks at each deck to seal off access to the bilges. Each deck was held up by a system of stanchions mortised into floor timbers, stringers, or deck knees depending on the location.

Mortella III

Interest in mapping the submerged Corsican coastline led France’s Department of Subaquatic and Submarine Archaeological Research (Département des Recherches Subaquatiques et Sous-Marines - DRASSM) to collaborate with the Center for Study in Nautical

[299] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 48-9
[300] Guérout, 'Epave de la Lomellina (1516) - Structures internes de soutien des châteaux avant et arrière', 3-7.
[301] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 54-8

Archaeology (Centre d'Etudes en Archéologie Nautique – CEAN) on a remote survey in Saint-Florent Bay between 2005-08.[302] In October 2005, the CEAN team located a ballast mound dubbed Mortella II, and subsequently found Mortella III 38 m to the south of the ballast mound the following month. Mortella III became an ideal candidate for further investigation, as Mortella II was a smaller mound at a much deeper depth (48 m). Preliminary surveys of both wrecks revealed evidence for anchors and wrought iron cannons that suggested a date at the end of the fifteenth or beginning of the sixteenth century. Full-scale excavations on Mortella III began in 2010 and continued intermittently (2012, 2014, 2015) over the next several years with the last season concluded in 2019.[303] The CEAN team has wrapped up excavations on Mortella III and are now turning their attention to Mortella II.[304]

The depth and open position of Saint-Florent Bay protected both ballast mounds over the centuries. Nevertheless, it was clear during the excavations on Mortella III that the ship was stripped before it sank of any artifacts, possessions, or other materials besides its anchors and armaments. The small collection of ceramics recovered from the hull indicated that many of the artifacts were Ligurian manufacture from the first half of the sixteenth century.[305] This analysis seems to support the original dating for the wrought iron guns found on the wreck. Geologic studies of the ballast from both Mortella wrecks found that the ships shared a similar source for this material.[306] What Mortella III lacked in artifact assemblage, it made up in the amount of

[302] Cazenave de la Roche, 'The Mortella II & III Wrecks: Preliminary observations on two 16th-century archaeological sites discovered in Saint-Florent Bay, Corsica, France', 69-71

[303] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 89; Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 16.

[304] Arnaud Cazenave del la Roche, pers. comm.

[305] Cazenave de la Roche, 'El pecio de la Mortella III (Córcega, Francia): Un aporte al conocimiento de la arquitectura naval del siglo xvi en el Mediterráneo', 856-8.

[306] Cazenave de la Roche, 'Les épaves de la Mortella II & III: Observations préliminaires sur des sites archéologiques de la période de la renaissance découverts dans la baie de Saint-Florent (Hte Corse)', 31.

preserved hull structure. Dendrochronological samples from different components proposed an origin in northern central Europe (possibly around Burgundy), while the dating from several layers of unremoved sapwood suggest a felling date for the timbers between 1517 and 1520.[307]

Archival work in Spain, France, and Italy focused on documents that might mention ships lost in Saint-Florent Bay in the first half of the sixteenth century. After reviewing several possible identities for the Mortella vessels, the best fit was that of two Genoese ships wrecked in 1527.[308] The Italian Wars (1494-1546) at this moment pitted a French coalition called the League of Cognac that included the Pope, Venice, and the Genoese Admiral, Andrea Doria, against the Spanish Imperial forces and their ally, the Genoese Doge, Antonitto Adrno.[309] Leading the naval forces for the League of Cognac, Doria managed to blockade Genoa from the sea, while allies also began cutting off all land routes. This encirclement caused starvation in the city and led to several merchantmen sent in search of grain across the Mediterranean. Two round ships, the *Ferrara* and *Boscaina*, were sent to Sicily to obtain grain and were apparently successful in securing supplies before attempting to return to Genoa. Neither ship passed the blockade, and they were chased by French forces into Saint-Florent Bay where the wind died, stranding both vessels. Instead of engaging with Doria's forces, the crews chose to offload everything they could and abandon the ships before lighting them on fire.[310] The few finds recovered from the

[307] Cazenave de la Roche et al., 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2012', 75.
[308] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 282-7.
[309] Finlay, 'Fabius Maximus in Venice: Doge Andrea Gritti, the War of Cambrai, and the Rise of Habsburg Hegemony, 1509-1530', 991
[310] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 286.

excavations on Mortella III appear to support this historical narrative, while surviving upper elements from the hull indicate the ship was burning before it sank.[311]

Mortella III's remains are covered by two separate ballast mounds close to each other, the longer of these mounds revealed the bottom of the hull (figure 36). Excavation near the endposts and a trench dug amidships provided evidence for two keel timbers, one above the other as the central axial structure. Investigators examining the double keel on Mortella III stress that the upper is rabbeted throughout and joined to the rider keel beneath.[312] This arrangement was well-suited for the single arc hull without a midship flat that required a significantly thicker keel to provide lateral resistance when sailing and lessen the overall rolling. The rider keel is also much thicker than a false keel and the bolts driven through it connect to the proper keel, frames, and keelson together. This fastening pattern emphasizes that the shipbuilders saw the rider keel as part of the original construction and not a subsequent addition for protection of the main keel.[313]

No physical evidence of the stem survives (only an estimated 8.6 m rake based on the hood ends of surviving planking), but the forward end of the keel suggests a flat scarf connected these two timbers together.[314] Amidships, two separate sections of the keel simply butt together with the rider keel beneath covering the seam. The keel timbers are roughly square throughout

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[311] Cazenave de la Roche, 'El pecio de la Mortella III (Córcega, Francia): Un aporte al conocimiento de la arquitectura naval del siglo xvi en el Mediterráneo', 859.
[312] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 146-54.
[313] Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 25-8.
[314] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 254; Cazenave de la Roche et al., 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2013', 24.

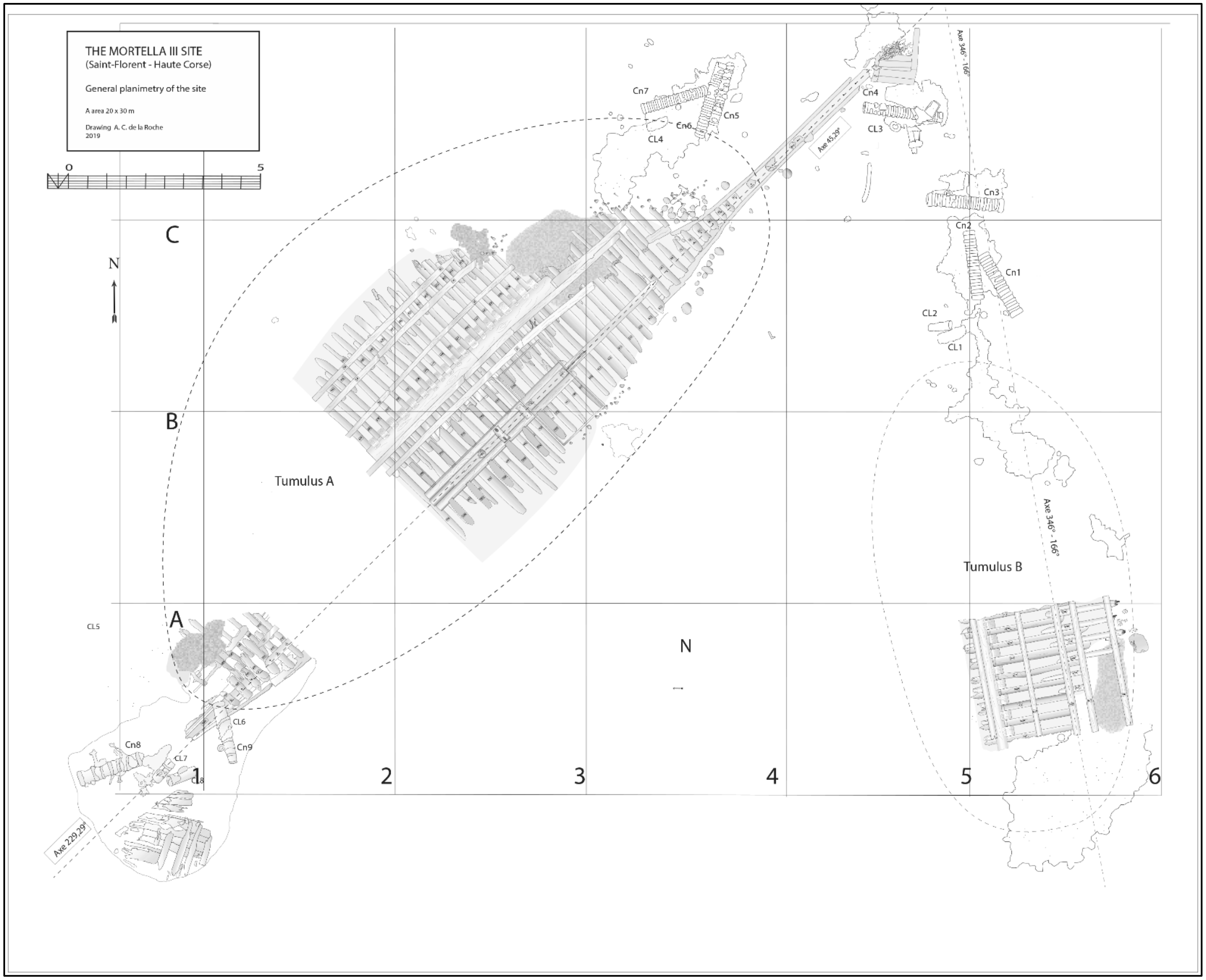

Figure 36 Site plan of the Mortella III shipwreck. (Courtesy of Arnaud Cazenave de la Roche)

until the stern, where they both increase in height. Only a small fragment of the sternpost remains, this piece originally butted the keel and extended upward at an angle of 76 degrees.[315] The skeg for this vessel is quite pronounced, as both the keel and rider keel extend beyond the sternpost. Elements from a rudder found just aft of the stern indicate the steering system for the ship.

A long-armed stern knee was fitted atop the keel and rested against the sternpost. While only the 3-4 m long lower section of the stern knee survives, its forward end appears shaped to butt or flat scarf to a missing additional piece that was part of the deadwood.[316] Shipbuilders filled this void with two timbers and cut them to fit over the area at the front end of the stern knee. No further evidence survives to explain whether the original adjacent deadwood timber was removed, the stern knee was a short replacement, or if the shipbuilders had inadequate resources and chose to fill the void between two deadwood pieces. The lower face of the first filler timber is cut to match the stern knee scarf, but still left a lower void, while the upper filler timber is on a slope that rebates into the top of the stern knee. This slope increases the height of the frames in this section slightly before leveling out toward the stern. The rabbet cut into the counter keel rounds upward before the lower sternpost, suggesting that the hood ends fit into the missing section of the stern knee or main sternpost.

Framing consisted of floor timbers hook scarfed to overlapping futtocks and secured with two round nails. Along with the hook scarf, several of the floor timbers have an additional recess to fit the shape of the overlapping futtock. The master frame consists of a floor timber with

[315] Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 31-2.
[316] Ibid., 27-8, fig. 7.

double futtocks attached on each end.[317] One of its surviving starboard futtocks is attached to the floor timber by a hook scarf with recess for the wronghead and the accompanying futtock was a reused timber (there was an unused scarf present on the opposite end). The reuse of the futtock is further demonstrated by a single fastener driven through it, while the other scarfed futtock includes two nails. Only the master frame fastening pattern is horizontal, the others are at an angle suggesting their floor timber-futtock connections were completed as these pieces were installed. Upper ends of the first futtocks are hook scarfed and recessed to accommodate the overlap of the second futtocks. Most frame elements are relatively square amidships and altered toward the endposts. The keelson is bolted through the floor timbers and keels. Two recessed bilge stringers on each side of the hull are fastened with round nails that overlay the floor timber and first futtock overlap at the turn of the bilge.[318] Another stringer is positioned roughly in the center of the first futtocks and a final pair of stringers are also present securing the overlap between the upper frame elements.

A single longitudinal ceiling strake was fitted between the dual bilge stringers, while there is a crenulated sill directly above it with filler pieces inserted between futtocks.[319] The bottom of the hold was covered with planking laid down transversely, atop the keelson and bilge stringers, creating a flat platform across the hold. Planking is thicker (8-10 cm) than seen on smaller vessels, suggesting a large ship capable of longer voyages. Each strake is fastened with two round iron nails per frame station; the nails were driven through each frame and clenched on

[317] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 225-9.
[318] Cazenave de la Roche et al., 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2013', 28.
[319] Cazenave de la Roche et al., 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2012', 32.

the inside face.[320] Both the inside and outside of the hull was covered in pitch that contained pine resin and animal fat. No evidence of treenails was identified in the surviving construction.

Located amidships, the mainmast step was composed of two long mast partners rebated to fit over the floor timbers and nailed into either side of the keelson. Along the outside upper edge of either mast partner is a rebate with deeper square cuts for the six accompanying buttresses per side. Each buttress was centered above a floor timber when fitted into its mast partner recess, while the outboard end was rebated into the lower bilge stringer.[321] The upper sections of the rebates were intended to fit the ends of the transverse ceiling in this area, although this ceases past the mainmast, due to the following area being cut off as part of the pump well. Two keys were dovetailed into both mast partners and fastened in place for extra strength. The area between the keys appears to be the mainmast mortise, while toward the bow there is a stanchion and near the front end of the mast partners a chock was connected to the top of the keelson. Aft of the mainmast mortise is the pump well, which includes two stanchions positioned atop the keelson and additional stanchions placed over the adjacent frames to create a rectangular box enclosed with several planks.[322] Toward the stern another chock was positioned on the keelson, creating the aft end of the mortise. The upper sections of the hull did not survive. The first deck is hypothesized as beginning directly above the charred remains of the second futtocks.[323]

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[320] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 168.
[321] Cazenave de la Roche et al., 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2012', 38-9.
[322] Cazenave de la Roche, 'Rapport de fouille programmée annuelle site de la Mortella III, Campange 2010', 20-4.
[323] Cazenave de la Roche, 'La construction navale au XVIème siècle en Méditerranée: L'apport de l'épave de la Mortella III (Saint-Florent, Haute-Corse)', 247-9.

Sardinaux

Pointé des Sardinaux and its associated skerries are found on the Mediterranean coast of France between Sainte-Maxime and Les Issambres. The submerged rocky outcrop to pose a danger to coastal shipping and led to the loss of several shipwrecks since antiquity. Diving in this area is difficult, due to the low visibility from mud deposited by the Argens river near Fréjus and carried south by the bottom current. Nevertheless, divers found an unknown shipwreck 52 m deep in 1986.

The wreck was a smaller vessel mainly packed with ceramics. The scatter trail on the bottom suggested the ship hit a rock outcrop and drifted 1400 m before sinking.[324] Over 4,000 individual ceramics were recorded in four layers, made up of cups, bowls, jugs, and various other shapes fitted into a 10-12 m long ship.[325] No evidence was found for any dunnage or packing materials employed in loading the vessel, ceramics were simply stacked together in horizontal layers perpendicular to the keel. A single anomalous sherd located near the stern was identified as tableware for the crew, but its small size limits any further diagnostic information.[326] Two pintles were also found in this area, inferring that the ship relied on a stern rudder for steerage. An iron concretion located toward the front end of the vessel was identified as a four-armed grapnel anchor.[327]

Subsequent analysis of the ceramic collection revealed that the cargo was probably from the nearby Fréjus workshops. Sixteenth-century documents mentions coastal vessels carrying

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[324] Joncheray, 'Un navire de commerce de la fin du XVII[e] siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 21-4
[325] Joncheray, 'Un navire de commerce de la fin du XVII[e] siècle, l'épave des Sardinaux. Seconde partie: Le matériel céramique', 131
[326] Joncheray, 'Un navire de commerce de la fin du XVII[e] siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 41
[327] Ibid., 60-4.

thousands of ceramics from Fréjus to Marseilles.[328] Researchers originally dated the wreck to the end of the seventeenth century, due to a small plate with graffiti found beneath the glaze. The graffiti is interpreted as the coat of arms for the bishop of Fréjus, Luc d'Aquin (1681-97), or his nephew, Louis (1697-99), who succeeded him.[329] Based on the late seventeenth century date, archaeologists suggested the vessel was a *tartane*, an open-decked coastal craft that mainly carried cargos between adjacent ports.[330] The ceramic collection from the Sardinaux wreck represented a unique collection of Fréjus craftsmanship for several decades. Recent terrestrial excavations around Fréjus uncovered workshops with unfinished, broken, or discarded ceramics that expanded the seriation possibilities of these artifacts. Based on these findings, the Sardinaux collection was re-dated to the first half of the sixteenth century and fits with the documentary sources mentioning similar coastal craft during this time.[331]

Despite seemingly optimal conditions (pinned beneath several thousand ceramics and buried in muddy sediment) the hull remains for Sardinaux were limited (figure 37). Two sections of the keel survive, both suggest a rectangular shape no evidence for a rabbet.[332] Boards were fastened to the keel and garboards between floor timbers. The original interpretation for these boards suggests they were installed for the lowest row of ceramics in the hold. Another interpretation is that they provided stronger reinforcement between the keel and garboard due to

[328] Ibid., 40.

[329] Joncheray, 'Un navire de commerce de la fin du XVII^e^ siècle, l'épave des Sardinaux. Seconde partie: Le matériel céramique', 108-10

[330] Joncheray, 'Un navire de commerce de la fin du XVII^e^ siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 65

[331] Amouric and Vallauri, 'Ateliers des champs, ateliers des villes, ateliers sur l'eau?: Du Moyen Age à l'Époque Moderne en Provence et Languedoc', 57; Amouric, Thiriot, and Vallauri, 'Fréjus: Des fours pour cuire des jarres et leur diffusion du XVIe au XVIIe siècles.', 16.

[332] Joncheray, 'Un navire de commerce de la fin du XVII^e^ siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44-5

the absence of a rabbet.[333] Only the foot of the stem survives and is horizontal flat scarfed with two iron fasteners to the front end of the keel. No evidence for the sternpost survives, only the two pintles indicate that it held a rudder.

Frame stations included a floor timber that is hook scarfed on either arm to a futtock. These frame timbers are fastened together with three or four square iron nails. Drawings of individual frames suggest most of these nails are blind, although a few may have pierced the other side and were clenched. The difficulty in determining the fastening pattern is complicated by the coasting of pitch inside the entire hull and over all scarfs. Scantlings for the frame elements are relatively squared, and each floor timber is fastened to the keel with two or three nails. Two frame stations amidships were identified as dual master frames. The hull section was characterized by a flat floor and round bilge.[334]

Due to the limited remains of the keel, it is not clear whether a keelson existed. The presence of a single willow treenail (3 cm diameter) inserted vertically into the keel between frame stations at the bow could be for an apron or the forward part of the keelson.[335] Connecting the keelson to the keel between frame stations seems plausible, due to the small scantling of the floor timbers and the absence of any vertical bolt holes in them. The upper face of four floor timbers forward of amidships are rebated to receive a mast step. The pattern of these recesses suggests a mast step system similar to that seen on other wrecks with the mast mortise built from step partners and chocks. Absence of any ceiling or deck support suggests the ship had an open plan, perhaps with a partial deck in the stern that is missing.[336]

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[333] Ibid., 58, 60.
[334] Ibid., 47-54.
[335] Ibid., 44.
[336] Ibid., 58.

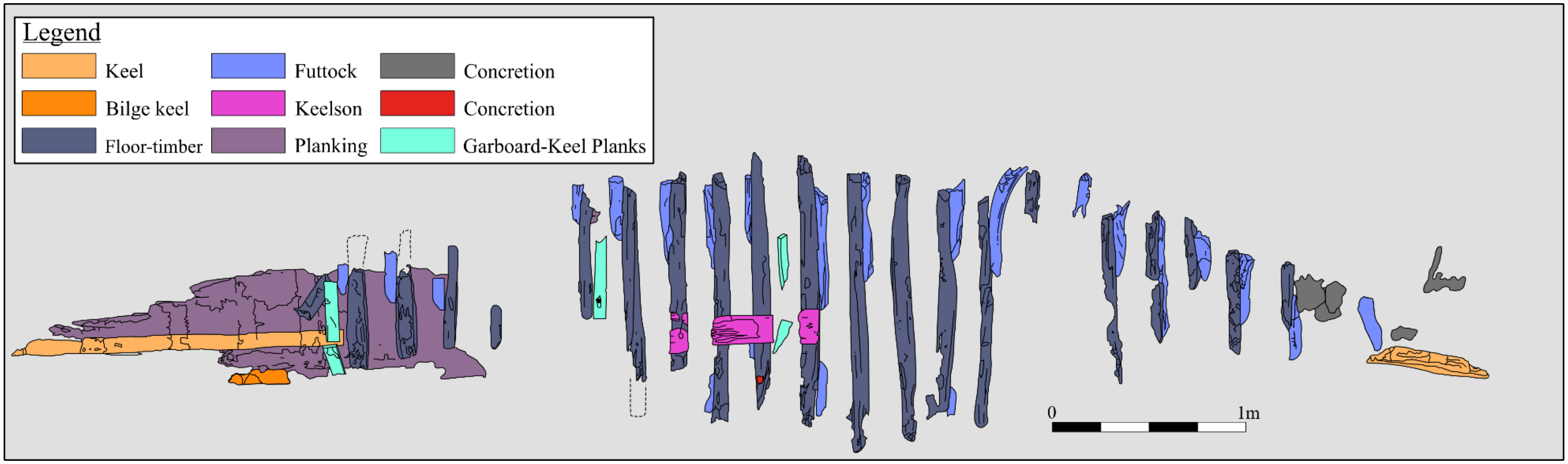

Figure 37   Site plan of the Sardinaux shipwreck. (after Joncheray, 'Un navire de commerce', 43)

Evidence for bilge keels was found outside the hull, the remains of these elements have a transitional shape that is triangular at the ends and closer to a parallelogram amidships. The inboard faces of these timbers are without any rebates, the bilge keels simply fastened against the outside of the frames. Fasteners holes are described passing through the bilge keels and a flat scarf between two pieces is also identified, but it is not clear whether they were connected only to the frames, the missing bilge stringers, or both.[337] Limited elements from the planking survive, suggesting thin boards (~3.7 cm) and modest widths (16.5-17.5 cm) that were recorded from the garboards. The few seams between surviving strakes did not include any identifiable caulking, while the pitch mentioned earlier is found on the inside and outside of the hull.[338]

Chrétienne K

Much like the Pointé des Sardinaux, the rocky coastline and shallow reefs of Antheor, France are a hazard to passing ships. Archaeologists have frequently visited this location, discovering shipwrecks as early as 1947. Among the hulls that were encountered, a lone anchor was found in the 1970s and subsequently used as a local dive destination. The anchor still rests 41-42 m deep, half buried in the sediment with its other fluke extending up. In March 1992, divers located a bronze breech-loading cannon nearby, which prompted further survey for hull remains. The after section of a ship and iron concretions were subsequently identified five days later, providing the impetus for an archaeological study.[339]

Beginning in April, investigators spent 30 days cataloging the exposed finds and recording the surviving hull timbers. The team experienced great difficulty at the site, due to high winds on the surface and a surge on the seafloor. Archaeologists identified two

[337] Ibid., 46.
[338] Ibid., 58.
[339] Lopez, Joncheray, and Brandon, 'L'épave post-médiévale Chrétienne K', 113

other anchors nearby, and recovered several breech blocks, a helmet, a fragment from an arquebus barrel, a sword hilt, and balance scales.[340] Ceramic finds included bowls, jars, and jugs, with one of the jugs having a twisted handle. Archaeologists originally associated the latter artifact with Fréjus manufacturing in the late seventeenth century, excavations of a workshop in 2008 provided a much more reliable dating sequence for manufacture.[341] Based on these new findings, the Chrétienne K wreck was placed in the first half of the sixteenth century.[342]

Limited remains from the hull survive, due to the little amount of sand that covered the timbers (10-20 cm) and the strong current on site (figure 38).[343] Divers were also instructed in the survey permits to not disturb the wood, so recording of key features was minimal. The keel was identified running along the center axis, and it appears rabbets were cut along the upper edges for the garboard. No remains were located for the bow or amidships, and the sternpost was gone, with only fragments of the rudder left nearby.[344]

Floor timbers overlapped with futtocks created the frames, but these timbers are not scarfed together. There is an instead an overlap, tapered overlap, or a recessed carving into the floor timber to accompany the futtock. Each overlap is fastened with two round iron fasteners driven through and clenched on the opposite side. Scantlings suggest that both the floor timbers and futtocks are relatively square. Floor timbers are spaced slightly more than their average

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[340] Ibid., 119-20, 127.
[341] Ibid., 128-9.
[342] Amouric and Vallauri, 'Ateliers des champs, ateliers des villes, ateliers sur l'eau?: Du Moyen Age à l'Époque Moderne en Provence et Languedoc', 57; Amouric, Thiriot, and Vallauri, 'Fréjus: Des fours pour cuire des jarres et leur diffusion du XVIe au XVIIe siècles.', 16.
[343] Lopez, Joncheray, and Brandon, 'L'épave post-médiévale Chrétienne K', 113
[344] Ibid., 120, 122.

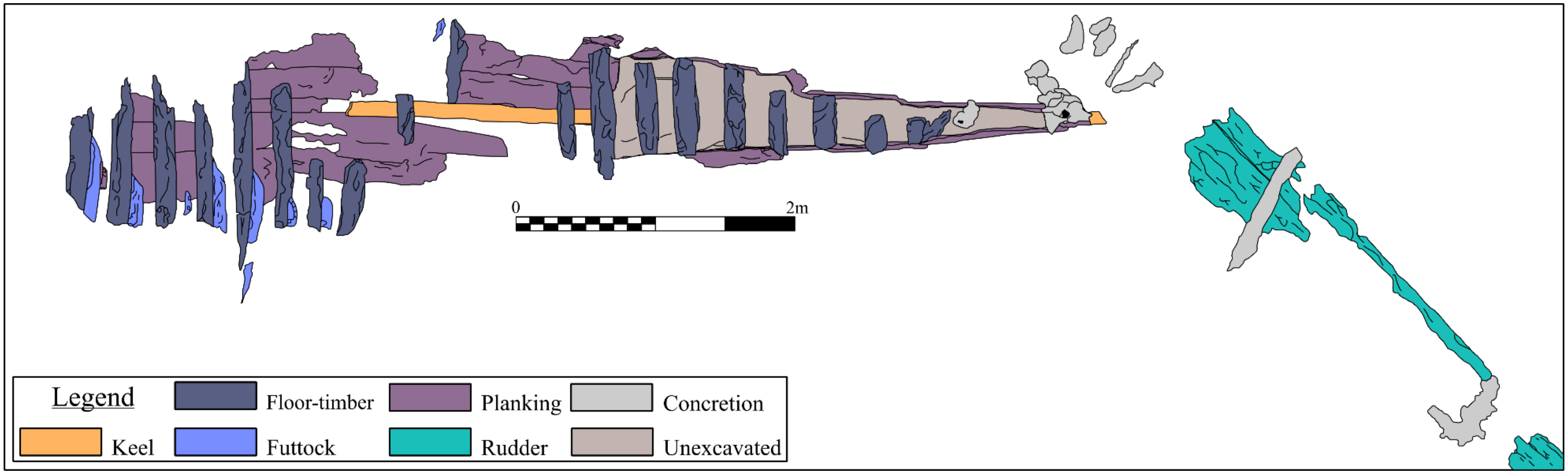

Figure 38 Site plan of the Chrétienne K shipwreck. (after Lopez et al., 'L'épave post-médiévale Chrétienne K', 121)

width and bolted to the keel. Surviving elements of the garboard and planking suggest they averaged 20 cm wide and were fastened to the frames using two or three iron nails per station.[345] The hull suggests a flat floor and round bilge amidships, and investigators believe the ship was 20-30 m in overall length.

West Turtle Shoals

Treasure hunters from Doubloon Salvage located the remains of a shipwreck along the Florida Keys at the beginning of the 1970s. The company was awarded permits to excavate the site between 1971-4.[346] Reports indicate that the salvors returned to the site in 1972 and spent roughly 19 days propwashing[347] the sand and seagrass to uncover intact hull remains.[348] Artifacts included two wrought iron cannons, three anchors, walnuts, animal bones, ceramic sherds (noted as olive jar sherds), and other materials.[349] During the excavation, the treasure hunters were required to have a state official on site, the archaeology representative, Gordon P. Watts, created a site map of the hull remains (figure 39).[350] After finding little precious metals, the wreck was abandoned by the treasure hunters. The site was subsequently mislabeled as a nineteenth-century American schooner and its precise location was lost.[351]

The estimated date for this wreck is the second half of the sixteenth century. This is based on several factors, including the shape of the anchors, which match those found on other sites of this period.[352] The projections or nuts below the ring on all three anchors, used to keep the (now-

[345] Ibid., 122.
[346] Florida State Archives (Series, Microfilm, Contract) .S 2188 MF007 E27, 2
[347] This is a method of removing sediment from the seafloor by directing a boat's propwash downward.
[348] Florida State Archives .S 2188 MF007 E27, 88, 216
[349] Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 6.
[350] Gordon P. Watts, pers. comm.
[351] Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 3-4.
[352] See Arnold, *The Nautical Archeology of Padre Island: The Spanish shipwrecks of 1554*, 224-30; Keith, 'The Molasses Reef Wreck', 232-46; Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 35-41.

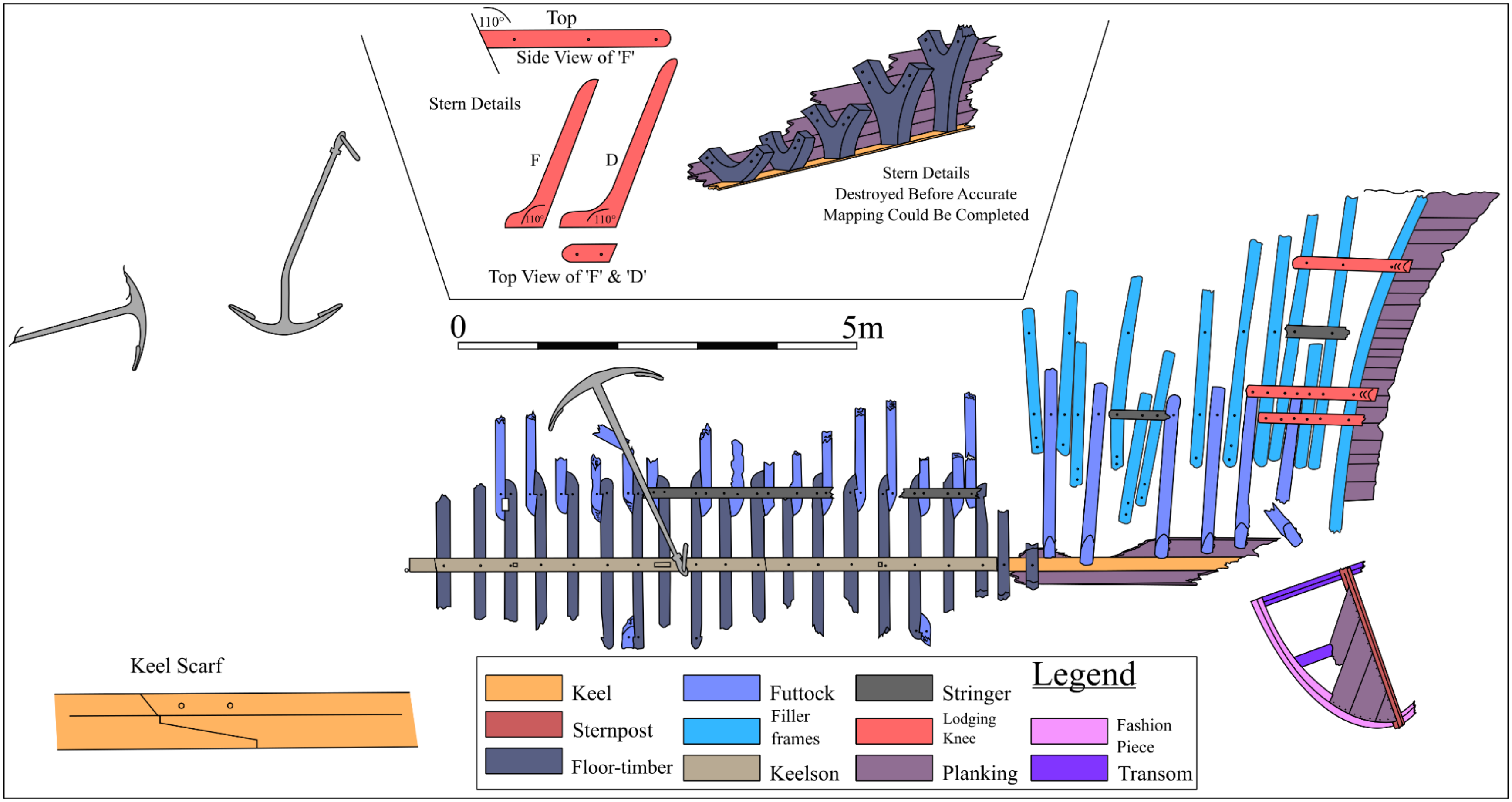

Figure 39 Site plan of West Turtle Shoal shipwreck originally drawn by Gordon P. Watts. (after Russo, West Turtle Shoals Wreck (8MO142), 7)

missing) stock from shifting, are parallel with the flukes, a diagnostic feature that changes after 1600. Square transoms become popular by the end of the fifteenth century, and the example from West Turtle Shoal site provides a generic shape with chevron planking similar to other contemporary examples.[353] The wrought iron guns also suggests an earlier date and the olive jar sherds imply an Iberian origin for the crew. The wreck's construction features match other Mediterranean-built vessels, while recent research has shown an increase in ships built within this time put into Atlantic service for the Spanish Crown.[354]

Information about the site can only be obtained based on Watt's rudimentary site plan. What Watts was able to draw suggests the keel was similar in width to the keelson and a separate excerpt shows a horizontal flat scarf was used. The salvagers never found bow of the ship and it appears that the sternpost is missing, except the section attached to partial remains at the flat transom. Framing included floor timbers that are hook scarfed to overlapping futtocks. Dual master frames are located amidships with the futtocks attached on the opposite floor faces. The floor-futtock join is secured with two iron nails (Watts has stated all fasteners were square).[355] An unusual connection is seen toward the front of the ship, where a floor timber / futtock overlap includes a mortise for a stanchion. The space between floor timbers suggest double or triple the width of the actual timber at each frame station. Not enough information exists to indicate whether the keelson is recessed over the frames, but every frame station includes a bolt connecting the keelson to the keel.

[353] See Loewen, 'The Square Tuck Stern: A Renaissance Innovation?', 132-3; Villié, 'L'épave Calvi 1 (1989)', 40-3
[354] Casabán, '*Santiago de Galicia* and the Illyrian squadron: Characteristics, dimensions and tonnages of Mediterranean-built galleons for Philip's II Atlantic fleets (1593–1597)', 243
[355] Gordon P. Watts, pers. comm.

No mast step assembly is recorded. Instead, it seems a mortise was cut into the top face of the non-expanded keelson for the mast heel. Two additional square mortises on the top face of the keelson suggest locations for stanchions holding up what was likely to be a single deck. One bilge stringer is present on the starboard side that is nailed over the floor timber and first futtock overlap. No evidence of any ceiling is shown between the keelson and stringer. Upper elements of the hull include a stringer covering the overlap between the first and second futtocks, and another stringer along the middle of the third futtocks. Toward the stern, several lodging knees are present with aspects of the planking recorded. Elements of the garboard suggest the planking is relatively thin (5 cm) and matches the estimated small overall dimensions of the ship.

Calvi 1

In 1979, Antoine Roucayrol reported finding a shipwreck within Calvi harbor on the northwestern coast of Corsica. The site is roughly 50 m from an industrial quay, directly adjacent to the remains of a historic fort. This location is only 8 m deep, and the harbor bottom consists of loose sand and plant debris that could fluctuate up to 2 m in depth over the site. [356] Luc Long from DRASSM examined the site and noted significant hull structure from amidships to stern. Full excavation of the site began in 1985, during which the forward end of the ship was not found.

The wreck site was heavily disturbed by its proximity to the industrial quay where cargo and cruise ships docked on a constant basis. The loose sand that covered the hull often moved and exposed timbers that were not seen during the original 1979 investigation. Initial surveys of the site in 1985 clearly show timbers exposed prior to excavation. During the four-year project

[356] Villié, 'L'épave Calvi 1 (1989)', 19-22

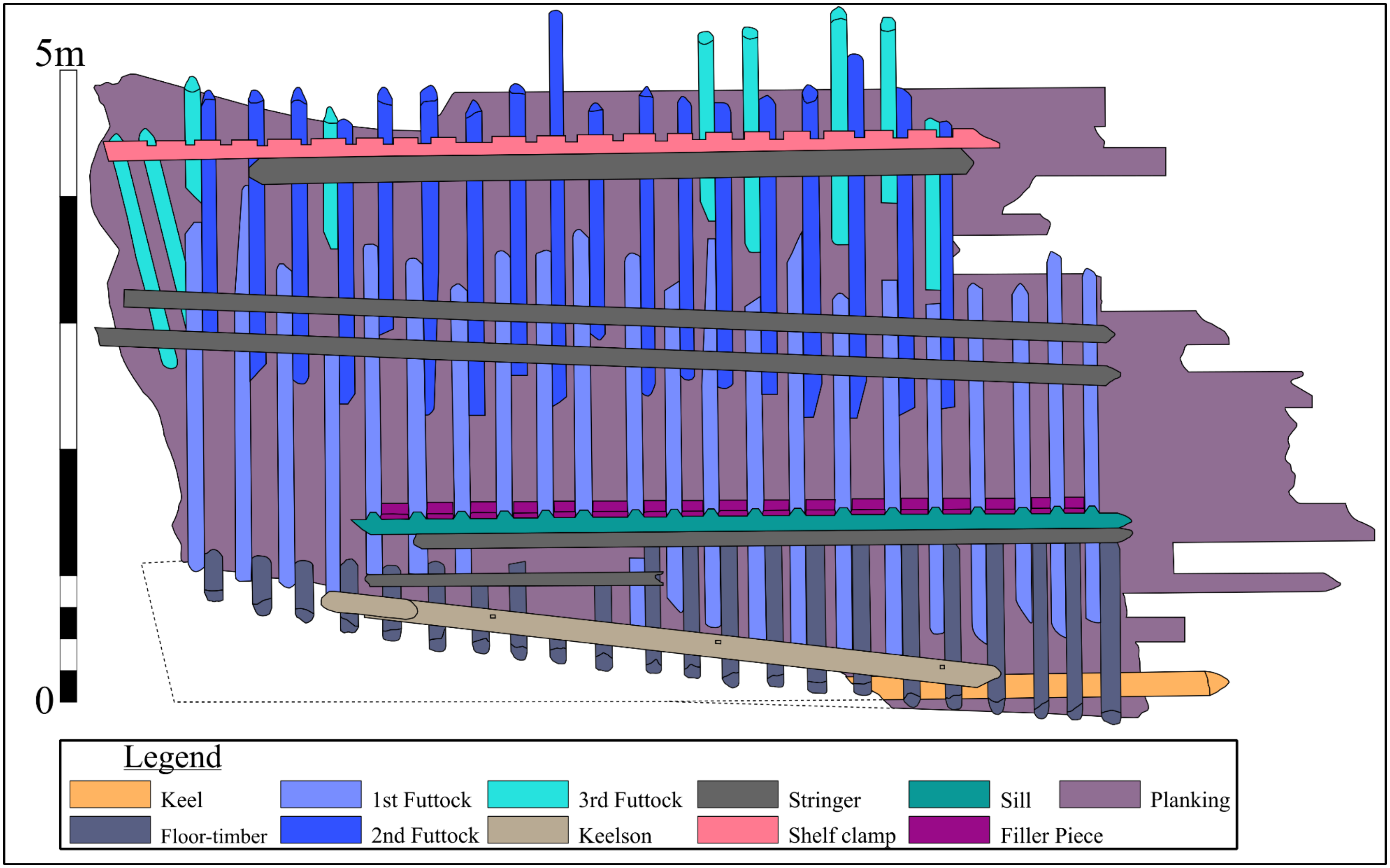

Figure 40 Site plan of the Calvi 1 shipwreck. (after Villé, 'L'épave Calvi 1', 26)

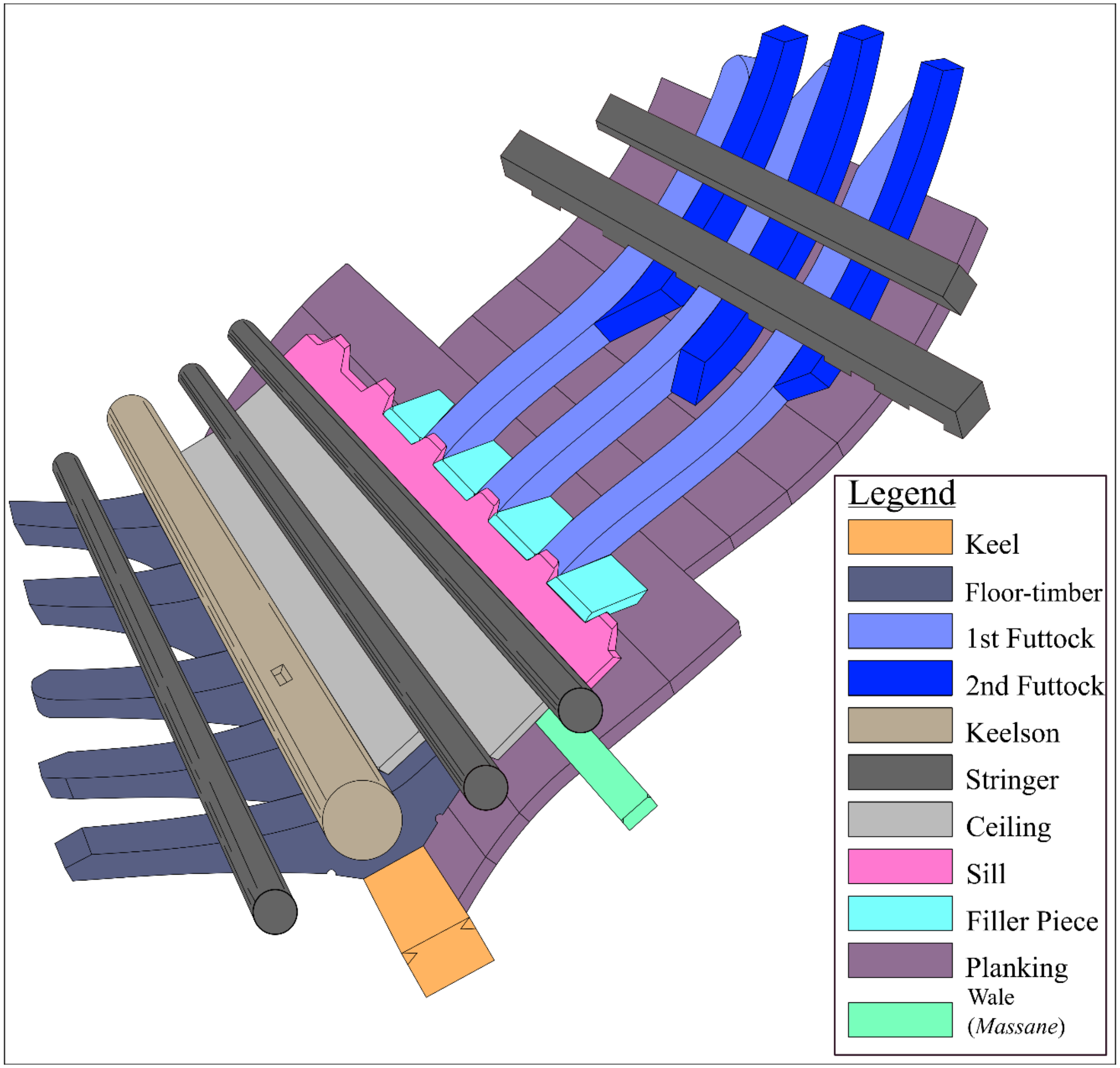

Figure 41 View of the internal assembly from the Calvi 1 shipwreck. (after Villé, 'L'épave Calvi 1', 115)

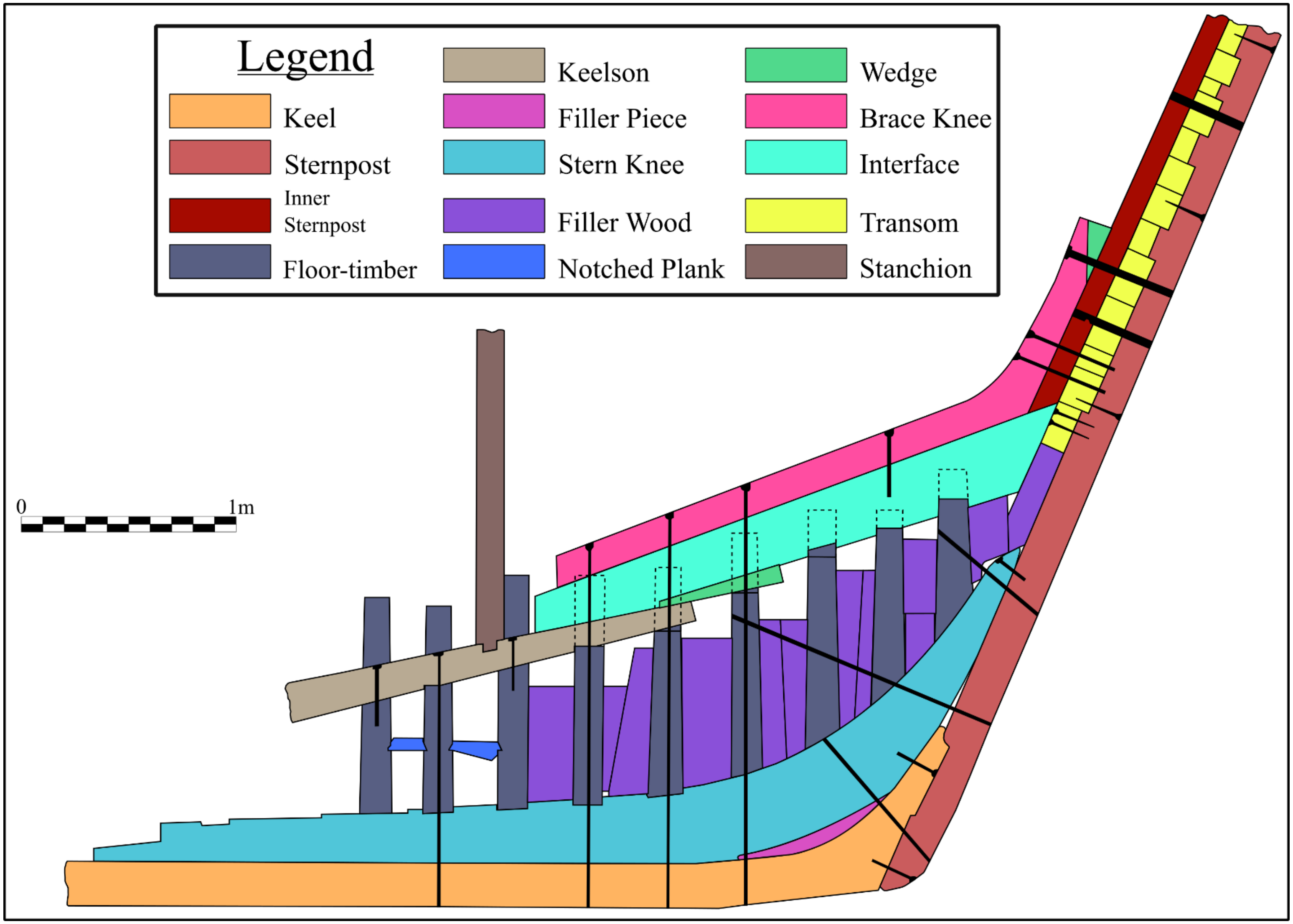

Figure 42   Stern assembly of the Calvi 1 shipwreck. (after Villé, 'L'épave Calvi 1', 26)

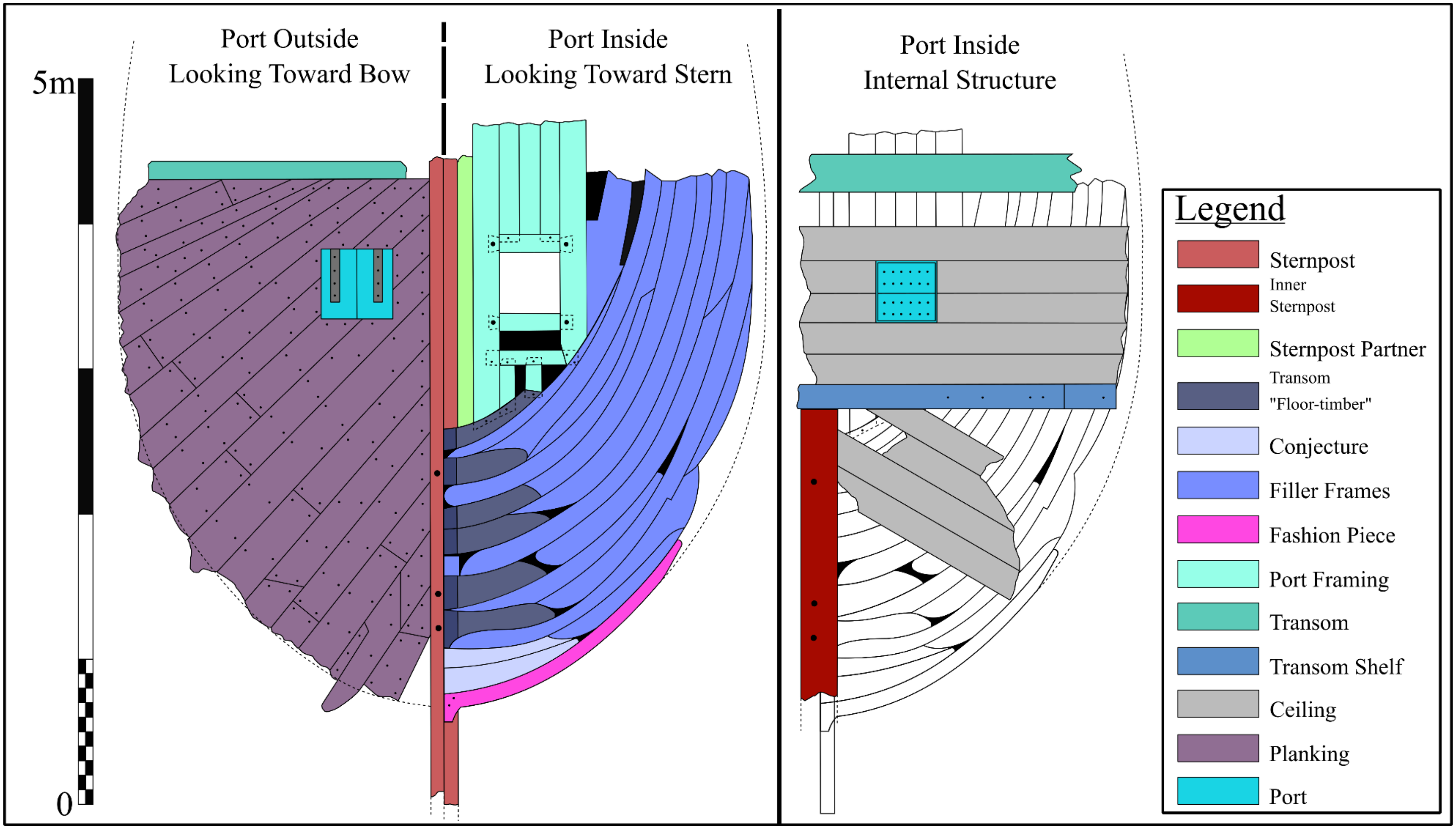

Figure 43 Flat transom assembly of the Calvi 1 shipwreck. (after Villé, 'L'épave Calvi 1', 36-37)

archaeologists collected artifacts from the sixteenth to the twentieth century.[357] Only after locating ceramics imbedded in concretions at the bottom of the hull structure were they confident that this was a late sixteenth-century vessel.

Based on the surviving hull structure, it appears that the ship sank and rolled onto its portside where the lower deck collapsed and protected the after section. As mentioned above, the earlier survey noted additional upperworks and possibly the forward section near the master frame that were no longer present by the beginning of excavations in 1985. Nonetheless, Calvi 1 provides nautical archaeologists with an important example of stern construction on an early modern Mediterranean round ship (figures 40 and 41). Calvi 1's keel is relatively square throughout and rabbeted for the garboards. The end of the keel rounds upward with its aft face hook scarfed to the sternpost at a 65°. At the after end of the keel carpenters cut a sharp angle to meet the heel of the sternpost (figure 42). Support for the keel/sternpost scarf is provided by a stern knee.[358] The forward end of this knee includes a flat scarf to connect to another deadwood timber providing additional rising for the floor timbers. On the top face of the stern knee are rebates to fit the bases of Y-timbers, while the bottom face of the knee does not follow the same curve as the keel. The difference between the stern knee and keel creates a void that is filled with a custom-shaped timber. Another void is created between the overlap of the keel, upper arm of the stern knee, and the sternpost that was left empty. Investigators believed that the stern knee might have been a reused timber, due to the fact it has such an imperfect fit within the stern assembly.[359]

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[357] Ibid., 45-53.
[358] Villié, 'L'épave Calvi 1 (1990)', 84-6
[359] Ibid., 86.

Differently sized filler pieces were filled in the spaces between Y-timbers to create additional deadwood in this area. The space between the first two floor timbers without filler pieces contain rebates on their fore and aft faces with a plank inserted between them. Above this assembly, the after end of the keelson terminates before the upward turn of the keel and stern knee. Two filler timbers overlap the keelson, the lower piece a short shim that supports a much larger timber extending diagonally to the sternpost. Another knee with a longer forward arm is bolted to the top this filler timber. The inside upper face of the sternpost supports a square composite transom made from many small, overlapping compass timbers that together create a surface for the attachment of the transom's chevron planking (figure 43).[360] This complex assembly is further reinforced with a false sternpost on the inside, which is also supported by the short upper arm of the second stern knee.

It remains unclear why the shipbuilders chose such a complex stern assembly, although theories suggest that the reduction in choice timber might have led to the use of many smaller pieces.[361] Several types of bolts were used to secure this section, including three incredibly long fasteners that connected the upper stern knee all the way down through the underside of the keel. All the Y-timbers further aft were connected to the sternpost with bolts driven at different angles to include most of the filler timbers.

Framing consists of floor timbers hook scarfed or dovetailed to overlapping futtocks. Overlaps between upper futtocks often include either a half lap or recess on one timber to accommodate the other. Floors and futtocks are fastened to one another with one to three round iron nails.[362] Floor timbers are often rectangular, due to the rising added at the stern, while the

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[360] Ibid., 118.
[361] Ibid., 86.
[362] Ibid., 104-11; Villié, 'L'épave Calvi 1 (1991)', 76-7

futtocks are square. The keelson is fashioned from a log with the bark removed and laid along the centerline of the ship. It was rebated amidships and bolted to the keel at every other frame station.[363] Any floor not bolted down by the keelson is connected to the keel with a single nail. Dual stringers are present at the overlap of the frame elements with space between each. The only exception is where the second futtocks cross the third; at this location a stringer supports a shelf clamp located directly above it.[364] Lower bilge stringers also appear to be logs with the bark removed, while the upper stringers all have additional squaring work with chamfered edges. Above the lower bilge stringers is a crenulated sill with filler pieces inserted between the futtocks for sealing the bilge.

Two longitudinal ceiling strakes are present between the keelson and lowest bilge stringers.[365] At the stern, angled knees rest over the middle pair of stringers and lodging knees connected to the shelf clamp support the internal face of the flat transom. Both the tops of the lodging knees and shelf clamp were rebated to fit beams intermittently spaced between each other. Hanging knees are positioned over underlying futtocks and recessed over the stringer and shelf clamp to fit flush with the beams.[366] Another rebate allowed the hanging knees to help partially support the adjacent beam.[367] Positioned over a vertical flat scarf that connects two sections of the shelf clamp together, a half-circle is cut into the inside face between futtocks without any clear indication for its purpose.[368] Surviving evidence suggests that the ends of the beams were shaped into narrower tenons that fit into the shelf clamp and were fastened

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[363] Villié, 'L'épave Calvi 1 (1990)', 87
[364] Ibid., 88-9.
[365] Ibid., 95, 115.
[366] Villié, 'L'épave Calvi 1 (1989)', 30-1
[367] Ibid., 29.
[368] Ibid., 25, 28.

vertically. Archaeologists found portions of a carling supported by stanchions fitted atop the keelson without evidence of ledges to create this deck.[369] Deck planking was fastened with square nails.

Tucked directly at the junction where the Y-frames give way to the first futtocks is a pair of *massane* (lower wales) on either side of the hull.[370] These wales disappear after the last surviving forward floor timber and transition into normal hull planking. As the hull shape opens forward from the stern, the placement of the *massane* also shifts on the outside of the hull from between the bilge stringers to directly under the lower bilge stringer near amidships. Planking dimensions vary depending on location, most of the lower strakes have the same thickness with different widths. After the *massane*, there is a purposeful difference in plank thickness that created an alternating recess every other strake. This rhythm is broken with two wales that fit directly adjacent to the stringer and shelf clamp, reinforcing this section on the outside. [371] Planking is fastened to the hull with two round iron nails per frame station. Nails are clenched on the inside of the hull. Both the inside and outside of the hull are pitched, while the keel and garboard are explicitly covered in lead sheathing. Only a single treenail was noted on the entire wreck driven into the portside shelf clamp.[372] Overall shape of the ship suggests that it had either a flat floor with round bilge at amidships or a wineglass form throughout.[373] The latter shape is supported by the one-fifth scale reconstruction, which required a 75 cm addition to the base of the furthest forward surviving floor timber to fair the hull lines.[374]

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369 Ibid., 31-2.
370 Villié, 'L'épave Calvi 1 (1991)', 82
371 Ibid., 78-82.
372 Villié, 'L'épave Calvi 1 (1989)', 25
373 Villié, 'L'épave Calvi 1 (1991)', 102-5; Daeffler, 'Deux exemples de conception des navires de commerce de la seconde moitié du XVI[e] siécle', 146-8
374 Villié, 'L'épave Calvi 1 (1990)', 86-7, 108

Sixteenth Century Yassıada

In 1958, Peter Throckmorton discovered the remains of several shipwrecks lost along the extended reef system of the small, uninhabited island of Yassıada off the southeastern shoreline of Turkey. Yassıada is part of an archipelago along the Chuka Channel near Bodrum. Subsequent fieldwork by archaeologist George Bass and the University of Pennsylvania, initially focused on the remains of a seventh-century shipwreck composed of an amphora mound.[375] Several meters from this mound another shipwreck was cataloged by Throckmorton and efforts to excavate this second wreck began in 1967.[376] Analysis on the amphora morphology and associated artifacts suggested this ship sank toward the end of the fourth century.

During the initial field season on the site, excavators encountered wood elements and artifacts that could not be associated with the same wreck. It slowly became evident that another vessel sank on top of the first, a shipwreck which was originally dated to the thirteenth century.[377] Few objects recovered from the first season on the newest discovery, mainly concreted fasteners, and ballast stones. When archaeologists returned to the site for further work with the fourth century shipwreck, the team also allocated time to collect stereoscopic photos of the exposed hull remains from the supposed medieval wreck.[378] Uncovering of the hull remains again for photography revealed a four *reale* coin minted by Phillip II of Spain (1566-89), which eventually provided the terminus post quem for the later site.[379]

No further work took place on sixteenth century Yassıada wreck until Bass and the Institute of Nautical Archaeology were approached by the Council of Europe about running a

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[375] Bass and Gifford, 'The Site', 3-4.
[376] Bass and van Doorninck Jr., 'A Fourth-Century Shipwreck at Yassi Ada ', 27
[377] Pulak, '16th-Century Ottoman Wreck: One of the Three Ships Trapped by Perilous Yassi Ada Coast', 138
[378] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 7.
[379] Pulak, '1983 Yassıada Sualtı Kazısı - 1983 Sezonu', 471.

field school from Bodrum. The site was chosen for the field school in 1982 with plans to excavate, map, and retrieve the surviving hull remains.[380] When the early modern-era Yassıada wreck was first identified, archaeologists found a well-preserved portside that suggested a similar level of intact structure on starboard. This belief was quickly dispelled in 1982 when it became evident that a significant debris field of broken hull elements were scattered across the starboard side of the hull.[381] Archaeologists returned the following year to map and retrieve the remainder of the hull still buried. Due to time constraints, the portside planking was left in situ. The subsequent loss of a Lebanese ship in 1993 atop the same area as the Yassıada shipwrecks makes it unclear whether any of the hull left in-situ survives.[382] That few artifacts were found in the wreck suggest that its crew were able to remove their possessions. Several fragments from wood not associated with the hull hint that the ship was possibly carrying a cargo of timber and other materials that were salvaged after the wreck.[383] Two stone cannonballs and a piece of iron could either be interpreted as part of an armament or associated with the minimal ballast.[384] Dendrochronology of the keel suggests the tree for one of its timbers was felled after 1572 and closely fits with similar chronologies for forests around the Black Sea.[385] Preliminary reconstruction of the hull suggests the ship was a *saique*, a naval support vessel used by the Ottoman Empire.

Although fragmentary, the surviving remains from the sixteenth century Yassıada shipwreck still provide solid clues about eastern Mediterranean shipbuilding (figures 44 and 45).

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[380] Pulak, 'A Rare Ottoman Wreck: Yassıada, Turkey', 139.
[381] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 11.
[382] Pulak, 'A Rare Ottoman Wreck: Yassıada, Turkey', 138.
[383] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 12.
[384] Pulak, '1983 Yassıada Sualtı Kazısı - 1983 Sezonu', 473-4.
[385] Pulak, 'A Rare Ottoman Wreck: Yassıada, Turkey', 140-1.

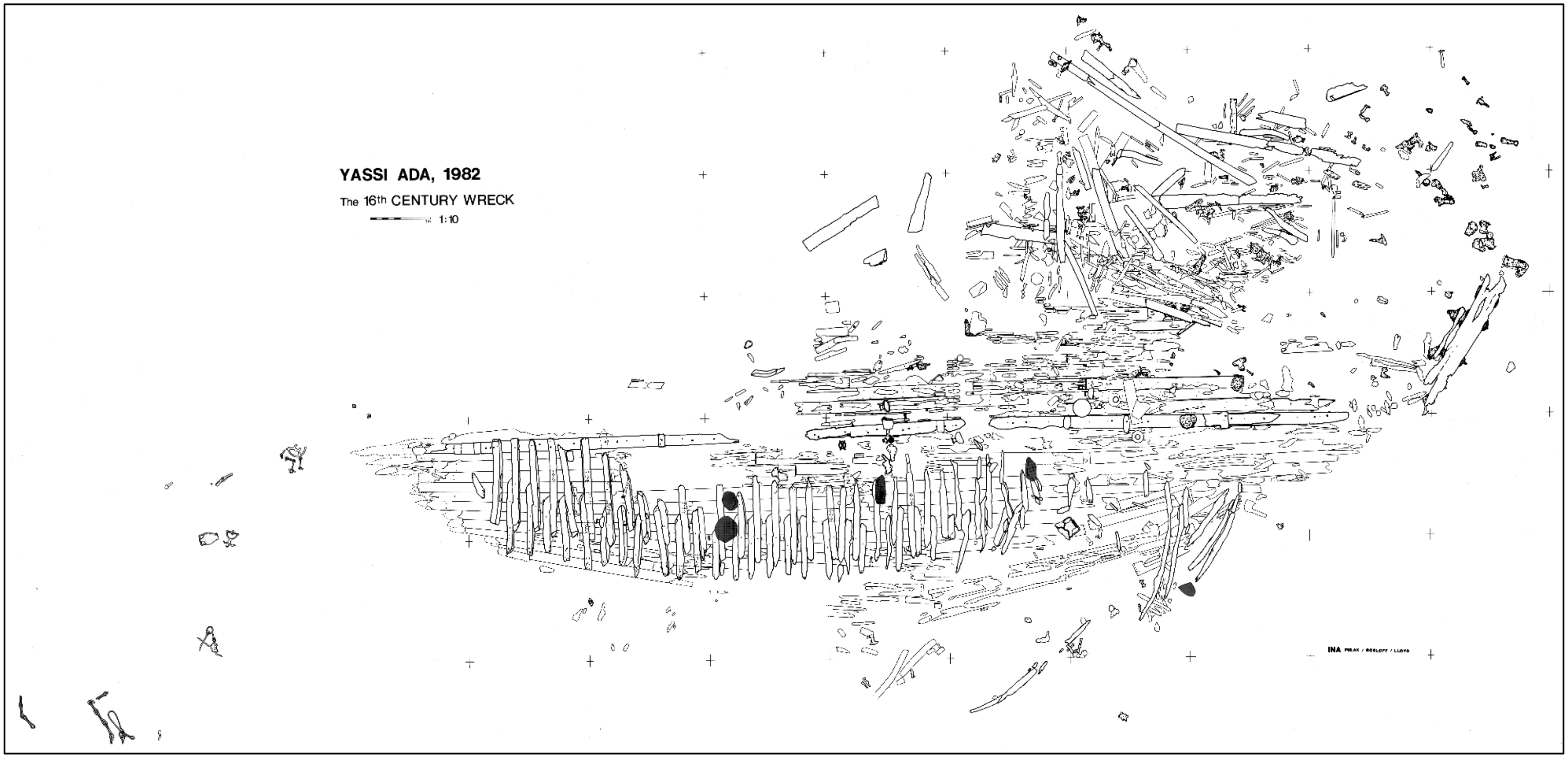

Figure 44 Site plan of the Ottoman Yassıada shipwreck. (Image: Cemal Pulak. © Institute of Nautical Archaeology)

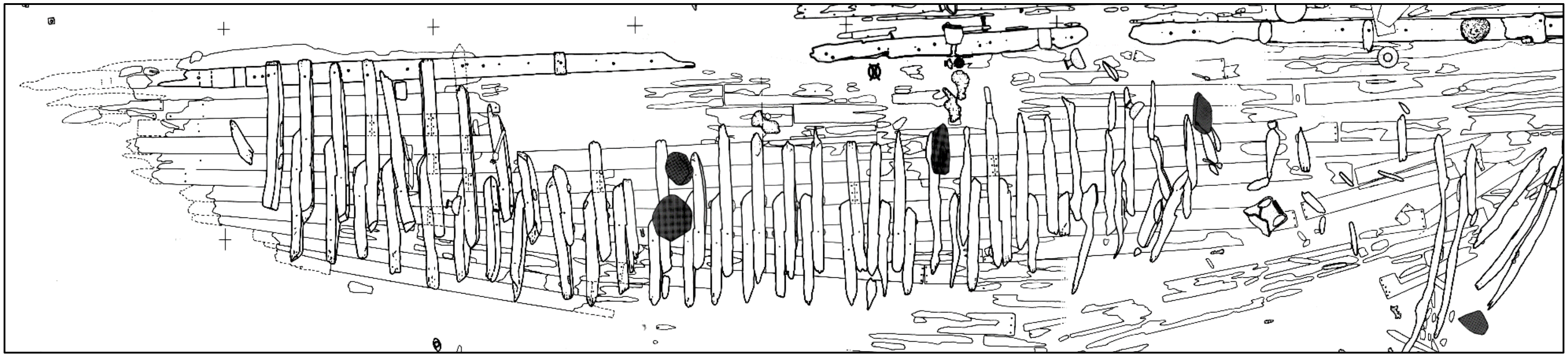

Figure 45   Expanded section of the Ottoman Yassıada shipwreck framing. (Image: Cemal Pulak. © Institute of Nautical Archaeology)

Yassıada's keel is square, without rabbets, and dendrochronology has indicated that this member was composed of three timbers.[386] Missing keel sections include the scarf connections to the endposts and each other, although the after face of the first keel section suggests a butt joint. No element of the stem survived, but a small lower section of a trapezoidal apron was recovered.[387] The shorter face of the apron rested against the keel to provide room for the garboard. It was held in place with nails, along with the bolts and treenails used to secure the keelson to the keel. Only a short section of the sternpost and associated inner sternpost survived, both pieces connected with four bolts.[388]

Based on the shape of the apron and sternpost, the ship is believed to be double ended. The lower assembly of a stern mounted rudder was found nearby, its shape suggesting it followed the curve of the sternpost. Floor timbers are believed to cross the centerline of the ship and were hook scarfed to overlapping futtocks. These two elements are fastened together with three iron nails clenched on opposite sides. Dual master frames were positioned slightly forward from the center of the ship. All framing had similar square dimensions with the space between frame stations roughly the same width as an average floor timber. This space is increased between futtocks. Each floor timber was initially connected to the keel with a single iron nail.[389]

No physical remains of the keelson survived, but its molded dimension (19.5 cm) could be deduced based on the surviving through bolts. Every third floor timber was bolted from the keelson to the keel, while treenails are inserted between frame stations. The straight direction of the treenails through the keelson and keel suggest this fastener was installed first, and the bolts

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[386] Liphschitz, 'Three Yassı Ada shipwrecks: A comparative dendroarchaeological investigation', 205-6 Cemal Pulak, pers. comm.
[387] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 44-50.
[388] Ibid., 50-4.
[389] Ibid., 56-60.

were later driven in at an angle from the outside.[390] Evidence of a bilge stringer was seen in excavation photographs from the 1967 field season, along with the presence of nail holes over the hook scarf connection between floor timbers and futtocks.[391] Preliminary analysis of the hull remains make no mention of any ceiling, although the size and shape (flat floor and round bilge) of the ship would suggest the presence of longitudinal planks between the keelson and stringer.

Planking is slightly thick for the size of the ship (5-6 cm), while its reported width (20 cm) also indicates direct access to a plentiful lumber supply.[392] Each strake is fastened to the frames with two or three iron nails. Treenails use was seemingly limited to construction sequence of the keelson. Fragments from a wale also survived, a piece double the thickness of the planking; its outside face had mushroom-headed bolts that acted as a guard when the ship was docked.[393] No caulking is identified, but pitch was used to cover both the inside and outside of the hull.

Cadiz-Delta II

Plans for a new container terminal in the Port of Cadiz, Spain included dredging within the proclaimed ‘Archaeological Easement Zone’. As a result, the Regional Department of Culture for the Self-Governing Region of Andalusia (Comunidad Autónoma de Andalucía) ordered a survey of the affected area. No archaeological sites were identified during a two-year survey in 2010/11.[394] The lack of finds allowed commencement of dredging operations within the area, while archaeologists were stationed to observe and halt progress if any cultural material

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[390] Ibid., 55-6.
[391] Ibid., 62-3.
[392] Ibid., 63-5.
[393] Ibid., 67-70.
[394] Alzaga García et al., 'El proyecto delta, ejemplo de investigación y protección del patrimonio arqueológico subacuático de Andalucía', 23-5.

was encountered. After dredges removed 7 m of sediment from the bottom of the harbor, two shipwrecks (Delta I and II) were uncovered. Delta I was later identified as a seventeenth-century Spanish shipwreck carrying goods from the Americas that included a silver ingot.[395] Subsequent dives identified Delta II as a 24 m by 8 m hull, 12-16 m tall structure with significant surviving cargo on board.[396] The Regional Department of Culture funded further archaeological work on both wrecks while construction of the nearby terminal continued. Due to the extent of preserved remains, Delta II was recorded in situ, while the reduced surviving hull structure from Delta I allowed this wreck to be moved to a shallower area within the port for further work.[397]

Seven bronze cannons cast by the Gioardi family of Genoa were uncovered on Delta II. Two of them appeared to be mounted for the ship's defense, and hurled stone cannonballs while the other five were found in the hold.[398] A single wrought iron cannon was found, along with two iron anchors stored with the bronze guns. Other cargo included a large quantity of ceramic jars carrying olives in brine; woven esparto grass was wrapped around the jars or placed beneath them to prevent breakage.[399] Large wooden barrels were found filled with cochineal dye from the Americas, along with a shipment of dense lignum vitae wood. Other cargo include boxes of agricultural foodstuffs, a pair of dividers for navigation, leather shoes, and animal remains.[400]

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[395] Manuel Higueras-Milena Castellano, Gallardo Abárzuza, and Ruiz Aguilar, 'Intervenciones arqueológicas en los dos pecios localizados durante la construcción de la Nueva Terminal de Contenedores del puerto de Cádiz', 206-7.
[396] Gianni Ridella et al., 'The Cadiz-Delta II wreck: The "San Giorgio", a Genoese merchantman sunk by Francis Drake in 1587', 12-13.
[397] Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta: Pecios localizados y excavados durante las obras de construcción de una nueva terminal de contenedores en el puerto de Cádiz', 872.
[398] Gianni Ridella et al., 'The Cadiz-Delta II wreck: The "San Giorgio", a Genoese merchantman sunk by Francis Drake in 1587', 11.
[399] Manuel Higueras-Milena Castellano, Gallardo Abárzuza, and Ruiz Aguilar, 'Intervenciones arqueológicas en los dos pecios localizados durante la construcción de la Nueva Terminal de Contenedores del puerto de Cádiz', 210-1.
[400] Ibid., 880-1.

Archival research identified the wreck as the *San Giorgio e Sant'Elmo* (also known colloquially as *Vassallo*) that sank during Francis Drake's 29 April 1587 raid on Cadiz. The ship was originally built at Portofino, outside Genoa, in 1573 by Pietro Paolo Vassallo.[401] Vassallo sailed on *San Giorgio*'s maiden voyage before turning over command to Clemente Vassallo, who remained the ship's master until its demise. Documents obtained from Spanish and Italian archives show the ship traveled mainly between Western Mediterranean ports and the Iberian Atlantic. It sailed as far east as Sciacca, Sicily, stopped at Ibiza in the Balearic Islands, and all along the Spanish coastline between Alicante, Cartagena, and Cadiz.[402] On its last voyage, the ship departed Genoa in July 1586 and stopped at Cartagena, where Vassallo obtained the bronze artillery meant for the 1588 Spanish Armada organizing in Lisbon. When Drake attacked Cadiz, the ship was in the process of unloading the cannons while taking on the Spanish and American cargos bound for Italy.[403]

Research on this wreck has yielded several publications mainly focused on the artifacts, cannons, and archival research. Only a preliminary description of the ship construction is available, due to the material being reserved for a dissertation in Spain.[404] What is known, suggests construction similar to other Mediterranean vessels. There is a single keel rebated for the garboards. A stern knee is fitted atop the keel's after end. Floor timbers are hook scarfed to overlapping futtocks and this connection is secured with two iron nails. No other information is

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[401] Gianni Ridella et al., 'The Cadiz-Delta II wreck: The "San Giorgio", a Genoese merchantman sunk by Francis Drake in 1587', 16.
[402] Ibid., 17-19.
[403] Ibid., 23-4.
[404] Manuel Higueras-Milena Castellano, pers. comm.

known about the frames, except that the Y-timbers near the stern were bolted to the keel. The keelson is briefly mentioned as composed of three separate pieces Jupiter scarfed together.[405]

Towards amidships, there is a mainmast step with two mast step partners along either side of the keelson supported by five pairs of buttresses. Three keys dovetailed into the adjacent mast partners create two mortises, with the forward section was reserved for the mainmast heel and the after section supporting the foot of the halyard knighthead and ship's pump.[406] A bilge stringer was fitted over the floor timber-futtock scarf with ceiling present between this timber and the keelson. Above the stringer is a sill crenulated for filling the spaces between futtocks. The bottom of the hold had a raised platform with planking running perpendicular to the centerline of the hull. The inboard ends of this planking fit into rebates cut into the top edges of the keelson, and the outboard ends terminated at the bilge stringers.[407] Planking had an average thickness of 6 cm and was attached to the framing exclusively with iron nails. Every strake below the waterline is covered in lead sheathing.[408]

No description of the overall shape of the hull is available. Other contemporary ships originating from the Ligurian coast are either wineglass shaped or round without a flat floor.[409] The raised platform found on *San Giorgio* suggest one of these profiles for this ship as well.

Kadırga

The Naval Museum of Istanbul contains a small galley once used by Ottoman sultans for ceremonies and travel along the Bosporus or Sea of Marmara. The longship, known simply as *Kadırga* (galley in Turkish), might represent one of the oldest examples of a vessel not recovered

[405] Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 879-80.
[406] Ibid., 878-9.
[407] Ibid., 880.
[408] Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880.
[409] See *Lomellina*, Mortella III, and Calvi 1 this chapter.

as part of an archaeological investigation.[410] Who made the vessel or when it was built are unknown. An inscription in the stern kiosk mentions a Sultan Mehmed who was originally thought to be Sultan Mehmed IV (1648-87).[411] Other scholars have also made the argument that Sultan Mehmed II (1444-46 and 1451-81), the conqueror of Constantinople, had the vessel built or secured it from the last Byzantine Emperor, Constantine XI Dragazes (1449-53).[412] Museum records for the ship are incomplete, but mention repairs or replacement of structure below the waterline.

Available ship plans also proved inaccurate, as the two main drawings that exist do not match each other. A French naval architect, Le Bas, was the first to create proper ship plans that were subsequently published by French Admiral François-Edmond Pâris in 1861.[413] The Director of the Shipbuilding Institute at Istanbul Technical University, Ata Nutku, completed new lines drawings in 1957.[414] The keel shape and stern assembly in the two plans do not match. Bas' drawing indicates that the *Kadırga* had a rockered keel and that the stern assembly was design to continue this curve upward. On the other hand, Nutku's plans are a closer representation of how the longship looks today, with a flat keel and a hard angle where the keel meets the curved sternpost. Recent re-recording of the stern revealed an inner sternpost that matches the curve of the true sternpost, but its lower half was cut off in the past. The same observation could be made for the rudder, which was longer on Bas' drawing, but is now cut shorter to match the current keel.[415]

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[410] Basch, 'A Galley in Istanbul: The Kadırga', 133
[411] Arcak, 'Kadırga: The Sultan's Galley', 15
[412] Basch, 'The Kadırga Revisited', 49
[413] Dönmez Yakarçelik, 'Deniz Müzesi'nde Sergilenen Tarihi Kadırga', 177
[414] Arcak, 'Kadırga: The Sultan's Galley', 19
[415] Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 242-3, figs. 36.2-36.3.

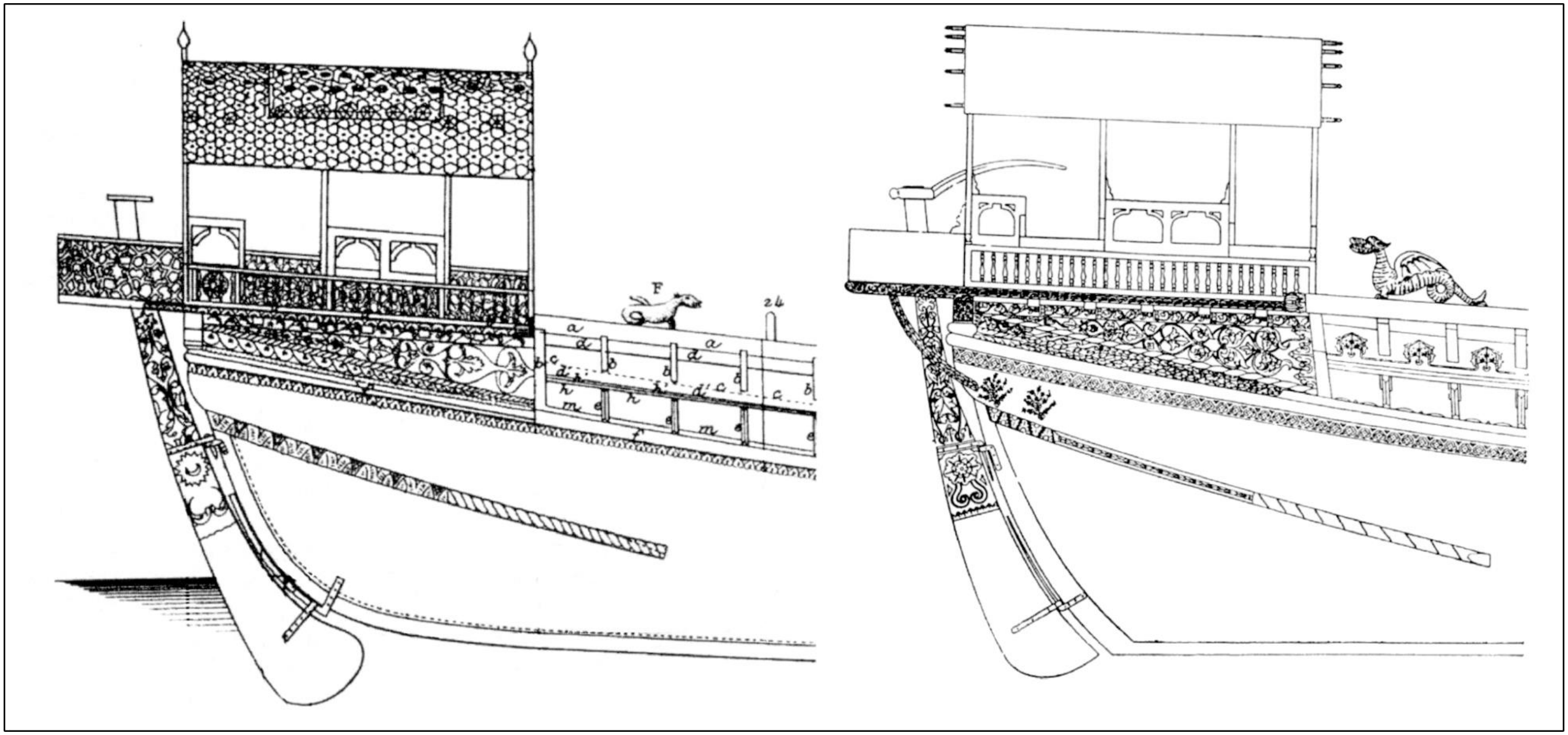

Figure 46   Stern plans for the Kadırga with Le Bas' 1861 drawing on left and Ata Nutku's drawing from the 1950s on the right. (*after Arcak, 'Kadırga', 242-243)*

Bas' original plans probably indicate the original design of the ship prior to a restoration effort that took place in the second half of the nineteenth century (figure 46).[416] Documentary and archaeological evidence from longships portrays rockered keels as standard until the beginning of the seventeenth century. This characteristic supports an earlier building date for the longship than the mid-seventeenth century.[417] Dendrochronological samples of a floor timber and the keel conclude that the timbers were possibly felled in the first half of the nineteenth century and support their inclusion in the hull as part of a rebuilding ordered in 1885 by Sultan Abdulhamid II (1876-1909).[418] Five other samples collected from two floor timbers, a futtock, an upper plank, and the kiosk were radiocarbon dated providing a 68 percent probability date 1528-1647 or 95 percent probability between 1521-1655.

An earlier argument that the vessel was built by Venice as a gift can also be ruled out, as an analysis of over 1,600 samples concluded all the timber were native Turkish species.[419] The dendrochronological analysis also determined that the hull was built before a kiosk was subsequently added. Current evidence suggests the ship was built sometime between the end of the sixteenth and beginning of the seventeenth century. If the inscription mentioning a Sultan Mehmed in the kiosk was not added at a much later date, then it may refer to Mehmed III (1595-1603). Another radiocarbon date between 1493 and 1807, and a silver stamp found in the kiosk imply Sultan Suleiman I (1520-66) as the original owner.[420]

Compared to archaeological sites that are sometimes described as time capsules for preserving a specific moment in history, *Kadırga* is more akin to a historical building or

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[416]Pulak, 'Dunyanin Yasayan En Eski Gemisi "Kadirga"', 22.
[417] Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 248.
[418] Liphschitz, 'The Kadirga Galley in Istanbul – The Turkish Sultan's Caique: A dendrohistorical research', 43.
[419] Ibid., 44-7.
[420] Dönmez Yakarçelik̇, 'Deniz Müzesi'nde Sergilenen Tarihi Kadırga', 174

monument that was repeatedly refurbished over several centuries. Original construction characteristics were lost due to indifferent reconstructions, with mixing of older elements and new without any documentation to differentiate them. Recent efforts to date the individual timbers has provided additional context and identified surviving material. Evidence from the dendrochronological studies supports that not all the framing and planking was replaced. The following text describes the current layout of the hull with its original and replacement pieces.

As mentioned previously, *Kadırga*'s current keel is a nineteenth-century replacement of an earlier rockered keel with a rabbet. The replacement keel is rectangular, flat scarfed to the stem and half-lapped at the stern, and there is no rabbet. Both endposts are curved and assembled with two pieces horizontally scarfed together. An apron covers the first few bow frames and is bolted to the stem, while its after section is flat scarfed to a replacement keelson.[421] Framing is composed of floor timbers hook scarfed to overlapping futtocks. This connection is fastened with three iron nails double clenched on their outboard ends. Floor timbers are rectangular in shape, while the futtocks are generally square. Space between frame stations is approximately three or four times the width of any given frame. The original assembly of the ship included dual master frames positioned amidships. *Kadırga*'s keelson is also a replacement from the nineteenth century.[422] The keelson is square and does not fit over the floor timbers, and there is no ceiling in the hold. Le Bas' drawing indicates the original keelson was rebated to fit over the floor timbers.

Three stringers are present: one placed between the keelson and turn of the bilge, one partly over the overlap between the floor timbers and futtocks, and the last along the center point of the first futtocks. The first two stringers are planks, while the last example is more robust and

[421] Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 244.
[422] Ibid., 244-5.

recessed over the futtocks with chamfered top edges.[423] Only the upper stringer appears to be original and its position along the futtocks is similar to other contemporary examples. Much like Calvi 1, there is a pair of *massane* (stern wales) attached at the outside juncture between the lower Y-frames and their turn outward to support the after deck. The *massane* transition into the rest of the planking toward amidships. Planking is thin (3.5 cm), corresponding to the smaller size and lighter weight intended for the vessel.[424]

Kadırga is a single decked ship and there is a heavy shelf clamp with an adjacent wale supporting the outrigger. Beneath the wale is a recessed strake thicker than the rest of the planking that provides extra longitudinal support in this area. A total of 54 beams span the hull and are covered in longitudinal deck planks.[425] Stanchions rest atop keelson support a *corsia* (gangway) running along the centerline of the hull beneath the beams. The current transverse hull section has a slight deadrise above the keel and around bilge that matches the shape drawn by Bas in 1861.

Cap Lardier 1

Along the Mediterranean coast of France, situated 400 m east from Cap Lardier, are the remains of a late sixteenth-century shipwreck. The wreck was known to local divers by 1960 but was not reported to authorities until 1969. Situated close to the rocky shoreline and buried in sand, its location encouraged tourism, but no scientific investigation took place until 1986/7.[426] Archaeologists removed Posidonia off the site and uncovered a moderately sized vessel containing a cargo of slate and other materials. The slate was stacked in rows at the bottom of the

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[423] Ibid., 245, fig. 36.7.
[424] Ibid., 245-6.
[425] Ibid., 246.
[426] Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVI^{e} siècle', 5-6

hull. Analysis of the stone suggested it was from quarries around Fontanabuona, Italy and was transported to the coastal town of Lavagna east of Genoa and loaded onto the ship.[427] Other parts of the cargo included polychrome tableware with incised decorations, ceramic jars, bags carrying iron nails, sandstone grinding wheels, floor slabs, and paving stones. Objects associated with the ship comprised common ceramics, a chisel, flint, a glass bottle neck, and an intricate set of tiny copper chains, rings, and needles.[428] Archaeologists working on the site discovered 15 m debris field in the direction of the cape. The current interpretation of the site suggests the heavily loaded vessel traveling too close to shore, hit the rocky coast, and sank a few hundred meters from the point of impact.

The slate cargo acted as ballast on this voyage and after the sinking its weight flattened the surviving hull structure, pinning it into the sandy bottom (figure 47). What remains of the keel includes the forward end, indicating it simply butted the missing stem, although a stopwater was inserted between these two timbers.[429] The keel is almost square and there is no rabbet for the garboard. The full length of the keel is unknown, as its after section is missing along with the stern assembly. Most of the framing was crushed by the slate cargo, but the few remains indicate that floor timbers merely overlapped with futtocks and the two were secured by three nails clenched on opposite sides. Floor timbers are rectangular and closely spaced in the surviving examples toward the front of the hull. None of the floors survive amidships, but their original positions can be identified by iron fastening concretions on the planking.[430]

It is difficult to determine whether the framing was based on a single or dual master

[427] Ibid., 46.
[428] Ibid., 31-43, 49-51.
[429] Ibid., 25.
[430] Ibid., 25-8.

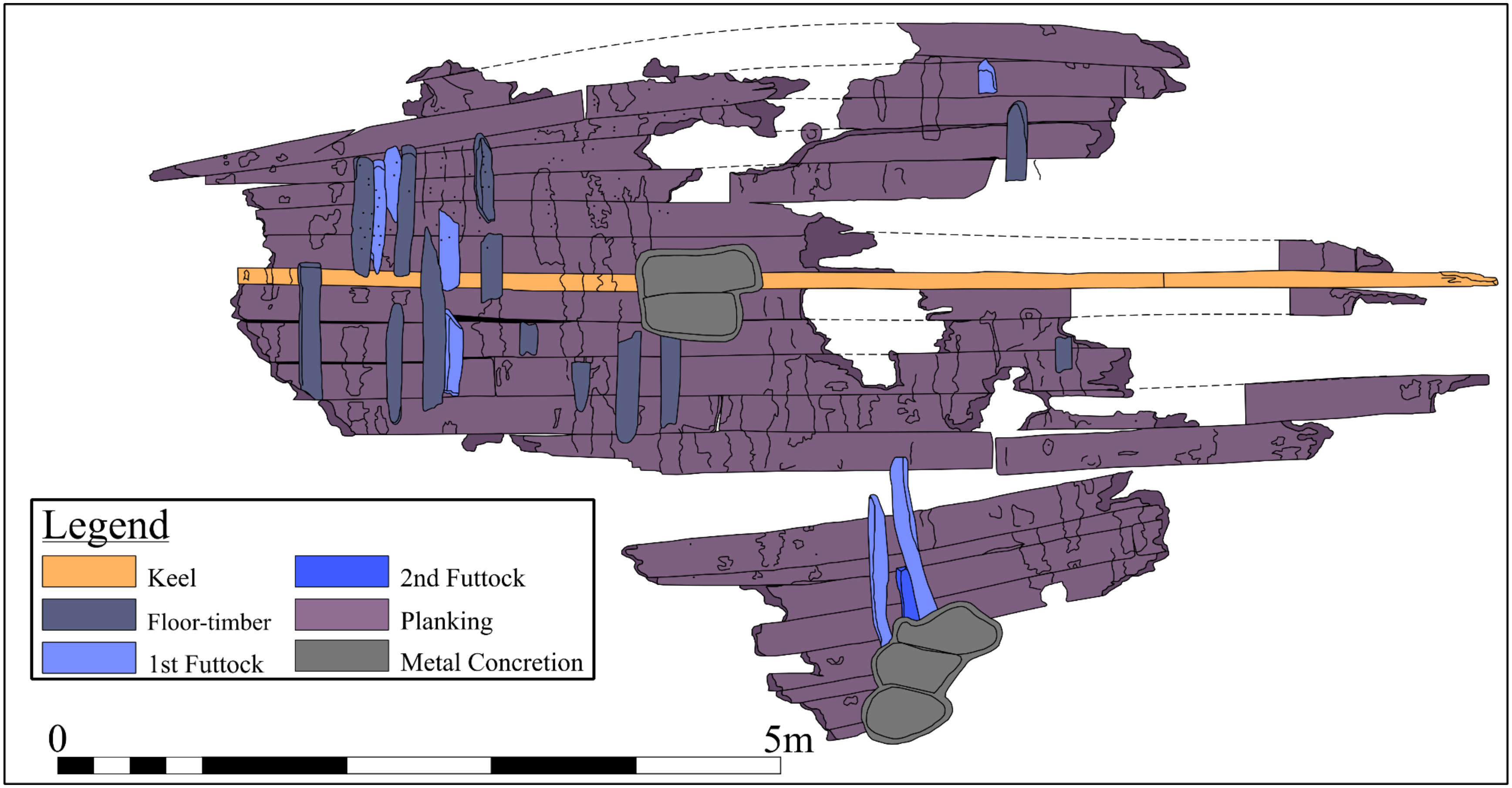

Figure 47 Site plan of the Cap Lardier 1 shipwreck. (after Joncheray, 'L'épave dite «des ardoises», au cap Lardier', 23)

frame. Two futtocks near amidships have little space between them, suggesting that they were on either face of a single floor timber.[431] The other surviving futtocks are attached on the faces of floor timbers toward the center of the ship (usually the pattern is the opposite). No evidence of the keelson survives, except for three bolts driven through floor timbers. Planking is slightly thicker (4.2 cm) than seen on similarly sized vessels. Each strake was fastened with one to three iron nails. Additional nails were included at key locations, such as the connection of the garboards to the frames, around the turn of the bilge, or for scarfs in the planking. There is at least one example of a half-lap scarf between two planks.[432]

Agropoli

Directly off the coast of Agropoli, Italy, a wreck was reported in 2000 to the Superintendence for Archaeological Heritage of Naples and Caserta (Soprintendenza per i Beni Archeologici di Napoli e Caserta). Located 130 m northeast of Castello Angioino Aragonese, the wreck rests on a sand substrate with a scattering of ballast covering wooden remains. Paolo Caputo documented the site for the Superintendence during the same year it was reported.[433] In 2004, the Italian Ministry for Cultural Heritage and Activities (Ministero per i Beni e le Attività Culturali e per il Turismo) initiated surveys for underwater cultural heritage in Campania, Basilicata, Calabria, and Puglia. The initiative was called Archeomar and involved a multidisciplinary approach to collect information in shallow and deep-water environments.[434] Archeomar project members revisited the Agropoli site in 2004 and recorded it in the master database as the remains of a galley.

[431] Ibid., 23.
[432] Ibid., 28-30.
[433] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 72.
[434] Vizzino, 'Il Recupero dei tesori sommersi: Progetto Archeomar'.

Due to the few longship remains known throughout the Mediterranean, the Archeomar project funded a short excavation to quantify the remains. [435] Only a single ceramic sherd was located on site but it lacked diagnostic features to provide a date.[436] The lack of artifacts may be a testament to the salvage of a wreck so close to shore, the shifting environment, and activity of divers after its discovery. Two wood samples sent for radiocarbon dating placed the wreck between the fifteenth and seventeenth centuries.[437] Archaeologists also located two cast iron cannons near the site that were also dated to the seventeenth century, while the ship construction itself suggest anywhere between the mid-sixteenth and early seventeenth century.[438] Only the axial timbers, stern rudder, several strakes of planking, and a handful of frames on the portside survived. Nonetheless, these elements discounted the original premise that the vessel was a longship and instead suggest it is more likely a round ship.

The mostly intact keel had a shallow rectangular cross section, although it is supplemented by a 7 cm thick false keel. The small surviving fragment of the stem indicates the lower section is hook scarfed to the keel and both are rabbeted. Two sections of the keel are butted together without any scarf amidships. The ship has a straight sternpost with a short inner post that butted the top of the keel.[439] The inner sternpost was cut to act as the rebate for the lower planking hood ends (figure 48). After the garboard and the next strake above, this rabbet becomes shallower and shifts the planks on each upper strake forward slightly. An unusual framing element which resembles a fashion piece at the transom is positioned between the stern

[435] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 71-2, note 2.
[436] Massimo Capulli, pers. comm.
[437] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 73.
[438] Ibid., 74.
[439] Ibid., 72-3; Capulli, 'Il relitto di Agropoli, risultati preliminari', 16-17.

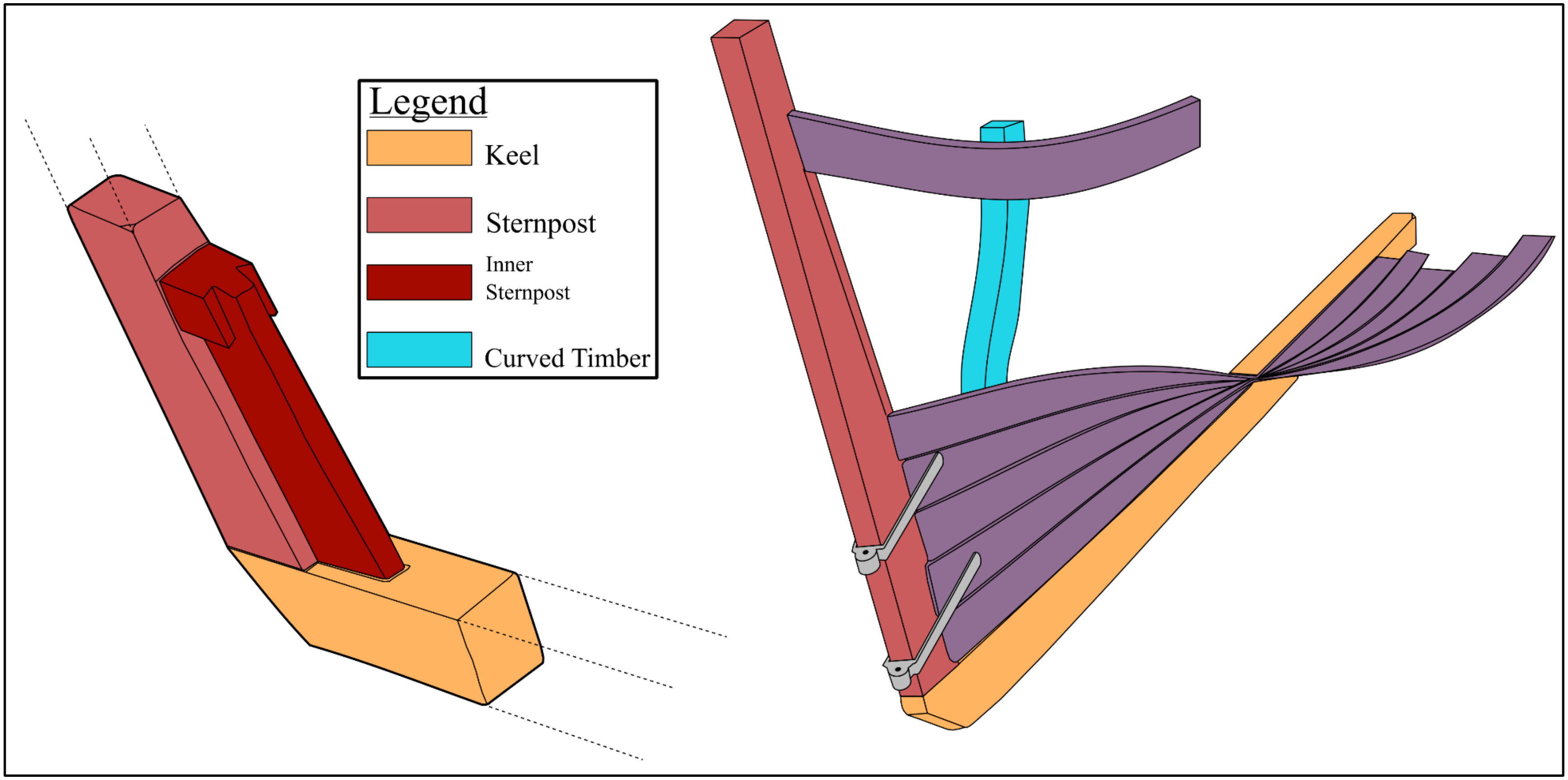

Figure 48   Stern assembly from the Agropoli shipwreck. (after Bondioli et al., 'Note storico-archeologiche', 74)

frame stations to help the upper strakes bend around it, creating a flat tuck.[440] Two gudgeons and pintle pairs were identified on the lower section of the sternpost alongside the adjacent rudder. The after end of the keel is cut off at an angle creating a chamfer instead of the skeg seen on earlier examples.

Framing consist of floor timbers that overlapped futtocks without any scarf but are secured using iron nails driven from both sides.[441] Floor timbers are rectangular with the space between frame stations roughly the same width. Initial construction utilized dual master frames that butted together at amidships. Iron stains on top of the floor timbers suggest these are nailed to the keel.[442] A relatively square timber found over the floor timber and futtock overlap is thought to be the keelson rather than the bilge stringer. There is a surviving square mortise on its top face, presumably for a missing stanchion rather than the mast step.[443] Garboards and the rest of the surviving planking are relatively thick (8 cm) compared to the estimated length of the original vessel (23 m). Planking is also relatively wide (32-34 cm) and there is evidence for at least one repair where a section of a strake was cut out and a new piece inserted.[444] The outside elements of the hull show evidence of lead sheathing up to the waterline. Examination of the surviving frame profile suggests the ship has a slight deadrise with a round bilge.

Sveti Pavao

Mediterranean coasts with island archipelagoes were often used by mariners for stopovers on long sea voyages.[445] The islands of the Dalmatian coast of modern Croatia were

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[440] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 73-4, fig. 5-6.
[441] Massimo Capulli, pers. comm.
[442] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 73.
[443] Capulli, 'Il relitto di Agropoli, risultati preliminari', 21.
[444] Ibid., 72-3.
[445] Crowley, *City of Fortune: How Venice ruled the seas*, 28.

adjacent to historic trade routes in the Adriatic and became a strategic area of importance occupied by various powers over the centuries. The remains of a shipwreck in the Sveti Pavao shallows along the southeastern shoreline of Mljet island southwest of Korita were reported to authorities in the early 1990s. Initial surveys of the site retrieved artifacts that suggested the ship was from the fifteenth century.[446]

Few wrecks along the Croatian coastline were known for this period, which led to systematic archaeological work on site beginning in 2007. Early fieldwork focused on retrieving seven bronze artillery pieces and other artifacts that could be lost to souvenir-hunting divers. Inscriptions of the artillery pieces included weights based on the Venetian pound and showed that they were cast by Venetian founder Tommaso di Conti before 1540.[447] Beginning in 2010, the Department of Underwater Archaeology and Croatian Conservation Institute began working with the Humanities Department of the Ca’ Foscari University of Venice to analyze the hull remains.

The site itself is 37-46 m deep on a steeply sloping sand bottom. Artifacts and ballast were scattered over a wide area. Bottom time was limited by the depth to 18-20 mins on average and the joint team worked for two field seasons to recover 316 artifacts.[448] Most of the recovered material suggests a ship carrying an inbound cargo from the Ottoman Empire, as the main assemblage consists of blue and white faience bowls from Iznik in modern-day Turkey and lead seals alluding to sacks or leather bags of textiles.[449] Other materials include ceramic jugs,

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[446] Beltrame and Miholjek, 'Introduction', 2.
[447] Beltrame, Mihajlović, and Miholjek, 'The hull of the 16th-century Venetian shipwreck off the Island of Mljet (Croatia)', 403; Miholjek and Zmaić, 'Recent underwater archaeological research off the Croatian coast', 108.
[448] Beltrame and Miholjek, 'Introduction', 4.
[449] Zmaić Kralj, 'A transport of Iznik pottery', 65-6; Bezak, 'Metal Finds', 119-20.

kitchenware, animal bones, and a collection of Ottoman (1512-85) and Saxony (1544-59) coins.[450]

Another major artifact recovered was a bronze bell with the year 1567 on the relief, suggesting a possible date for when the ship was built.[451] Based on the collection of artifacts, it is believed the ship was a Venetian round ship sunk in a storm while returning home and sometime between 1574-85 (presumed 1580).[452] Although the cooperation between the Croatian and Italian groups ended in 2012, the Croatian Conservation Institute continues to excavate the wreck today (2020).[453]

Sveti Pavao is an unusual round ship, due to investigators claim that its construction was bottom-based with a keel plank rather than a true keel (figure 49). Only a 6 m by 3.7 m section of the hull is published from the earlier excavation.[454] This section includes part of the forward end of the ship and amidships. Further uncovering of the structure may reveal how the keel plank was attached to the stern (timbers toward the bow are eroded away).[455] Framing consists of floor timbers with shallow hook scarfs to connect the overlapping futtocks. The connection was secured using two iron nails. Floor timbers and futtocks are square near amidships and become rectangular further away. Spacing is the same width as the average floor timber, although this is also reduced at amidships beneath the mainmast step. Based on the increased size of the floor timbers beneath the mainmast step and the framing pattern, it is believed that the ship was first

[450] Miholjek and Zmaić, 'Recent underwater archaeological research off the Croatian coast', 107-8.
[451] Bezak, 'Metal Finds', 114-6.
[452] Beltrame, 'Considerations of dating and the historical context of the Mljet shipwreck', 151.
[453] Igor Mihajlović, pers. comm.
[454] Beltrame, Mihajlović, and Miholjek, 'The hull of the 16th-century Venetian shipwreck off the Island of Mljet (Croatia)', 405.
[455] Beltrame, 'The ship, its equipment and the crew's personal possessions', 48.

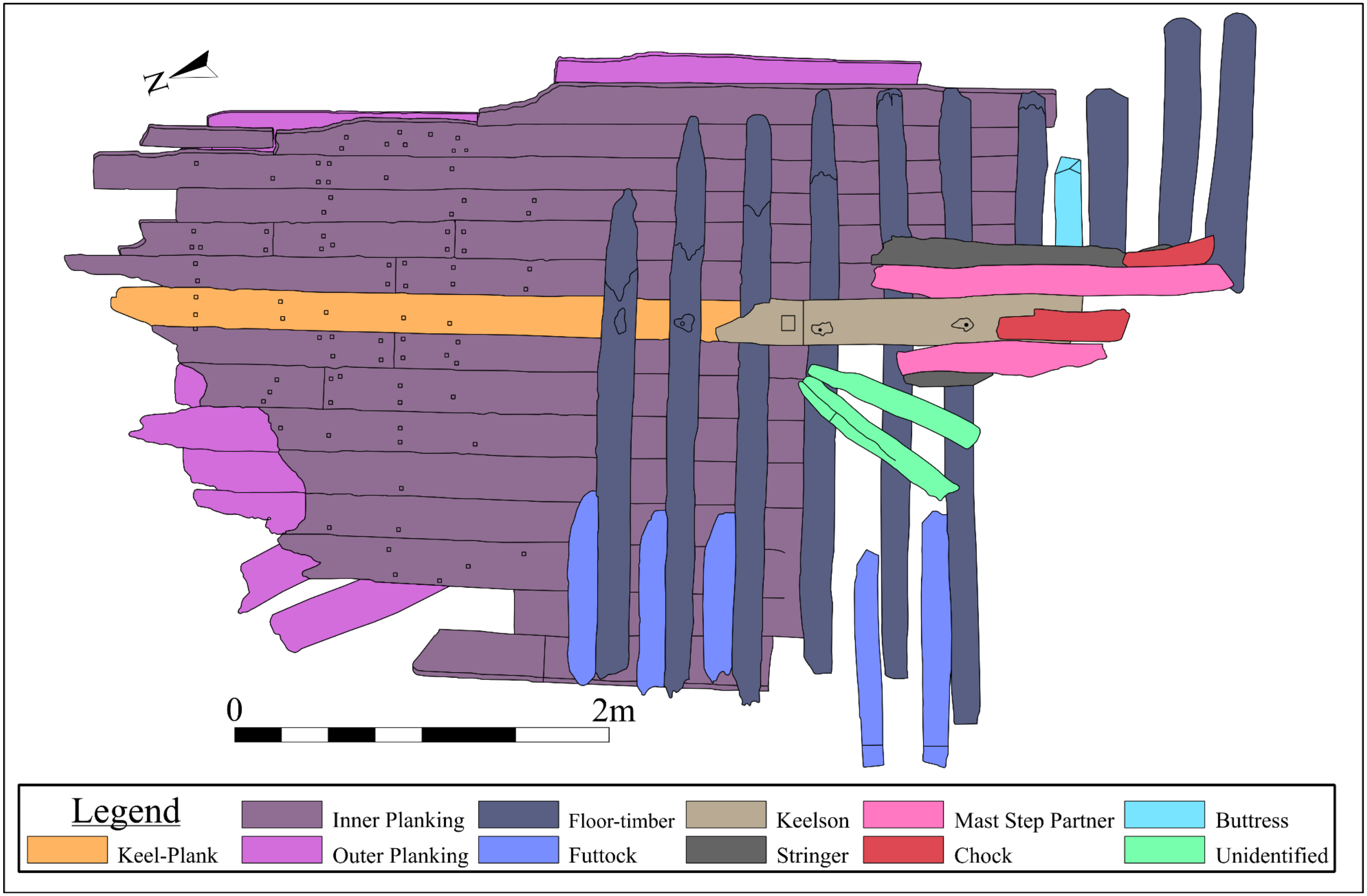

Figure 49 Recorded remains from the Sveti Pavao shipwreck. (after Beltrame, 'The ship', 46)

assembled with dual master frames.[456] Surviving elements of the rebated keelson include bolts that were driven through every other floor timber to connect with the keel plank. No surviving evidence for bilge stringers was noted, but these were likely fitted over the floor-first futtock scarf.

Excavators also uncovered part of the mainmast step, composed of two mast partners on either side of the keelson. Each mast partner is shorter at the extremity and rose higher near the center of the mast step. The starboard mast partner includes a mortise for a buttress and a loose example of a buttress was found in this area. On either side of the two mast step partners a pair of stringers helped to secure the partners in place. A wedge-shaped chock was also found above the keelson and a broken section of it rests against the starboard mast step partner. The chock was originally used to create the forward edge of the mainmast mortise.[457] None of the top faces of the floor timbers exhibit iron stains or fastener holes for ceiling. Absence for ceiling fasteners may suggest a transverse platform in the hold with its inboard ends resting against the mast step partners and the outboard ends over the bilge stringer.

Another unusual trait of Sveti Pavao wreck is its double-planked hull. The inner planking is slightly thinner (5 cm) than the outer casing (7.8 cm).[458] Investigators believe that the thickness of both layers downplays the outer planking rule as sacrificial planking. Fastener patterns recorded for the inner planking suggest a familiar pattern for most contemporary examples with two to four iron nails per frame station. There was no evidence for treenails in the ships' assembly. If future work on Sveti Pavao confirms the keel plank, this shipwreck would

[456] Beltrame, Mihajlović, and Miholjek, 'The hull of the 16th-century Venetian shipwreck off the Island of Mljet (Croatia)', 404, fig. 2.
[457] Beltrame, 'The ship, its equipment and the crew's personal possessions', 48-9.
[458] Beltrame, Mihajlović, and Miholjek, 'The hull of the 16th-century Venetian shipwreck off the Island of Mljet (Croatia)', 405.

represent the largest known example of Mediterranean bottom-based construction classified as a merchantman.

Church Rocks

Near Teignmouth, Devon in the south of England a snorkeler swimming along the coast at the Church Rocks reef located a Venetian bronze saker sticking out of the sand in 1975 after a season of winter storms scoured the area. Two more bronze cannons were retrieved the following year and the site was given protected status in 1977 under the guidelines of the 1973 Protection of Wrecks Act.[459] Excavations in 1979 located further artifacts, including ship fasteners, a wrought iron breech block, tools, and the pintle for a stern rudder. Additional items, including three more bronze cannon, a few ceramics, and a portion of the ship's hull were located in 1982.[460] The Archaeological Diving Unit at the University of Saint Andrews, Scotland initiated renewed fieldwork between 1990 and 1994. Only in 1992 were excavators able to revisit the timbers from 1982 and uncovered a few more associated items.[461]

The bronze cannons were likely cast by Venetian gun founder Sigismondo Alberghetti II. Sigismondo was the chief founder at Venice between 1582 and 1601. Due to the limited finds from the wreck, the earlier date is also the terminus post quem for the site.[462] At least one of the swivel cannon recovered includes imagery of the lion of Saint Mark, a well-known personification of the Venetian Republic.[463] Excavators also recovered a caulking pot, kitchen ware, tools, a merchant seal to brand on wooden containers, and a steelyard. Limited ceramic

[459] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 99-101
[460] Preece and Burton, 'Church Rocks, 1975-83: A reassessment', 257
[461] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 109-10
[462] Tomalin, Cross, and Motkin, 'An Alberghetti bronze minion and carriage from Yarmouth Roads, Isle of Wright', 79-80, 3-4; Dudley, 'Alberghetti Guns', 268
[463] Preece and Burton, 'Church Rocks, 1975-83: A reassessment', 261-4

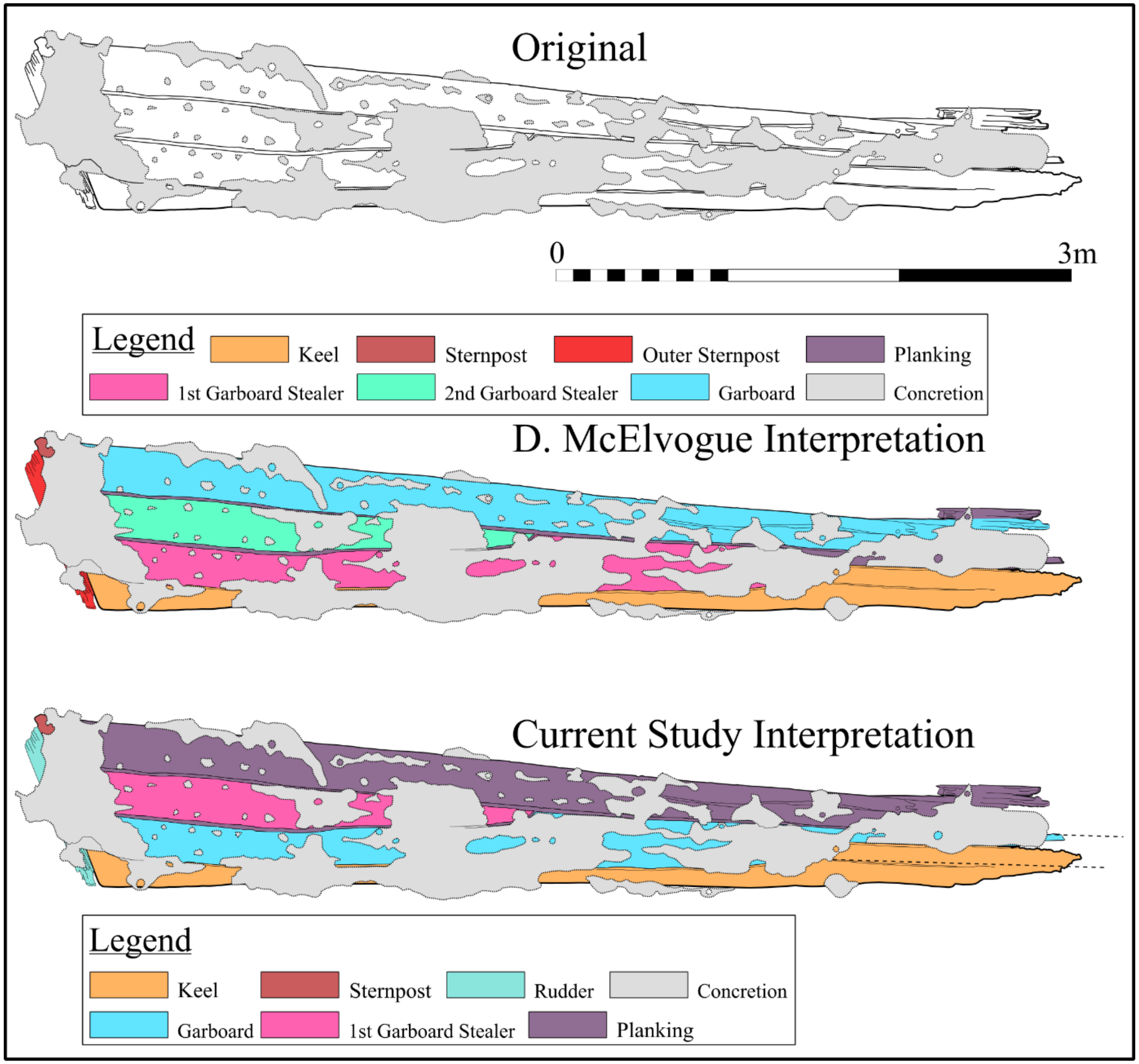

Figure 50 Surviving stern assembly from the Church Rocks shipwreck. (after Preece et al., 'Church Rocks', 111)

finds include sherds associated with an incendiary weapon known as a firepot.[464] Two pieces of a Wan Li porcelain bowl also helped to date the site to the last quarter of the sixteenth century. Another fragment of a blue tin-glazed decorated sherd of Italian ware and a piece of orange earthenware identified as Portuguese *terra sigillata*, suggested elite personnel or merchants traveling on board the ship.[465]

The only major piece of ship architecture recorded is the bottom of the stern assembly that was found in 1982 and documented a decade later (figure 50).[466] The 5.75 m keel fragment is longest piece of structure, measuring 35 cm molded and an estimated 55 cm sided. This measurement does not seem to correlate with the site plan, which suggests that the broken forward end of the keel was roughly 24 cm deep. A rabbet extends along the top of the keel where the garboard is inserted.[467] The concretion still attached to the hull prevented the gathering of further information, such as how the sternpost is connected to the keel. Information collected during the 1992 survey indicates the sternpost is angled 70°. A separate outer post is attached to the after face. As with the keel measurement, a similar difference is seen from the site plan with a 68.5° angle. The after post may also be a portion of the rudder, as archaeologists also acknowledge that the concretion in this area might encapsulate a lower gudgeon-pintle assembly.[468] Three strakes of planking survive, each fastened with two or three iron nails per frame station, while several larger bulbous concretions suggest horizontal bolts also connecting

[464] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 104-9
[465] Ibid., 109, 112.
[466] Preece and Burton, 'Church Rocks, 1975-83: A reassessment', 259
[467] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 116-7
[468] Ibid., 117.

the planks to the frame underneath. Poor diving conditions in 1993 prevented the recording of cross sections or the internal framing.[469]

Based on the limited hull remains and small collection of finds, the type it vessel represents is open to question. The artifacts, including the Venetian bronze cannons, and the lack of treenails in the hull assembly, suggest a late sixteenth-century Mediterranean vessel.[470] The confusion stems from whether the hull represents a longship or round ship, depending on how the surviving material is evaluated. The Historic Buildings and Monuments Commission for England lists the ship as a trading galley, due to the historically recorded armament for these vessels.[471] Doug McElvogue argues that the short stealers in the stern assembly are indicative of a sharp change in the hull, alluding to a reduced length-to-breadth ratio typically associated with round ships.[472] On the other hand, the Teign Heritage Center, which displays many of the recovered artifacts, proposes that the wreck might be similar to a small *Zabra*.[473] This type of vessel was a hybrid supposedly combining the best traits of longships and round ships; they were used as service vessels in fleets from the second quarter of the sixteenth century onward.[474]

Trinidad Valencera

In February 1587, former Queen of Scotland, Mary Stuart (1542-60), was beheaded by order of Queen Elisabeth I of England (1558-1603).[475] This act by the Protestant queen against her devout Catholic cousin sent shockwaves throughout Europe and was one of the final events

[469] Ibid., 114.
[470] Preece and Burton, 'Church Rocks, 1975-83: A reassessment', 265
[471] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 115; Wildman, 'Historic England Complete Monument Report - Church Rocks (1082124)', 2.
[472] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 117
[473] The Church Rocks Wreck: The remains of a 16th century Venetian vessel, accessed 13 Sept. 2020, https://www.teignheritage.org.uk/index.php/the-church-rocks-wreck.
[474] See for example: Casado Soto, *Los barcos españoles del siglo XVI y la gran armada de 1588*, 133, fig. 8.
[475] Wormald, *Mary, Queen of Scots: A Study in Failure*, 168.

that prompted King Philip II of Spain (1556-98) to send a grand armada to invade England.[476] This armada was supposed to depart Lisbon and sail into the English Channel before escorting the Spanish army in Flanders across the water in an amphibious assault on England.

At the beginning of March, the Venetian ship *Balanzara* entered the Sicilian port of Palermo it was possibly carrying a cargo of grain for England.[477] Sicily was well-known at the time as a grain basket for the Mediterranean, but it was also a territory ruled by Philip II. After its arrival, *Balanzara* was commandeered by local officials to transport Neapolitan troops and supplies to Portugal for the invasion of England. After the ship arrived in Lisbon, royal officials decided to confiscate it for the Spanish Armada and began preparations to include the vessel as part of the Levant squadron.[478] The ship was renamed to *Trinidad Valencera* and was one of the largest ships of the entire fleet.

Spanish naval forces departed Lisbon in May 1588 and engaged the English fleet in a series of skirmishes in the Channel beginning on 20 July. The Battle of Gravelines was the ultimate engagement that occurred eight days later.[479] Although the fleet was damaged and beleaguered, strong western winds prevented the armada from staying off the Dutch coast and the fleet began to head north. English forces pursued for several days before abandoning their quarry, while the Spanish began a long journey around the British Isles before heading back to Spain. Many of the ships were damaged from the previous battles and supplies were running low. Sporadic winds and storms during this homebound passage eventually led to many shipwrecks, some along Scotland, but most off Ireland. *Trinidad Valencera*, damaged and

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[476] For a discussion on other factors that led to the Spanish Armada, see: Jensen, 'The Spanish Armada: The Worst-Kept Secret in Europe',
[477] Beltrame, 'Three Venetian ships in the Armada', 196
[478] Martin, *Full Fathom Five: Wrecks of the Spanish Armada*, 192.
[479] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 15

carrying survivors from *Barca de Amburgo*, sought shelter in Ireland and eventually ran aground on a reef along the western side of Kinnagoe Bay, near the Inishowen Peninsula of North Donegal.[480] Over the next two days the ship broke up and scattered its contents between submerged rock gullies and across the sandy bottom.

In 1971, the City of Derry Sub-Aqua Club in 1971 was performing a routine dive in Kinnagoe Bay when two divers spotted an exposed bronze cannon.[481] Over the remainder of the day, the group located three additional cannon and three wooden carriage wheels. The divers were convinced they had found the *Valencera*, due to common knowledge that the wreck was somewhere in the bay. One of the bronze cannons they discovered included Philip II's coat of arms and the gunfounding date of 1556.[482] Over the next three years, the Club surveyed and mapped exposed objects. Collin Martin of St. Andrews University was recruited as staff archaeologist, which allowed the Club to begin excavation in 1974. Excavators found that the remains of *Valencera* were scattered over a wide area and the 6 m deep stratigraphy in parts of the site yielded artifacts buried at different levels.[483] The team uncovered many iron nails, rope, wooden bowls, arquebus stocks, leather shoes, fabrics, and ceramic sherds.

Divers found organic remains in the deeper and more static sediment were well-preserved. These included the remains of barrels still full of gunpower, various blocks and sheaves, and additional carriage wheels.[484] Researchers determined that the largest guns on the

[480] Martin, *Full Fathom Five: Wrecks of the Spanish Armada*, 193.
[481] Kelleher, '*La Trinidad Valencera* - 1588 Spanish Armada wreck: Results of the Underwater Archaeology Unit's work at the site, 2004-6', 126
[482] Martin, *Full Fathom Five: Wrecks of the Spanish Armada*, 189-91.
[483] Kelleher, '*La Trinidad Valencera* - 1588 Spanish Armada wreck: Results of the Underwater Archaeology Unit's work at the site, 2004-6', 126-7
[484] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 19, 25-6, 35; Martin, 'Spanish Armada pottery', 299-300; Martin, 'Incendiary weapons from the Spanish Armada wreck *La Trinidad Valencera*, 1588', 207

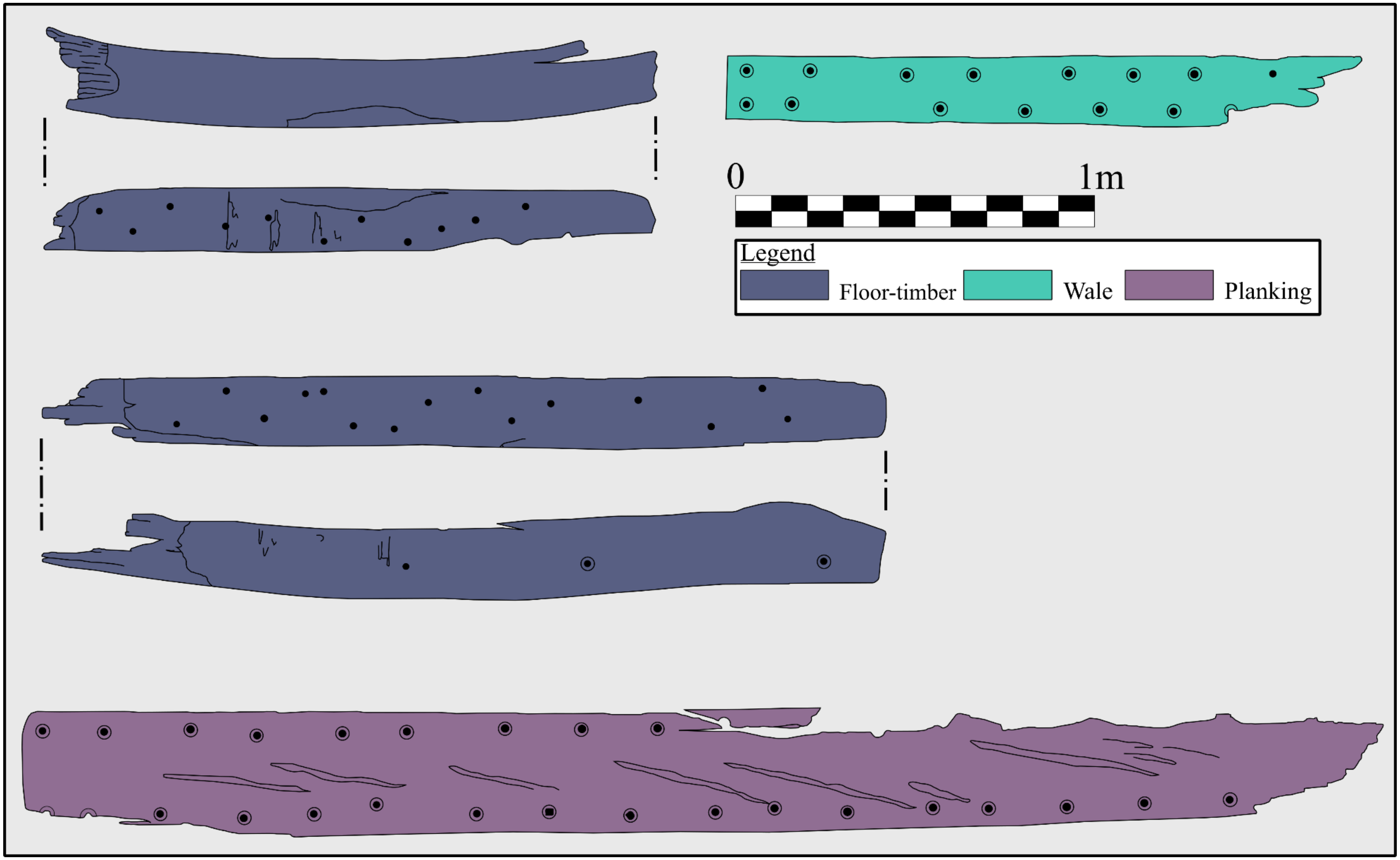

Figure 51 Fragments of Trinidad Valencera. (after Martin, 'La Trinidad Valencera', 30)

wreck were siege weapons capable of firing 40 pound (18.14 kg) shot were cast at the royal gun foundry at Malines, near Antwerp in modern-day Belgium. They were part of a larger collection brought to Spain and placed on the troop transports to provide additional firepower.[485]

Remains of *Trinidad Valencera*'s hull were limited. Timber fragments were scattered throughout the site, while one deposit included 10 elements with better preservation. The remains of two frames and two planks were raised for further analysis (figure 51). Both frames are square and at least one appears to be a floor timber, based on the three horizontal fasteners and shallow hook scarf present near the wronghead. The shape of the floor timber suggests it was originally positioned around amidships.[486] Two of the horizontal fastener holes are countersunk on the same side as the shallow hook scarf, while a single fastener was driven from the other face. This fastening pattern suggests two futtocks were attached to the wronghead in a similar manner as the master frame on Mortella III with only one hook scarf used.

Evidence on both frames suggest that there was ceiling and that an internal layer of pitch was applied to the hull. The planks represent a common strake and a wale. Thickness of the planking (10 cm) suggest a larger size vessel that traveled on longer voyages. The wale is only 4 cm thicker than the planking. Main difference between these two pieces is that the plank is twice the width (36 cm). Both the plank and wale are fastened with two round iron nails per frame station.[487]

[485] Martin, 'Master Remigy's Guns: 16th-century Spanish Armada cannons found on *La Trinidad Valencera*', 21-2
[486] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 29-31, fig. 14
[487] Ibid., 28-9, figs. 14-15; Kelleher, '*La Trinidad Valencera* - 1588 Spanish Armada wreck: Results of the Underwater Archaeology Unit's work at the site, 2004-6', 131-2, fig. 5

Ribadeo (1)

Surviving ships from the 1588 Spanish Armada limped back to Spain, with many being lost along the northern coastline of the British Isles, others at sea, and a few managed to reach port before foundering. The shortage of naval vessels for the original armada already indicated a dearth of available resources and difficulties by the Spanish Crown with financing its global empire. Once news of the defeat reached Philip II, the king still ordered a new shipbuilding program to construct 21 galleons for a future invasion effort.[488] Philip II and his administrators also began looking more towards the Crown's Italian possessions to supply ships and materials for the naval effort. Two Ragusan nobles Pedro de Ivella, and his nephew, Estefano de Oliste, were granted a contract to build and outfit 12 galleons for the Atlantic fleet (Armada del Mar Océano).[489]

Both men were trusted and loyal subjects. Ivella served in earlier fleets when Philip II invaded Portugal (1580) and defended the Azores. Oliste provided his own ship for the 1588 campaign that were lost on the return voyage. Philip II's plan for his new Mediterranean galleons was to have these built in Naples and the Republic of Ragusa (now Dubrovnik, Croatia). This force would be known as the Illyrian squadron and its lease to the Crown would extend between 1590 and 1594. The largest ship, *Santiago de Galicia*, was built by Neapolitan master shipbuilder, Colea Bonifacio, at Castellammare di Stabia, south of Naples.[490]

Philip II did not call for the squadron to enter his service until 1595. In the meantime, Ivella used some of the ships as traditional merchantmen to carry wheat and wool around the

[488] San Claudio Santa Cruz, 'Excavating a 16th-century Galleon at Ribadeo, Spain', 25
[489] Casabán, '*Santiago de Galicia* and the Illyrian squadron: Characteristics, dimensions and tonnages of Mediterranean-built galleons for Philip's II Atlantic fleets (1593–1597)', 239-40
[490] Ibid., 240.

western half of the Mediterranean. Three of the original ships built for the squadron were captured by Ottoman forces, so Ivella and Oliste replaced them with other vessels.[491] Once orders arrived to rendezvous with the Atlantic fleet, the squadron sailed to Lisbon. Here Ivella died and Oliste took over command. Royal officials evaluating the ships concluded that the Italian shipbuilders had ignored the prescribed instructions for the galleons and that the vessels were more comparable to traditional Mediterranean round ships.[492] Nonetheless, Spain was in dire need of ships and the Illyrian fleet eventually became part of the 1597 Armada that once again attempted to invade England. After departing Coruña in October, the fleet met a harsh winter storm and was scattered. Several ships managed to offload troops in Cornwall, but without additional supplies, all were forced to return to Spain.[493]

The Illyrian squadron fared poorly, and *Santiago de Galicia* was damaged by the storm and in subsequent naval battles. The ship managed to return, arriving at the Galician port of Ribadeo before promptly sinking.[494] Dredging operations for Ribadeo located the site in 2011 and archaeologists assessed its historical significance over the following year.[495] Test excavation units in the stern and a trench in the bow uncovered a well-preserved hull and associated artifacts.

Dendrochronological samples confirmed that the site was a sixteenth-century shipwreck. Initial artifact finds included bronze breechblocks for cannons, stone cannonballs, and fragments

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[491] Ibid., 241.
[492] Ibid., 257.
[493] San Claudio Santa Cruz, 'The Armadas' Wars in the Iberian Northern Atlantic, a chance for forSEA-Discovery project', 47.
[494] San Claudio Santa Cruz, 'Excavating a 16th-century Galleon at Ribadeo, Spain', 26
[495] San Claudio Santa Cruz et al., 'El precio de Ribadeo, un excepcionalmente bien conservado pecio español del siglo XVI', 209.

Figure 52 Photogrammetric model of the Ribadeo shipwreck. (Courtesy of Miguel San Claudio Santa Cruz and Archaeonauta)

of pottery that confirmed the dendrochronological date.[496] The remains became part of the Finisterre Shipwreck project, designed to survey the northern coastline around Cape Finisterre. After confirming the date and significance of the wreck, the team covered the remains until 2015. Excavations on the site resumed in 2018 and are currently in progress with the team uncovering sections of hull structure over the last two years. The cold temperatures and fresh water originating from the Galician mountains provide an ideal environment for organic preservation, although the strong current threatens any section of the remains that is exposed.[497] Recording of the hull structure is piecemeal, due to many barrels and other organic artifacts that need to be removed beforehand. Plans for the project include building a local conservation lab so that this material can be preserved and more of the hull structure recorded.[498]

Since this project is in its early stages and only a few sections of the hull are recorded, much is published about the construction (figure 52). Excavators have not uncovered many axial timbers at this moment, so the exact configuration of the vessel is unknown. Recent field seasons have uncovered the mainmast step and gleaned details about the framing. The ship clearly has floor timbers overlapping with futtocks, but without disassembling the hull, the type of scarf or fasteners used are unknown. Upper sections of overlapping futtocks suggest relatively square dimensions with equal space between each frame station.[499]

The mast step is built atop the keelson near amidships. It consists of a pair of mast step partners fastened horizontally on either side of the keelson. The mainmast mortise is complete with two wooden wedges on top of the keelson and a chock remaining inside the step. Six pairs

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[496] San Claudio Santa Cruz, 'Excavating a 16th-century Galleon at Ribadeo, Spain', 28-9
[497] San Claudio Santa Cruz et al., 'El precio de Ribadeo, un excepcionalmente bien conservado pecio español del siglo XVI', 219-20.
[498] Filipe Castro, pers. comm.
[499] Borrero et al., '*Santiago de Galicia* 1590 - Field Notes', 38-9, 41.

of buttresses are rebated into the mast partners, while their lower outboard ends are cut to fit over two strakes of longitudinal ceiling. Another rectangular cut was found along the bottom inboard ends of the buttresses. Three short vertical boards were inserted in the space between the buttresses. Bilge boards running fore and aft were used to cover over the buttresses and seal the bilge. Surrounding the mainmast step are elements of a pump well, this is composed of stanchions with the planking half lapped along the edges to fit each other.[500]

Exposed upper sections of the hull include a shelf clamp supported by a stringer directly underneath. Along the outside of the framing there is an accompanying wale at the same level as the shelf clamp. All timbers are recorded as square without chamfering. Two internal castle riders to support the sterncastle were also identified by the rebates on the side faces to fit over the internal stringers. Planking is thicker than that seen on most other wrecks examined in this dissertation, perhaps as a result of the intended use of the vessel for naval purposes. Several seams in the hull include lead sheathing strips.[501] *Santiago de Galicia* is an anomaly for several reasons, it was built in southern Italy along the Tyrrhenian Sea and there are few examples of wrecks from this area. The ship was supposed to be built as a galleon to operate in the Atlantic Ocean, but the official reports evaluating the ships in 1597 clearly infer that it had the qualities of a carrack or *nao*.[502] Further work is required to evaluate the shape of the hull. No doubt Ribadeo will provide much more information in the future about whether Italian carpenters actually followed Spanish directions or if the construction included any major differences as a warship.

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[500] Ibid., 44-50.
[501] San Claudio Santa Cruz et al., 'El precio de Ribadeo, un excepcionalmente bien conservado pecio español del siglo XVI', 211-2.
[502] Casabán, '*Santiago de Galicia* and the Illyrian squadron: Characteristics, dimensions and tonnages of Mediterranean-built galleons for Philip’s II Atlantic fleets (1593–1597)', 257

Rondinara

Rondinara Bay on the southeastern coast of Corsica (roughly halfway between Bonifacio and Porto-Vecchio) contains the remains of a shipwreck sunk in 4-7 m of water. It is a popular destination for sports divers over the last several decades, with significant looting carried out by souvenir hunters. Archaeologists worked on the wreck in 1982 attempting to collect information on the exposed remains before they were permanently lost.[503] Three segments were uncovered, the greatest distance between two sections is approximately 20 m (figure 53). The bottom of the half of the hull was exposed and recorded, while the remainder laid buried under ballast, seagrass, and sand. The other two sections are much closer together and appear to be upper sections of the hull that broke away and sank further afield. The ballast stones were a metamorphic rock not known along Corsican coastlines.[504]

Only three items of the ship's hardware were recovered, two toggles and a belaying pin, which suggest a lateen sail was used.[505] The main cargo of the vessel was ceramics, with over 800 individual fragments; they date to the late sixteenth or early seventeenth century and originated from Italy, particularly along the Ligurian coast. Ceramic typologies include plates and bowls of different sizes composed of an orange paste and different polychrome slips.[506] Other ceramic sherds recovered from the general area during the excavations suggest Rondinara was used as a port in Antiquity between second century BC and AD fourth century.

An exposed section of the forward keel indicates this timber is relatively square and has a rabbet along its length. No scarf is present at the forward end, this piece simply butted the

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[503] Villié, 'La Rondinara, épave d'un caboteur du XVI/XVII[e] siècle', 137
[504] Ibid., 149.
[505] Ibid., 146.
[506] Ibid., 150-7.

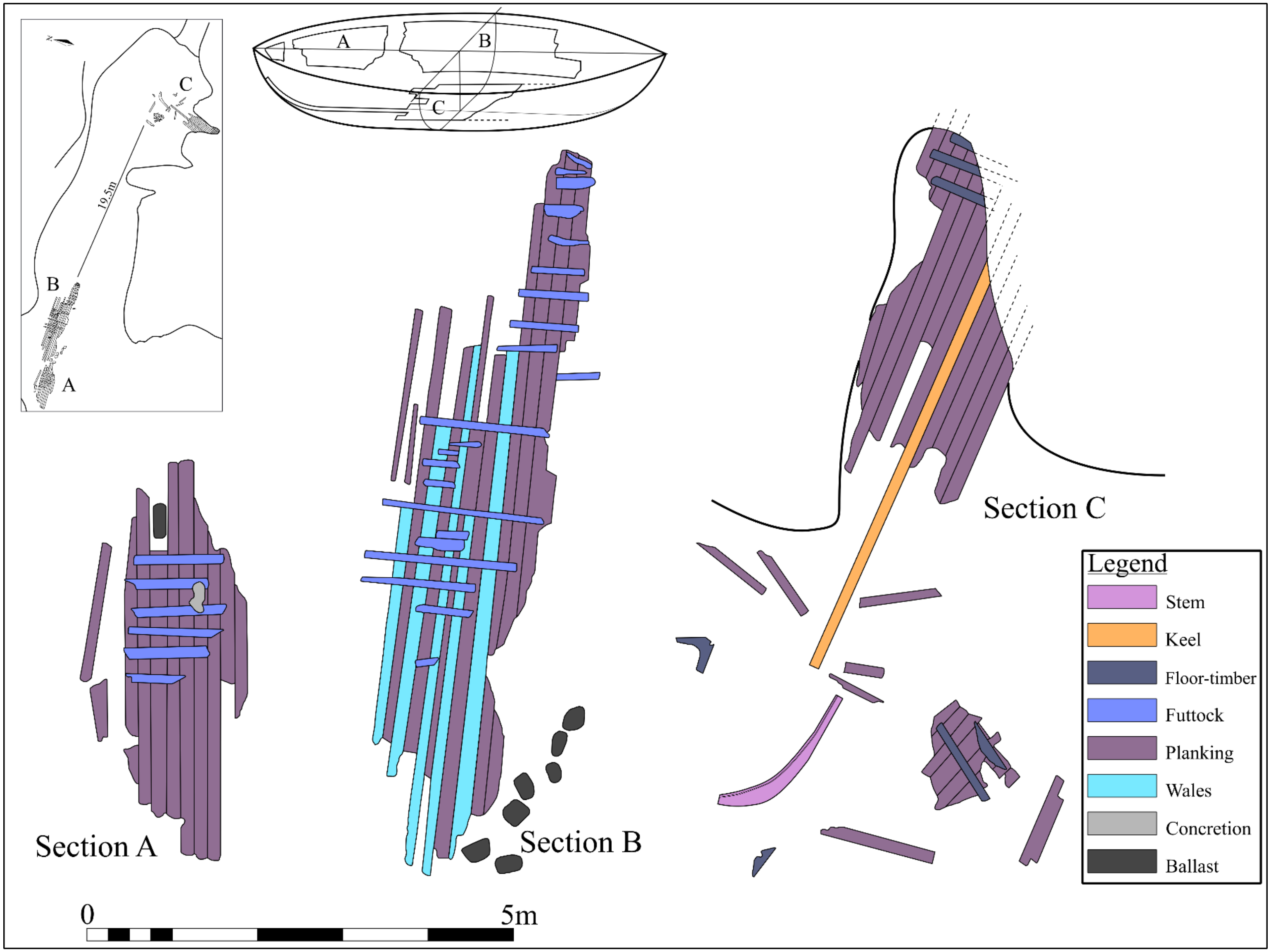

Figure 53 Site plan for the Rodinara shipwreck. (after Villié, 'La Rodinara', 140-42, 148)

surviving lower half of the stem. The lower stem piece continues the same dimensions as the keel with the rabbet, but as it rises upward, the dimensions become rectangular with an increased molded scantling and rounded forward face. Only two bolt holes are noted, one close to where the lower half butts to the keel and another at the beginning of the curved rake. The remainder of the axial timbers, such as the aft part of the keel and the sternpost, are still buried and were not recorded.[507]

Many of the framing elements from the surviving hull sections are eroded or missing, but investigators determined that the ship is assembled with floor timbers overlapping with futtocks. Floor timbers are square and not enough information survives to know whether a scarf or horizontal fasteners were used. The spaces between frame stations are equal to or twice the width of the floor timbers. Examination of a V-timber toward the bow indicates this frame was nailed to the keel, while the bolts mentioned earlier suggest the missing keelson was bolted through the floor timbers.[508] Planking is thin (3 cm) and fastened with two iron nails per frame station. Upper sections of the hull also include four wales (another fifth wale might be present near the waterline represented by a slightly thicker plank) that are separated by a strake of normal planking between each. None of the wales have the same dimensions or rebated over the frames, and it appears there were no chamfered edges on the outside corners. Except for the bolts, all the other fasteners are square and there is no mention about caulking or pitch.[509]

Saint-Honorat 1

Between the islands of Saint-Marguerite and Saint-Honorat off the coast of Cannes, France lie the remains of a shipwreck originally reported in November 1990. The Saint-Honorat

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[507] Ibid., 138, 143.
[508] Ibid., 138, 144, 145.
[509] Ibid., 140, 144-5.

1 wreck was first identified by an exposed cannon that was left in situ after it was discovered, still connected to surviving hull structure beneath. Due to the position of the wreck in 4-6 m depth of water and situated in an area frequented by the local boating community, there was an immediate necessity for the wreck to be reburied for protection.[510] Archaeologists returned to the site in May 1991 to conduct a survey of the remains and excavate areas previously exposed by the original wreck finders. Conditions during the excavation did not allow the investigators to excavate as much of the structure as originally intended.[511] What was found suggests that the shallow nature of the site allowed locals and others over time to systematically loot the site. Evidence of fire found on some of the hull structure also suggests that the ship was either burned when it ran aground or shortly thereafter.[512]

The few artifacts uncovered included concretions, musket balls, fragments of wooden staves for a bucket or barrel, and a hazelnut.[513] Archaeologists also recovered 128 ceramic sherds with decorations or forms that suggest manufacture along the Ligurian coast (including Pisa), as well as French workshops in Vallauris, Biot, and Marseille. Many of the sherds provide dates either from the latter half of the sixteenth or the first half of the seventeenth century.[514] Initial archival research suggests the ship might be related to a local episode in the Franco-Spanish War (1635-1659). Spanish and allied Genoese forces occupied the archipelago at the beginning of the war and were immediately blockaded by the French until 1637. Prior to the French amphibious

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[510] L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 125
[511] Ibid., 126-7.
[512] Ibid., 131-2.
[513] Ibid., 128-9.
[514] Ibid., 129-31.

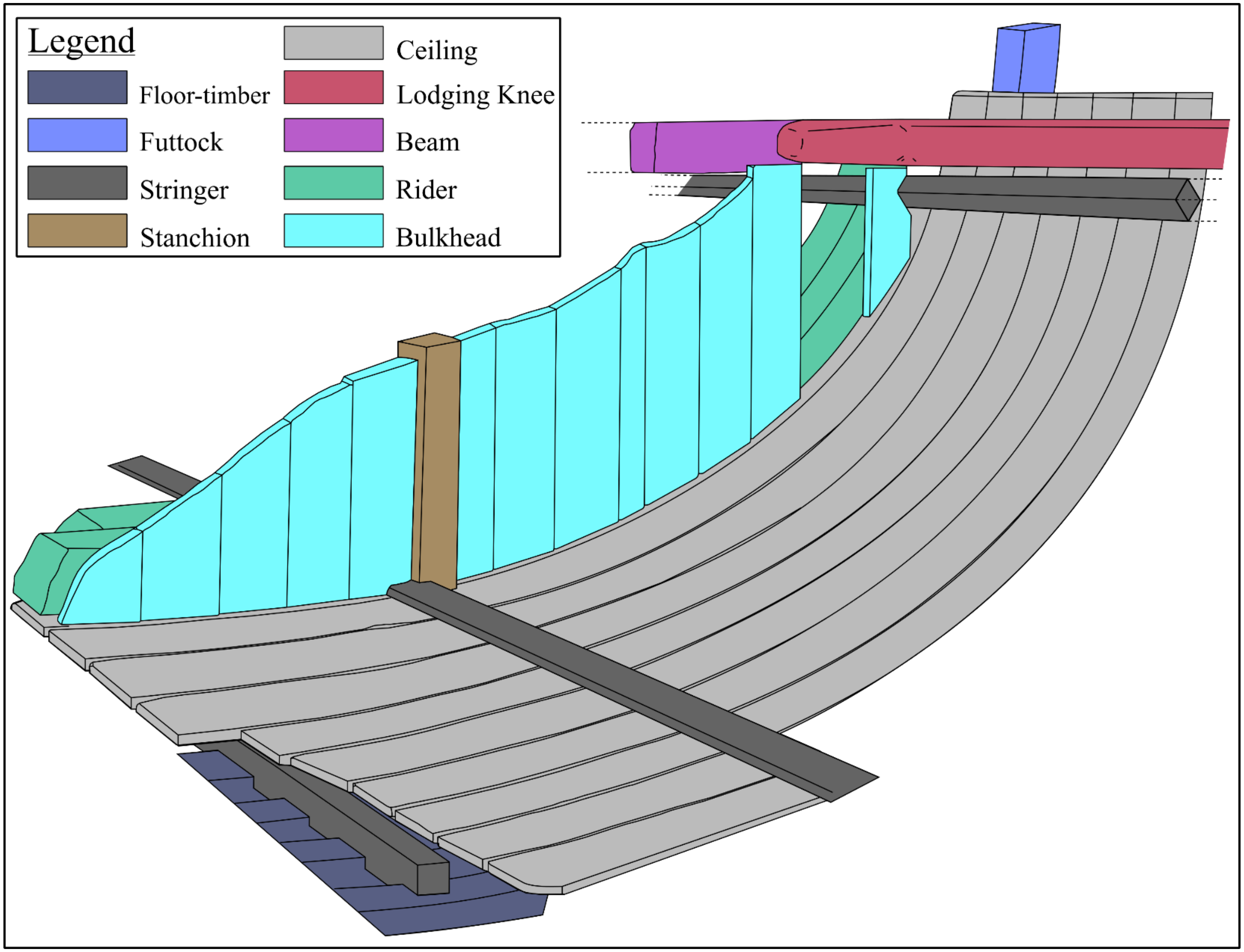

Figure 54 Ship architecture uncovered during the limited excavation of Saint-Honorat 1. (after L'Hour and Richez, 'Sondage sur un site sous-marin', 134)

assault to retake the islands that spring, a ship from Naples was dispatched carrying wheat for the defenders. This ship attempted to run the blockade before grounding and being lit on fire by the pursuing French. The recorded position for this ship fits the location of Saint-Honorat 1, although more archival work will be needed in the future to confirm this possible identity.[515]

Only two weeks were spent excavating and recording Saint-Honorat 1, providing limited information about the hull besides estimating that it was 20-30 m long (figure 54).[516] Archaeologists were able to expose an outside section of the keel, providing evidence that the garboards fit against chamfered top edges of the keel. The dimensions of the keel are not yet known. No other axial elements were uncovered or recorded during fieldwork.[517] Floor timbers are square with roughly the same amount of space between frame stations. Instead of limber holes cut into the bottom faces of the floor timbers, investigators describe a gap naturally made between the frames, keel, and garboard. This arrangement is seen on the Dutch East India Company's *Mauritius* (1609) and the wreck A/B de Saint-Vaast la Hougue (1692), which suggests that Saint-Honorat 1 has a shallow wineglass profile.[518]

Above the keel and floor timbers a keelson is rebated to fit over each frame. The keelson is bolted through the floor timbers to connect with the keel. Most of the internal framing is covered with transverse ceiling that terminated at the bilge stringer, ran atop an intermediate stringer, and fit into a rabbet on the keelson. The ceiling is fastened down using both iron nails and treenails. Elements for a bulkhead were also uncovered. This divider is mainly formed with planks butted vertically against each other and a stanchion partially inserted into the bilge

[515] Ibid., 137-9.
[516] Ibid., 128.
[517] Ibid., 132.
[518] L'Hour, Long, and Rieth, 'The wreck of an 'experimental' ship of the 'Oost-Indische Companie': The Mauritius (1609)', 65-6, fig. 2

stringer. Only the exposed garboard provided a thickness for the planking (10 cm), but there is no more available information about fastening patterns.[519]

Summary

Over the last several decades, archaeologists working throughout the Mediterranean and elsewhere around the world have discovered numerous shipwrecks dating between the late medieval and early modern period. Many sites are simply artifact deposits scattered over the sea bottom without any surviving hull remains. Fortunately, at least 41 of these shipwrecks include some level of structural preservation. Earlier wrecks, such as Çamaltı Burnu I, provide few wooden pieces that could be tied to the hull or allow some insight into the construction technique. Recent finds associated with Ligurian ship production (Villefranche, Mortella III, and Calvi 1) include much more surviving hull structure that is rewriting how nautical archaeologists view ships from the early modern era. Marsala B, Precenicco, Rhodes 1, and Boccalama A contain evidence for a bottom-based approach to build for riverine or coastal sailing craft in the eastern Mediterranean. Several of these sites are tied to locations where settlements of Northern Europeans were known to exist. These associations should not discredit the use of a local Mediterranean bottom-based approach influenced by coastal environmental conditions.

Several issues are also apparent with this dataset, especially the lack of information available about larger ships built in the eastern Mediterranean. Çamaltı Burnu I and *Trinidad Valencera* are two examples with very limited material. Rhodes 4 is promising, due to a high level of preservation, but limited excavations because of the wreck's location adjacent a busy pier and the amount of surviving amphora cargo prevent further research. There are also few

[519] L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 133-6

examples of western Mediterranean shipbuilding until the beginning of the fourteenth century. Culip VI remains the earliest evidence for exclusively frame-based construction outside antiquity in this region. The use of treenails for the stringers on Culip VI and Les Sorres X or throughout Cavoli and Marinières also brings into question the exclusivity of iron fastening for Iberian-Mediterranean construction.

Another major issue is the reporting of surviving hull remains with adequate dissemination of their scantlings and construction. Boccalama A and B represent some of the more well-known examples of surviving hull structure that are hindered by unpublished datasets. The same issue is also seen with the summary accounts reported for the Mariposa and Olbia wrecks. Other sites are equally problematic. Only a crude site plan exists for the West Turtle Shoals wreck and no revisit to the site was ever made for what could be a rare Mediterranean find in the Americas. Future reporting from Cadiz-Delta II and Ribadeo will provide additional information about ships built at the end of the sixteenth century. Cadiz-Delta II is one of several Ligurian-manufactured hulls that could be scrutinized in the future within a sub-regional level. Ribadeo promises to provide a robust amount of information on construction techniques from the southern Italian Peninsula. At the same time, both wrecks are additions to a period with many other known vessels with various levels of preservation. Regardless of the geographic location, it will benefit nautical archaeology in the future to focus on finding earlier wrecks in the west or later versions in the east to supplement the sample size currently available.

The above issues notwithstanding, the sample size provided in this chapter still includes relevant information about construction patterns across the Mediterranean. The similarities between these vessels are the focus of the next chapter, which discusses a comparative analysis of the construction techniques. Several vessels include characteristics that are often related to earlier shell-based methodology that either survived as part of a *longue durée* in shipbuilding or continued as a necessary structural provision within a frame-based practice. Differences in construction techniques also provide evidence for unique regional shipbuilding, while later examples suggest an exchange of ideas between craftsmen.

CHAPTER III

COMPARATIVE ANALYSIS OF CONSTRUCTION FEATURES

Ships built in the late medieval and early modern period were part of a great transition in wooden shipbuilding. In this era the earlier shell-oriented practices were abandoned and in their place there was a widespread adoption of frame-based shipbuilding. This chapter begins by summarizing the key features of Mediterranean shipbuilding during late antiquity and the early medieval period. The chapter will identify the similarities and differences in the frame-based approach as it was adopted and then determine whether earlier construction preferences remained in certain locations. Did round ships, longships, and bottom-based vessels share construction signatures that were similar in function and intended purpose even if the overall hull shapes were different? The last section reviews available dendrochronological data as part of understanding if and how different wood species were utilized for specific purposes throughout construction. Previous fieldwork focused on species identification rather than the more recent scholarly approaches (timber morphology, shipyard practices, and forestry management).

Shell-Based Shipbuilding (Second to Eleventh Centuries)

Shipbuilding was transformed over the first millennium after the earlier collapse of the centralized Roman state and the onset of large-scale cultural migrations across western Europe and North Africa.[520] Earlier shipbuilding followed predominantly a shell-first format that conceivably relied on a skilled but enslaved labor force.[521] By the beginning of the eleventh century, most Mediterranean shipyards adopted a transversal vision and frame-based

[520] Halsall, *Barbarian Migrations and the Roman West, 376-568*, 200-1.
[521] Hocker, 'Lead hull sheathing in antiquity', 203.

methodology. Shipbuilding during this later period invested single individuals with the required experience to design the initial layout for the hull and left the remainder of a paid workforce with more menial tasks.[522] The reasons for these changes are not immediately clear, but some suggestions include a reduction in the overall population, changes in political powers, and limited finances for the construction of major works. The last could be supported by the excessive material waste in shell-first construction that was significantly reduced when a ship is constructed in a frame-first manner.[523] Several archaeologists consider that the earliest evidence for frame-based construction appears in the AD 7th century, the date of a handful of shipwrecks with planking nailed to frames found in the Eastern Mediterranean.[524] Others have argued that frame-based construction was not fully realized until the beginning of the eleventh century.[525] This debate falls outside the purview of the current discussion, but a brief summary of the transition of shell-first to frame-first is important regarding later shipwrecks.

Patrice Pomey, Yaacov Kahanov, and Eric Rieth reviewed the corpus of shipwrecks dated throughout the first millennium and found several features that exemplify the transition from shell-first to frame-based shipbuilding.[526] These should be considered general trends, even though several shipwrecks from their list do not necessarily follow the transition.

Most shell-first construction includes the assembly of the axial timbers with the keel rabbeted or chamfered for the garboard. This signature is supposedly lost on later ships, when the

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[522] Harpster, 'Designing the 9th-Century-AD Vessel from Bozburun, Turkey', 311
[523] Steffy, 'The Kyrenia Ship: An Interim Report on Its Hull Construction', 101
[524] Kahanov, 'The Tantura B Shipwreck. Tantura Lagoon, Israel. Preliminary Hull Construction Report', 153; Israeli and Kahanov, 'The 7th-9th Century Tantura E Shipwreck, Israel: Construction and reconstruction', 375; Kahanov and Mor, 'The Dor 2001/1 Byzantine Shipwreck, Israel: Final report', 48; Barkai and Kahanov, 'The Tantura F shipwreck: Hull remains and finds - final report', 12
[525] Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 245.
[526] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 237

frame provides the shape of the hull and the keel-garboard connection loses importance.[527] Endposts maintain a rabbet for the fastening of the planking hood ends, practice that remains universal. Edge-joinery for the planking and wales to create the overall hull shape becomes less ubiquitous. Wider spacing between mortises and the employment of smaller tenons (with some shipyards utilizing coaks instead) continues until eventually this joinery is no longer needed.[528]

Evidence from later ships indicate planking ends were simply butted and nailed at each framing station. Wales were also fastened to the framing, but the timbers in each strake scarfed together. The thickness of the planking is dependent on the hull size. Earlier framing relied on an alternating pattern between floor timbers and half-frames that simply butted against each other.[529] The transition leads to this same system overlapping at the centerline of the hull and occasionally fastened to the keel. Later ships use alternating L-shaped floor timbers with the short arms overlapping or scarfed to an adjacent futtock. Ships that are frame-oriented are more likely to have the frames fastened to the keel. It should be noted that the practice of bolting certain frames in shell-first construction was likely done to compensate the weakness of the keel in wineglass profiles.[530]

Most metal fasteners in Ancient ships were originally made with copper (or bronze), but this gradually transitioned to iron equivalents until the latter became exclusive for shipbuilding.[531] Treenails in shell-oriented construction were predominantly used for attaching

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[527] Ibid., 297.

[528] Jézégou, 'L' épave II de l' anse Saint-Gervais à Fos-sur-Mer: Un navire du haut Moyen-age construit sur squelette.', 140.

[529] This pattern continues up until the end of the first millennium, see for example Joncheray, 'L'Épave sarrasine AGAY A. Campagne 1996', 239-40

[530] Pomey, 'Principes et methodes de construction en architecture navale antique', 51; Pomey, 'Remarques sur la faiblesse des quilles des navires antiques à retour de galbord', 17.

[531] Example of earlier cupreous fasteners, Gassend, Liou, and Ximénès, 'L'épave 2 de l'anse des Laurons (Martigues, Bouches-du-Rhône)', 98

the framing to the hull. Early frame-oriented ships included treenails for attaching the planking and wales to the frames, but are absent on later frame-based hulls (caveats to this are discussed below). Most shell-first hulls are covered inside and outside by pitch as a water sealant.[532] The presence of caulking on earlier shell-oriented hulls may indicate a repair replacing a section of the planking or adjust between strakes.[533] Longitudinal reinforcements (such as keelsons, sister keelsons, and stringers) provide additional strength to the overall hull but their structural role in the transition from shell to frame-based is still unclear.[534]

Comparison of Frame-Based Construction (Eleventh to Seventeenth Centuries)

Axial Timbers

Eastern Mediterranean ships were predominantly equipped with deep rectangular keels that reduced lateral drift and improved sailing qualities. Rhodes 4 is an exception with a shallower keel, although the scantlings for this timber were recorded at the transition to the sternpost.[535] Contarina I also had a slightly wider keel that was much closer to square than Rhodes 4.[536] Reconstruction of the fragmentary remains from Yassıada 3 suggest the keel was square throughout.[537] Flat-bottom construction, recorded on Marsala B, Precenicco, Boccalama A, Rhodes 1, and Sveti Pavao, all include a central keel plank.[538] Ships from the Western

[532] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 297

[533] Bockius, 'Coating, sheathing, caulking and luting in ancient shipbuilding', 120-1.

[534] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 299; Helfman, Nishri, and Cvikel, 'Finite Element Analysis of Shell-First and Longitudinally Reinforced Frame-Based Wooden Ships', 301-7

[535] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 7-8.

[536] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 24.

[537] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 42.

[538] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 296; Capulli, 'Il relitto di Precenicco', 113; Romanelli, *La galea ritrovata*, 44; Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 481; Beltrame, 'The ship, its equipment and the crew's personal possessions', 48.

Mediterranean include various keel dimensions that do not seem to be related to an exclusive type or intended operation. Culip VI, Villefranche, Mortella III, Sardinaux, and Cap Lardier 1 had deeper keels, while Les Sorres X, Calvi 1, Rondinara, and Agropoli's keels were generally square.[539] Marinières, and Olbia Wreck 10 keels were much wider than the others.[540]

Carving rabbets into the top edges of the keel is often identified as a shell-oriented construction practice. Several frame-based ships also include evidence for rabbets along the entire keel instead of only on the endposts. Evidence from surviving endposts suggest rabbets for the planking hood ends was universal. Contarina I is an exception without rabbets on any of the axial framework.[541] Serçe Limanı and Yassıada 3 suggest a possible trend in the far eastern end of the Mediterranean where keel rabbets were no longer used after the transition to frame-based shipbuilding.[542] The presence of a keel rabbet on Marsala A stands out as possibly a delayed transition or imperfect method of frame-oriented construction by shipbuilders who were more familiar with shell-based traditions.[543] Additional evidence suggesting unfamiliarity with the new method includes the abundance of filler pieces inserted between frames and planking to create a solid connection for fastening these elements together. Another consideration for keel rabbets is the longitudinal strength created between the overlap with the garboards. Both Bacàn wrecks

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539 Rieth and Pujol i Hamelink, 'L'arquitectura naval', 118; Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 23; Cazenave de la Roche, *The Mortella III Wreck: A Spotlight on Mediterranean Shipbuilding of the 16th Century*, 74; Joncheray, 'Un navire de commerce de la fin du XVII^e siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44; Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVI^e siècle', 25; Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 34-5; Villié, 'L'épave Calvi 1 (1990)', 84; Villié, 'La Rondinara, épave d'un caboteur du XVI/XVII^e siècle', 138; Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 72-3.

540 Daeffler, 'L'épave des Marinières', 19-20; Riccardi, 'Medieval boats from the Port of Olbia, Sardinia, Italy', 314.

541 Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 413

542 Matthews and Steffy, 'Serçe Limanı', 87; Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 41.

543 Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 298-9

include keel rabbets and the hulls were discovered pinned beneath heavy stone slab cargoes.[544] Perhaps as a preventative measure, the original shipbuilders included the keel rabbet to counter sagging stresses that would develop over the life of either vessel. This explanation seems equally plausible for most longships, as almost all examples include a keel rabbet. Camarina's keel is chamfered rather than cut with rabbets, its location near Marsala A may suggests a blending of earlier practices in this region centuries after the domination of frame-based shipbuilding throughout the Mediterranean.[545]

Many western ships (Culip VI, Les Sorres X, Chrétienne K, and Cap Lardier 1) include flat floor and round bilge profiles similar to their eastern equivalents but without keel rabbets.[546] Rondinara and Agropoli both have rabbeted keels.[547] There is no published amidships profile for Rondinara and its estimated length versus breadth ratio suggests a typical round ship. Agropoli has a flat floor with a round bilge, and the estimated dimensions suggest a much longer ship (roughly 1:4) that would benefit from the keel-garboard reinforcement. Sardinaux has no rabbet and it is unclear whether the installation of planks fastened to the keel and garboard between floor timbers were an original feature or a later addition. Investigators of this wreck suggest the boards created a raised platform for the ceramics to sit above the bilge.[548] It seems equally plausible that their presence and fastening pattern were due to a concern about strengthening the central longitudinal axis for carrying bulk cargoes of ceramics on a small vessel.

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544 Medas, 'I relitti tardo-medievali del Bacàn alla bocca di porto di Lido (Laguna di Venezia)', 79-82.
545 Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87
546 Rieth and Pujol i Hamelink, 'L'arquitectura naval', 165; Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 291, fig. 8; Lopez, Joncheray, and Brandon, 'L'épave post-médiévale Chrétienne K', 118; Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVIe siècle', 26
547 Villié, 'La Rondinara, épave d'un caboteur du XVI/XVIIe siècle', 138; Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 72-3.
548 Joncheray, 'Un navire de commerce de la fin du XVIIe siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 58, fig. 33

Marinières technically does not have a keel rabbet, due to the ingenuity of the shipbuilders by providing a wider keel to support the lower inboard edge of the garboard as it was carved and fastened against the counter-keel.[549] Most of the seafaring ships with wineglass or round hulls (Villefranche, Mortella III, Calvi 1, and Cadiz-Delta II) have rabbeted keels.[550] Rabbets for this group appear intentional as a longitudinal reinforcement for the deeper complex shape of the hull. Connection between the keel and garboard is an explicit shell-oriented construction that requires these elements to be erected prior to the installation of any frames. Saint-Honorat 1 fits this group with its shallow wineglass profile, although the keel is chamfered rather than rabbeted.[551] Mortella III is also divergent with a rider keel that was instrumental for its sailing capabilities and part of its original construction.[552]

Les Sorres X represents an exceptional case with a counter keel plank utilized for the initial installation of the framing before attachment of the keel and endposts.[553] The keel was explicitly shorter than the counter keel plank, which allows the latter to cover the butt join between the keel and endposts. This configuration creates a type of half-lap scarf that suggests the counter keel was part of the building process. The assembly is a mix between bottom-based and frame-based construction. Mariposa B and Agropoli report false keels at their respective bows.[554] Dimensions for Mariposa B are not included, while Agropoli's false keel is only 7 cm

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[549] Daeffler, 'L'épave des Marinières', 19-20.
[550] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 25-8; Cazenave de la Roche, *The Mortella III Wreck*, 73; Villié, 'L'épave Calvi 1 (1990)', 84; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 879.
[551] L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 132
[552] Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 25-8.
[553] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 34.
[554] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 281; Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 73.

thick. Further research is required to discern whether either false keel is only a protective timber that also covers keel butt joins or acts in a similar manner as the rider keel reported for Mortella III.

Keels are often preserved on shipwrecks beneath collapsed decks, cargo, or ballast, but the limited remnants of stems and/or sternposts indicate this was less frequently the case for the axial extents. Surviving stems suggest a round curvature from circular arcs with diameters related to the forward end of the keel and ship size. Marsala A's first reconstruction has an elongated stem not emphasized on other vessels, while subsequent reanalysis suggests both ends were the same shape.[555] Sixteenth-century ships, including Lake Garda, *Kadırga*, and Yassıada 3, all include aprons or stemsons bolted to the keel and stem providing reinforcement at scarf junctions between axial timbers.[556] Early sternposts were round and transition to straight designs did not occur until the introduction of a new technology from Northern European (i.e. the stern rudder) into the Mediterranean.[557] Double ended ships similar to Serçe Limanı later examples such as Culip VI, Boccalama B, Les Sorres X, Contarina I, Yassıada 3, and *Kadırga*.[558] Boccalama B includes a sternson, while Les Sorres X, Contarina I, and Yassıada 3 each have a stern rudder assembly that was adapted for round sternposts.[559] The adoption of the straight

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[555] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 297, fig. 12; Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 182, fig. 3

[556] Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 109-14; Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 243-4; Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 46-50.

[557] Mott, *The Development of the Rudder: A Technological Tale*, 132-3.

[558] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 288, fig. 2; Romanelli, *La galea ritrovata*, 12; Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 14, fig. 4; Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 157, fig. A.7; Basch, 'A Galley in Istanbul: The Kadırga', 134

[559] Romanelli, *La galea ritrovata*, 65; Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 47; Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 38; Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 50.

sternpost and rudder was gradual; this feature starts to appear in western Mediterranean iconography by the twelfth century. The fifteenth-century Marinières wreck represents the earliest archaeological example with an internal sternpost rabbeted for the hood ends of the planks and true sternpost butted to the heel timber using a stopwater.[560] The stern knee sat above the counter keel and rested against the inner sternpost.

The surviving stern assemblies on the Villefranche, Mortella III, and Calvi 1 wrecks were similar but varied in their construction features. Villefranche’s sternpost is scarfed to the upper arm of the heel timber with internal support by a stern knee.[561] Mortella III’s sternpost is simply butted to an extension of the keel and also supported by a stern knee.[562] Calvi 1 is the most complex, as the sternpost is hook scarfed to the after end of the keel and connected to the overlapping stern knee.[563] Above this assembly are Y-frames, deadwood comprised of filler timbers, and an internal sternpost that only exists at the transom. Limited recording for the Church Rocks wreck suggest a heel timber connected to a sternpost.[564] Most of these wrecks include a similar configuration with a heel timber or the after end of the keel connected to a separate sternpost. Supporting this connection is a long-armed stern knee that extends forward and is rebated along the top to fit the heels of the Y-timbers. The forward end of the stern knees from Villefranche, Mortella III, and Calvi 1 all contain a scarf for a front extension of this timber. Few remains from Villefranche and Mortella III survive above the stern knee, while the complex described for Calvi 1 suggest shipbuilders stuffed this area with smaller pieces of wood

[560] Daeffler, 'L'épave des Marinières', 44, fig. 11.
[561] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 23-4
[562] Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 31-2.
[563] Villié, 'L'épave Calvi 1 (1990)', 118-9
[564] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 117

to fill the void prior to installing long bolts through the assembly to hold it together. These wrecks suggest widespread common practices for the assembly of the stern by the sixteenth century, but decisions were made individually on the methods for attachment based on timber qualities. Differences between ships are more pronounced with sternpost angles. Calvi 1 has the widest angle recorded at 65°, suggesting it had a shorter height between decks than other examples.[565] In comparison, Villefranche has a sternpost raking aft between 75-78°.[566] Except for the Church Rocks sternpost (68.5°), most of the other sternposts are between 72-78°. The adoption of the sternpost rudder assembly encouraged the development of the square tuck stern and a desire to provide more cargo space than the traditional double ended design at the end of the fifteenth century.[567]

Scarf connections between axial timbers rarely survive in the archaeological record. Serçe Limanı represents one of the few eastern wrecks with evidence of the horizontal flat scarfs that connected its stem and sternpost to the keel.[568] The stem to keel connection on *Kadırga* relies on a horizontal flat scarf, while the replaced lower sternpost only has a half-lap.[569] Several western ships, such as Villefranche and Agropoli, utilize a hook scarf connection between the stem and keel.[570] Mortella III and Sardinaux instead use a horizontal flat scarf for the bow.[571] Many other ships from this region have no scarf connection between any of the axial timbers and these pieces are instead simply butted together. The eleventh-century Marsala A and thirteenth-

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[565] Villié, 'L'épave Calvi 1 (1990)', 118
[566] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 29
[567] Loewen, 'The Square Tuck Stern: A Renaissance Innovation?', 132.
[568] Matthews and Steffy, 'Serçe Limanı', 85.
[569] Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 244.
[570] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 30
[571] Cazenave de la Roche, *The Mortella III Wreck*, 71; Joncheray, 'Un navire de commerce de la fin du XVII^{e} siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44

century Culip VI wrecks provide the earliest evidence for butting axial timbers, and by the seventeenth century, treatises describe this technique as superior to scarf connections.[572] Cap Lardier 1 is unique because the butt join between the keel and stem includes a stopwater dowel inserted between components.[573]

Framing

Frame patterns for the earliest wrecks relied on a system of long-armed floor timbers complemented by short-armed futtocks. This system is non-exclusive to frame-based construction and seems to be carried over from shell-oriented assemblies, as seen in the Yenikapı harbor project hulls and the Bozburun shipwreck.[574] Except for a few fashion frames with vertical scarfs fastening sections together on Serçe Limanı (and possibly Marsala A), few other wrecks feature frame stations with a reinforced overlap besides staggering between floor timber wrongheads and the lower ends of the first futtocks.[575] By the twelfth century, the Marsala B, Precenicco, and Rhodes 4 wrecks indicate that the overlap is more pronounced.[576] Every ship afterward, regardless of conception or construction methodology, predominantly relies on the staggered overlap between full floor timbers and futtocks. Frame dimensions across time are predominantly square at amidships with differences in the spacing between floor timbers. Smaller round ships or longships include greater spacing between frames, while it diminishes

[572] Cazenave de la Roche, *The Mortella III Wreck*, 73-4.
[573] Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVI^{e} siècle', 25
[574] Kocabaş and Özsait Kocabaş, 'Technological and construction features of Yenikapı shipwrecks: A preliminary evaluation', 99; Harpster, 'A Re-Assembly and Reconstruction of the 9th Century AD Vessel Wrecked Off the Coast of Bozburun, Turkey', 158-9.
[575] Matthews and Steffy, 'Serçe Limanı', 94-6.
[576] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 294; Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 132; Rieth et al., 'The Rhodes 4 Shipwreck: Final report', 18-19.

moving as ships increase in size. Most longships maintain greater space between frames to keep the weight and displacement of these vessels to a minimum.

Scarf connections between floor timbers and futtocks are initially absent outside of key frame stations. Strength between frame elements is provided by horizontally fastening the wrongheads with the heel of the first futtocks at the turn of the bilge. Hook scarfs on the thirteenth-century Culip VI wreck represent the earliest and western most example for this connection between frame elements.[577] Most hook scarf rebates are relatively shallow and suggest that their use was part of the assembly process rather than for transversal hull strength. Absence of scarfs for frames outside the tailframes on most vessels supports this observation. Marinières, Cavoli, Villefranche, and Calvi 1 (at certain frame stations), include the use of single or double dovetail scarfs, which may suggest an Iberian influence on western Mediterranean shipbuilding.[578]

Dovetail joinery was generally practiced in Mediterranean carpentry since antiquity without evidence in contemporary shipbuilding.[579] Absence of frame scarfs on Cap Lardier 1 and Agropoli suggest the continuation of earlier frame-based practices.[580] Chrétienne K includes a recessed overlap with the floor timber or futtock completely rebated to fit the shape of the overlapping timber. This practice is also present on Les Sorres X, Mortella III and Calvi 1, although on the latter vessels recessed overlaps are predominantly between upper futtocks.[581]

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[577] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 148-9.
[578] Daeffler, 'L'épave des Marinières', 20-2; Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 63-4; Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 43; Villié, 'L'épave Calvi 1 (1990)', 107
[579] Bockius, 'The Nydam ship finds (Denmark) and the crystallization of North Europe shipbuilding tradition during the Roman Iron Age', 253-4.
[580] Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVIe siècle', 25-8; Capulli, 'Il relitto di Agropoli, risultati preliminari', 9; Lopez, Joncheray, and Brandon, 'L'épave post-médiévale Chrétienne K', 122
[581] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 36; Cazenave de la Roche, *The Mortella III Wreck*, 62, 65.

Mortella III's master frame includes a hybrid hook scarf with recess connection for the accompanying wronghead.[582]

Nail patterns for the floor timber to first futtock connection relate to the overall dimensions of each hull. Earlier eastern ships include one to two nails, while slightly larger equivalents (Yassıada 3), include three nails double clenched on their exterior face.[583] *Trinidad Valencera* and most examples of eastern longships all utilize three nails.[584] *Kadırga* is the only other eastern ship reported as having clenched fasteners.[585] Clenching nails after driving them through frame elements appears earlier in the western Mediterranean, possibly as a continental introduction or holdover from earlier practices. The early sixteenth-century Mariposa B is the earliest reported example employing clenched nails, while Cavoli proves this technique goes further back for use connecting planking to frames.[586] Several ships with a Ligurian provenience (Villefranche, Mortella III, Chrétienne K, Calvi 1, and possibly West Turtle Shoals) utilize round nails rather than the square fasteners seen on most other examples.[587] Contarina I and II also had round fasteners connecting frame elements, but the planking relied on square nails.[588] Smaller western ships included additional fasteners to connect overlapping frame elements compared to the larger examples.

Connections of the floor timbers, V-, and Y-timbers to the keel and endposts on eastern ships is achieved with a single nail. Precenicco and Camarina are exceptions, for they used

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[582] Cazenave de la Roche, *The Mortella III Wreck*, 60-1.
[583] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 57.
[584] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 29-31
[585] Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 244-5.
[586] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 63.
[587] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 43; Cazenave de la Roche, *The Mortella III Wreck*, 86; Lopez, Joncheray, and Brandon, 'L'épave post-médiévale Chrétienne K', 118; Villié, 'L'épave Calvi 1 (1990)', 25; Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 7.
[588] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 28.

treenails instead.[589] Western ships, such as Culip VI, Les Sorres X, Sardinaux, and Cap Lardier 1 also rely on iron fasteners. Contarina I had the keelson, frames, and keel fastened together using a single bolt at each frame station. The bolts are clenched along the outboard face of the keel.[590] Culip VI and Les Sorres X stand out from others for the nails were driven upward through the keels and into the floor timber above. Only Les Sorres X's four central frames are nailed to the keel plank and keel from above.[591] On both Culip VI and Les Sorres X, the floor timbers seated on the endposts are toenailed in place.[592] Toenailed frames on either endpost is also consistent on larger ships, such as Marinières, Rondinara, and Cadiz-Delta II, as a temporary measure for later bolting of these frames to the keel.[593] Bolting frames is often part of a connection between the keelson and the keel to create a rigid backbone for the ship. Earlier examples, including Serçe Limanı, Marsala A and B (using nails), Rhodes 4, Çamaltı Burnu I, Rhodes 1, Camarina, Culip VI, and Les Sorres X (using treenails) show a common signature of the bolts connecting the keelson between frame stations. Camarina is recorded with bolts between every other frame station near the bow, while this is increased to between every third floor timber amidships.[594] Surviving elements from Sardinaux's keel include a single treenail near the bow between frames that could be related to a missing keelson, apron, or possibly as a bitt post.[595]

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[589] Capulli, 'Il relitto di Precenicco (XI-XIII d.C.): Lettura dello scafo e osservazioni sull'uso dei madieri asimmetrici alternati', 79; Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87
[590] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 15
[591] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 36-7.
[592] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 118; Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 37.
[593] Daeffler, 'L'épave des Marinières', 20-3; Villié, 'La Rondinara, épave d'un caboteur du XVI/XVII^e^ siècle', 138, 44; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880.
[594] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 89-90
[595] Joncheray, 'Un navire de commerce de la fin du XVII^e^ siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44

By the fifteenth century, shipbuilders bolted through the frame stations with differences on how often floor timbers are connected to the keel. Bacàn 1 had a mere handful of bolts for the entire length of the keelson, while Yassıada 3 had a bolt for every third floor timber.[596] The latter is also unique with the assembly first utilizing treenails through the keelson and keel before the bolts were installed. Lake Garda has bolts associated with the keelson scarfs that are supported using additional nails toward the bow.[597] Most of the floor timbers on Mariposa B, West Turtle Shoals, Chrétienne K, Mortella III, Cadiz-Delta II, and Rondinara are bolted to the keel. Floor timbers on Marinières are bolted, but there are also several frames with no connection to the keel.[598] Central frames on Villefranche are bolted to the keel at the mainmast step, but the surviving structure towards the bow suggests only every other frame is connected to the keel.[599] Bolts at every other frame station are also recorded on Calvi 1 and Sveti Pavao.[600] No direct evidence survives for bolts on Agropoli, and concretions on top of the floor timbers suggest that they were simply nailed to the keel.[601] A single floor timber from Olbia Wreck 10 includes an iron nail and treenail.[602] Based on Culip VI and Les Sorres X, it is likely that on Olbia Wreck 10 the nail secured the floor timber and the treenail was for the keelson.

Lower Internal Components (Keelson, Stringers, Mast Steps, and Ceiling)

Keelsons and other internal components play an important role in supporting transverse framing. Most keelsons are rectangular throughout their entire length and only narrow towards

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[596] Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 121; Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 55, 82, fig. 4.2.
[597] Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 101-6.
[598] Daeffler, 'L'épave des Marinières', 23.
[599] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 42; Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 43.
[600] Villié, 'L'épave Calvi 1 (1990)', 86-7; Beltrame, 'The ship, its equipment and the crew's personal possessions', 48-9.
[601] Massimo Capulli, pers. comm.
[602] Riccardi, 'Medieval boats from the Port of Olbia, Sardinia, Italy', 314.

the ends. Recesses on the underside allow this timber to fit over the frames and appears almost universal on Mediterranean ships of the late Medieval and Early Modern eras. This trait is also seen on most northern European ships and suggests it was considered a necessity for strengthening the centerline. Several ships associated either with Ligurian or Adriatic production (Contarina I, Villefranche, and Calvi 1) include evidence that the rebates are only over the central section of the hull or around the mast step(s).[603] Earlier shell-oriented construction included sister keelsons that were loosely fastened to the frames and occasionally recessed along the bottom side to provide lateral support to the unfastened keelson or mast step. Evidence from Serçe Limanı indicates a true keelson bolted to the keel, but sister keelsons are still installed on either side of central timber.[604] On the other hand, Marsala A and Rhodes 4 have sister keelsons that are spaced further away from the central axis with at least a single strake of ceiling or limber boards between them.[605]

Subsequent vessels have a pair of stringers covering the floor timber and first futtock overlap; these components are recessed on the bottom and nailed to the accompanying framing, while earlier examples were also bolted to an accompanying bilge keel. Lack of iron staining on the stringers for Culip VI suggest that the use of (now-missing) treenails.[606] Les Sorres X confirms this practice with the use of treenails between frames.[607] The upper stringers were originally treenailed to a ribband that was later sawn off and covered over with the planking. Marinières' stringers are missing, but there is evidence for treenails present at the floor timber to

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[603] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 27; Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 43; Villié, 'L'épave Calvi 1 (1990)', 118-9
[604] Matthews and Steffy, 'Serçe Limanı', 116-9.
[605] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 302; Rieth et al., 'The Rhodes 4 Shipwreck: Final report', 20-1.
[606] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 134-5.
[607] Pujol i Hamelink, *La construcció naval a la Corona d'Aragó, Catalunya (segles XIII-XV)*, 218-9.

futtock connection.[608] The above ships, along with Cavoli, could indicate another influence by Iberian practices by including treenails in their construction. Ship contracts throughout Sicily by the fourteenth century (after the island became an Aragonese possession) also specify the use of treenails for reinforcing longitudinal elements.[609] Larger oceanic ships, such as Villefranche, Calvi 1, and Mortella III, include dual stringers that cover overlaps at key points along the hull.[610] Between overlaps, the common trend is to add a single stringer over the central section of each futtock for reinforcement.

Mast step development suggests construction differences depending on the size of the ship and its intended purpose. Earlier shell-oriented mast steps, such as the one seen on the sixth-century BC Bon Porté wreck, include a wooden block mortised on the top face and recessed on the bottom to fit over several frames.[611] Subsequent examples within shell-based hulls suggest that the mast step dimensions varied based on overall hull size. The system allowed the keelson or mast steps to remain unfastened, although several examples include tenons or rebates to fit on top of sister keelsons.[612] The sister keelsons restricted lateral movement, while the rebates underneath prevented the mast step from shifting forward or aft. True keelsons appeared once the practice of bolting the centerline timber to the keel was introduced.[613]

Keelsons initially included a mortise along the top face for the mast heel, but on most ships dated after Serçe Limanı this simple approach was abandoned and replaced by an assembly

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608 Daeffler, 'L'épave des Marinières', 39, fig. 6.
609 Bresc et al., *Studi di storia navale*, 11-12.
610 Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 67-9; Villié, 'L'épave Calvi 1 (1990)', 94-6; Cazenave de la Roche, *The Mortella III Wreck*, 80-1.
611 Joncheray, 'L'épave grecque, ou étrusque, de Bon Porté', 32
612 See for example, Liou, Gassend, and Roman, 'L'épave Saint-Gervais 3 à Fos-sur-Mer (milieu du II e siècle ap. J.-C) [Inscriptions peintes sur amphores de Bétique. Vestiges de la coque]', 223, fig. 85
613 Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 269.

of timbers that formed the step. On Marsala A and Rhodes 4 sister keelsons continue as stringers supporting transverse ceiling but are no longer adjacent to the keelson.[614] Medieval and early modern mast step configurations (Table 6) on Boccalama B, Culip VI, Mariposa B, Contarina I, Lake Garda, Villefranche, Mortella III, Sardinaux, Cadiz-Delta II, Ribadeo, and Sveti Pavao show sister keelsons were no longer present or were replaced with mast step partners. This timber only covers a short section adjacent the keelson. On larger vessels mast step partners are keyed together using wooden tenons (often the space between them becomes the mast mortise). Wedge-shaped timbers (sometimes called chocks) were installed on the top face of the keelson at either end of the mast step partners. The resulting mortise was filled with the mast heel and additional chock(s) to lock the heel place. Smaller versions of this system on Culip VI (figure 55), Contarina I (figure 56), and possibly Sardinaux indicate the mast step partners are boards fitted vertically on either side of the keelson and reinforced by either buttresses or the raised profiles of the upper face of the accompanying floor timbers.[615] Boccalama B (figure 57) and Lake Garda had much longer mast step partners accompanied by wedges of similar length installed above the keelson to create mast step mortises reinforced by several pairs of buttresses.[616] Villefranche (figure 58), Mortella III (figure 59), and Cadiz-Delta II present more robust mainmast step complexes.[617] The length is not shortened on these vessels because a second mortise is included for the heel of a halyard knighthead post or the pumps and their

[614] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 302; Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 8.
[615] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 127-30; Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 413; Joncheray, 'Un navire de commerce de la fin du XVII^{e} siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 51
[616] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 67; Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 109.
[617] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 72-9; Cazenave de la Roche, *The Mortella III Wreck*, 95-100; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 878-9.

Table 6 Mast step dimensions

Shipwreck	*Date*	*Mast Step (Single Piece) length, sided, moulded (cm)*	*Foreword Wedge length, sided, moulded (cm)*	*Aft Wedge length, sided, moulded (cm)*	*Mast Step Partners length, sided, moulded (cm)*	*Keys length, sided, moulded (cm)*	*Buttresses count (x), length, width, molded (cm)*	*Mast Mortise length, width, depth (cm)*
(1) Precenicco	1180-1300	75 x 5-13 x ? -recessed over floor-timbers					Molded Floor-timbers	6.5 x 6.5 x 3.5
(2) Culip VI	1290-1300				**Fore:** (57(?) x 6-7 x ?) **Main:** (? x 11-13 x 13-1.5?)		**Fore:** 28 x 12 x 16 40 x 11 x 17 **Main:** 62 x 12 x 13 76 x 12 x 16.5 -fastened	
(3) Boccalama A	1300-1325						47 x 14 x 12 36 x 11 x 12 34 x 9 x 18 40 x 12 x 14 -fastened	
(4) Boccalama B	1300-1325		present	present	present		(7x) present	present -chock with lip fitted over mast step partners
(5) Les Sorres X	1390s	70 x 12 x 11-12 -recessed						17 x 4 x 8
(6) Bacàn 2	1420s	Expanded keelson section: 14.5 x 9.5 x 8						

Table 6 Continued

Shipwreck	*Date*	*Mast Step (Single Piece) length, sided, moulded (cm)*	*Foreword Wedge length, sided, moulded (cm)*	*Aft Wedge length, sided, moulded (cm)*	*Mast Step Partners length, sided, moulded (cm)*	*Keys length, sided, moulded (cm)*	*Buttresses count (x), length, width, molded (cm)*	*Mast Mortise length, width, depth (cm)*
(7) Contarina I	1460s		**Fore:** 38 x 13 x 10 **Main:** 40-41 x 13 x 10	**Fore:** 38 x 13 x 10 **Main:** 40-41 x 13 x 10	**Main and Fore:** 120 x 10 x 20		Molded Floor-timbers	**Fore:** 43 x 18 x 10 **Main:** 37 x 12 x 10 -chock reduces main mortise to 24 cm
(8) Mariposa B	1500-1525		present	22 x 20 x 10	141 x 22 x 43 -recessed for floor-timbers	(2x) 55 x 17 x 17 -dovetailed to partners	None(?)	44 x 26 x 12
(9) Lake Garda	1509		missing	present	~600 x ? x ? x 14-28 -recessed for floor-timbers		present -fastened	30 cm length
(10) Villefranche	1516				508 x 30 x 24-40	(2x) 88 x 16-25 x 16 -dovetailed to partners	(9x) 121 x 23 x 18-59	150 x 28 x 15
(11) Mortella III	1527		? x 23 x 15 -rectangular	present?	510 x 18-20 x 22-28 -recessed for floor-timbers -rebated for buttresses -horizontal fastened to keelson	(2x) 40 x 20 x 15 -dovetailed to partners -hang 6 cm above keelson	(6x) 80-90 x 18 x 9-18 -do not sit on floor-timbers	65 x 23 x 15
(12) Sardinaux	1500-1550 (1540s?)	Possible expanded keelson: 77 x 15-15 x 1.5-2						
(13) West Turtle Shoals	1550-1600	Mast mortise cut into top of keelson (not expanded) -Missing rest of support network						19 x 5 x ?
(14) Cadiz-Delta II	1573 (1587)				200 x 5 20 x 50	(3x) present	(5x) present	

Table 6 Continued

Shipwreck	*Date*	*Mast Step (Single Piece) length, sided, moulded (cm)*	*Foreword Wedge length, sided, moulded (cm)*	*Aft Wedge length, sided, moulded (cm)*	*Mast Step Partners length, sided, moulded (cm)*	*Keys length, sided, moulded (cm)*	*Buttresses count (x), length, width, molded (cm)*	*Mast Mortise length, width, depth (cm)*
(15) Sveti Pavao	1580		present	unexcavated	150 x 13 x 25		present	
(16) Ribadeo	1590 (1597)		unexcavated	present	? x 22 x 63		(5x+) 110 x 19-21 x 23-63	? x 35 x ? -chock 34 cm sided

(1) Capulli, 'Il Relitto di Precenicco'; (2) Rieth, 'L'Arquitectura Naval'; (3, 4) Romanelli, *La Galea Ritrovata*; (5) Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc'; (6) Medas, Due relitti con carichi lapidei rinvenuti al Bacàn'; (7) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (8) Beltrame, 'Investigating Processes of Wreck Formation'; (9) Capulli, *Le navi della Serenissima*; (10) Guérout, 'Le navire Génois de Villefranche'; (11) Cazenave de la Roche, *The Mortella III Wreck*; (12) Joncheray, 'Un navire de commerce de la fin du XVII[e] siècle'; (13) Russo, *West Turtle Shoals Wreck (8MO142)*; (14) Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto Delta'; (15) Beltrame, 'The ship'; (16) Borrero et al., *Santiago de Galicia 1590 – Field Notes*

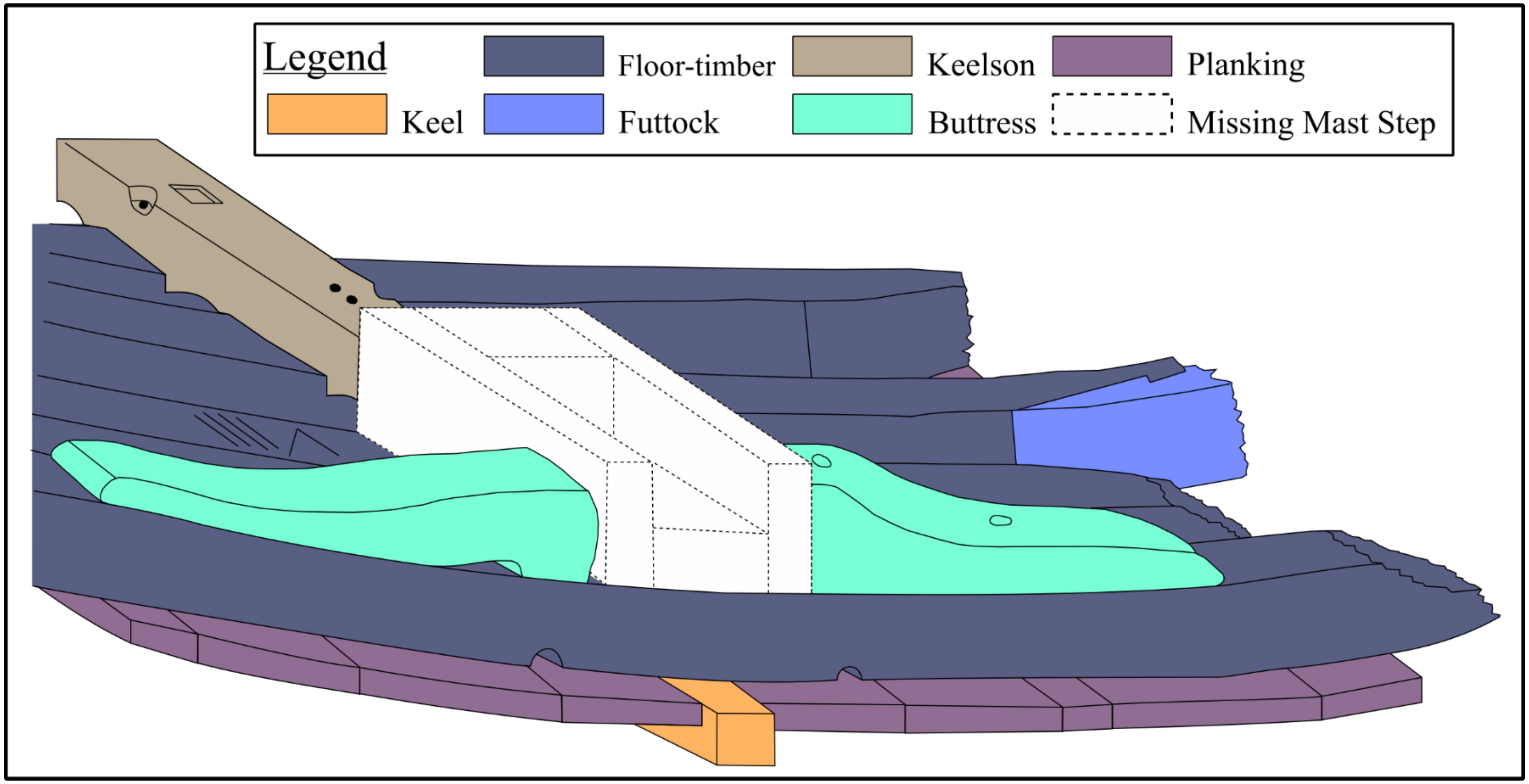

Figure 55 Mainmast step complex from Culip VI (No scale). (after Rieth, 'L'Arquitectura Naval', 129, fig. 59)

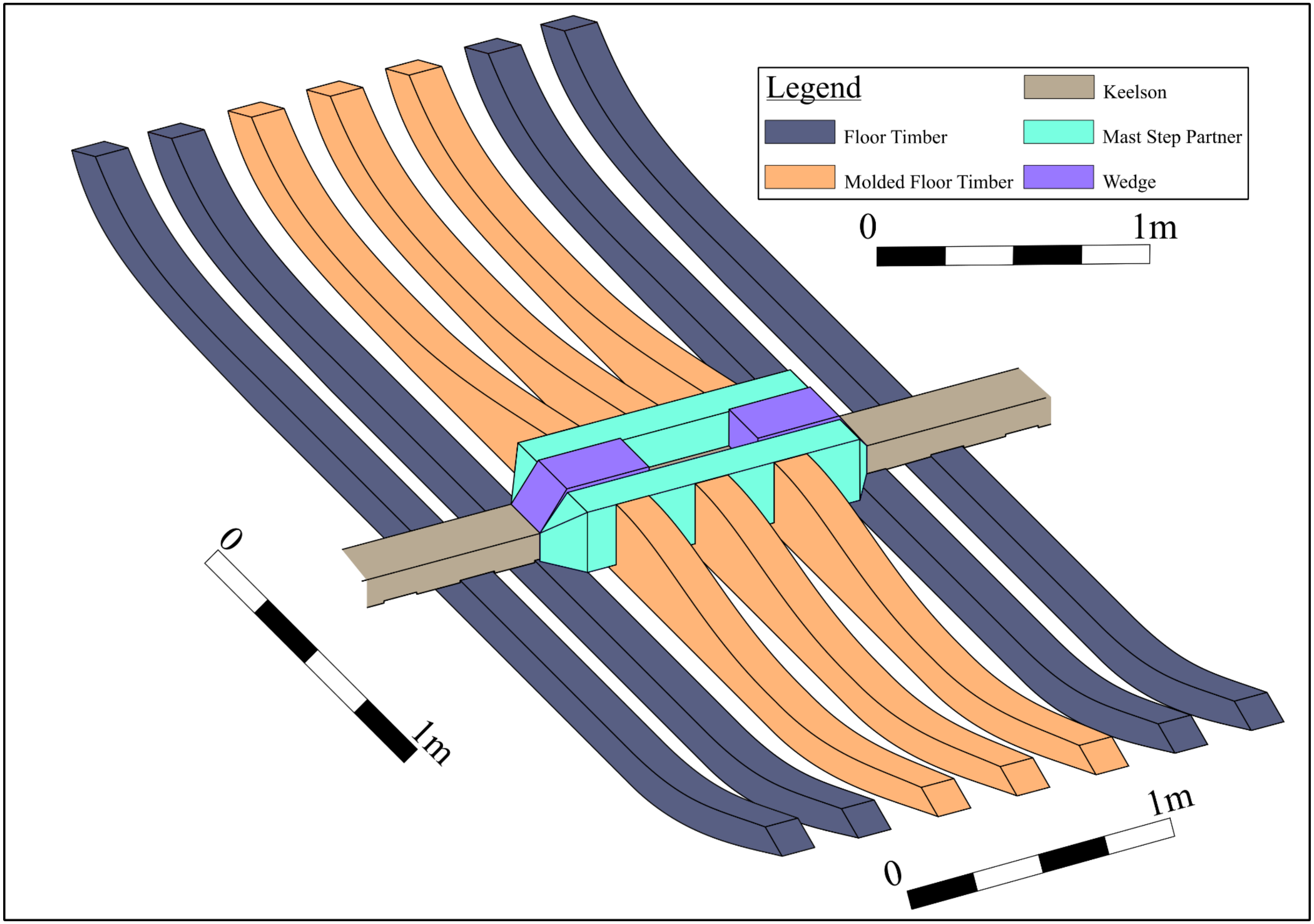

Figure 56 Mast step complex from Contarina I. (Author's Drawing)

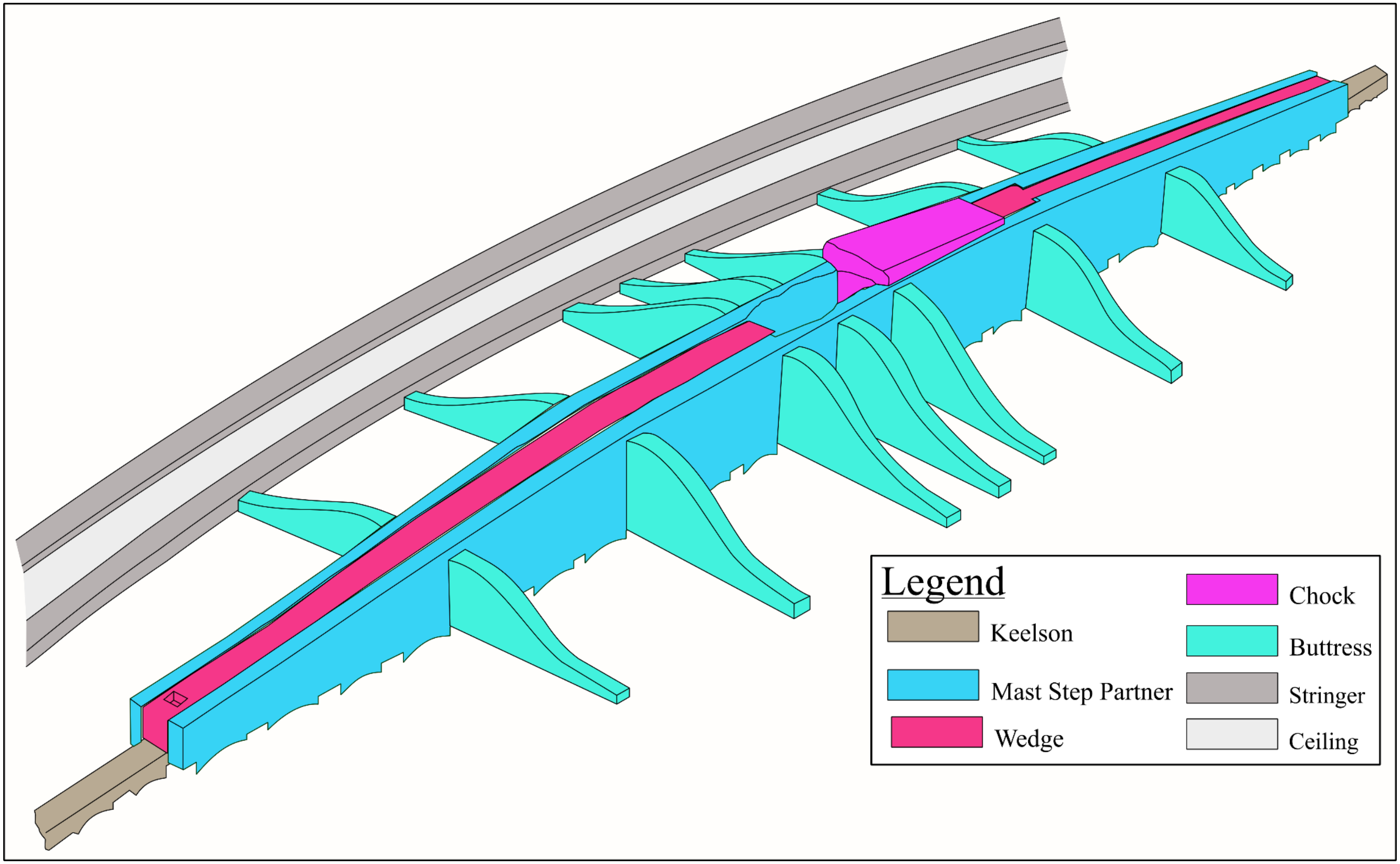

Figure 57 Mast step complex from Boccalama B (No scale). (after D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione', 67)

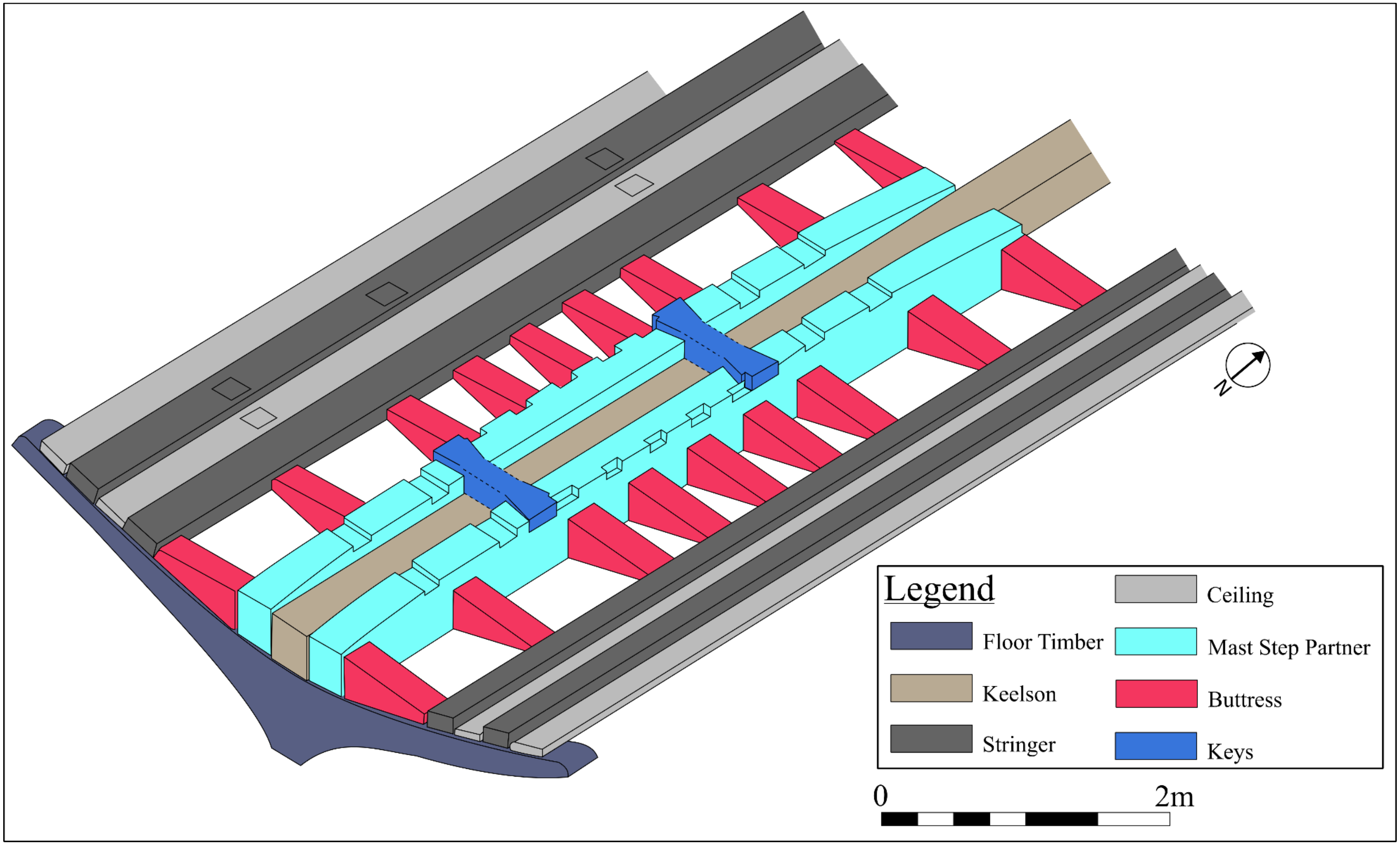

Figure 58   Mainmast step from Villefranche shipwreck. (after Guérout et al., 'Le navire Génois de Villefranche', 70, fig. 33)

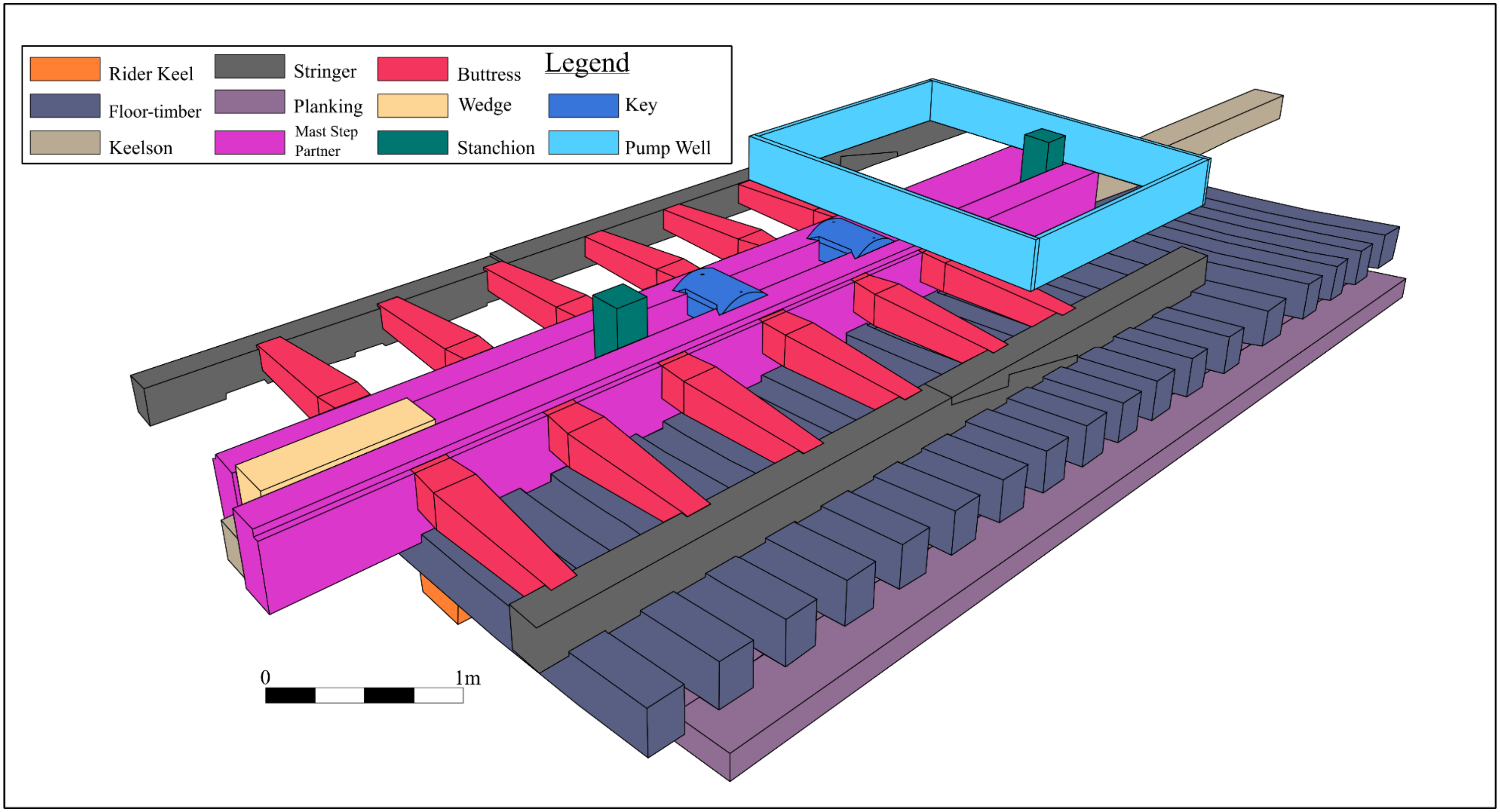

Figure 59 Mainmast step from the Mortella III shipwreck. (after Cazenave de la Roche, The Mortella III Wreck, 95, fig. 115; Original Illustration by Jesús Guevara (Aingurak)

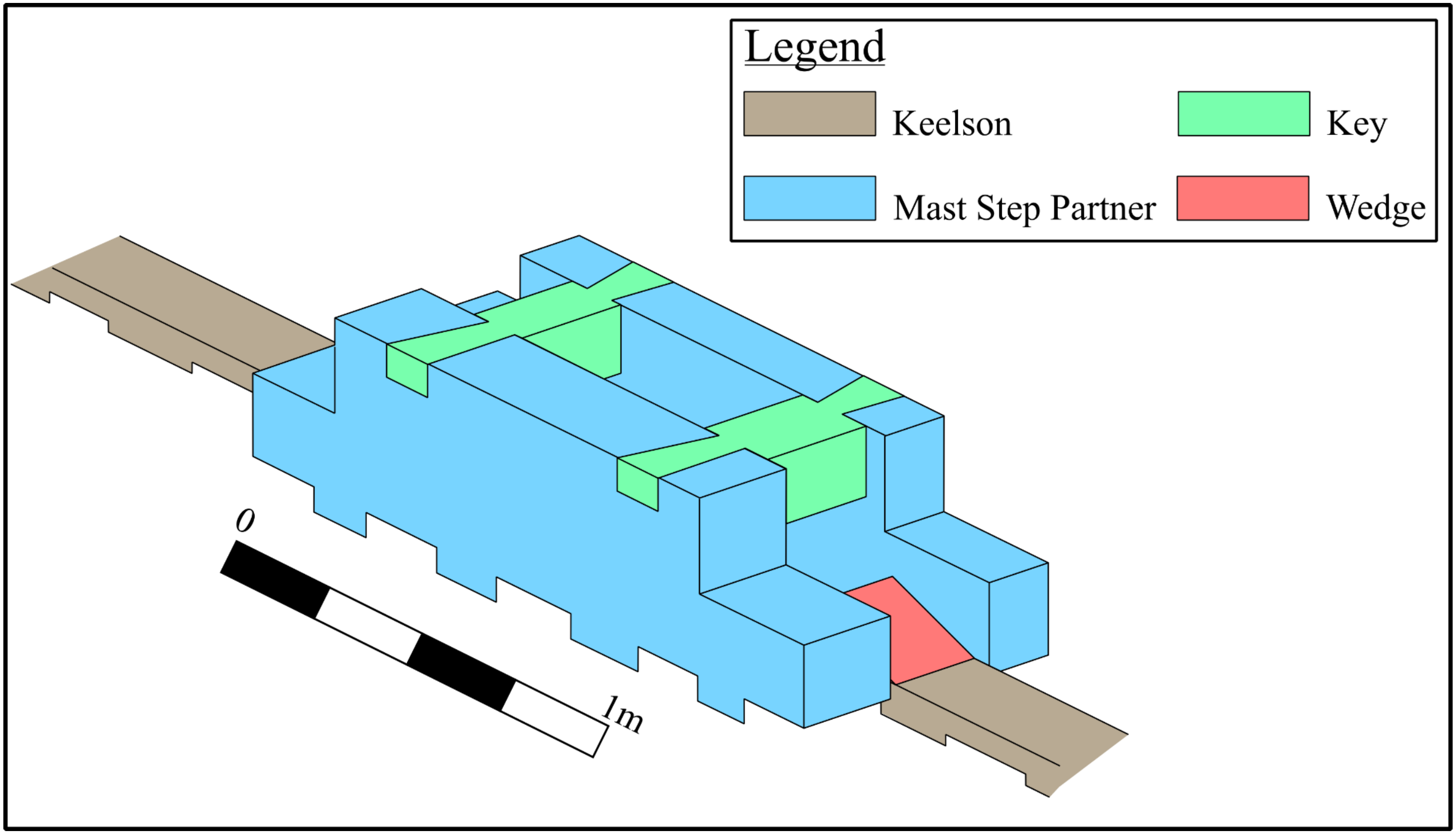

Figure 60 Mast step from Mariposa B. (Author's Drawing)

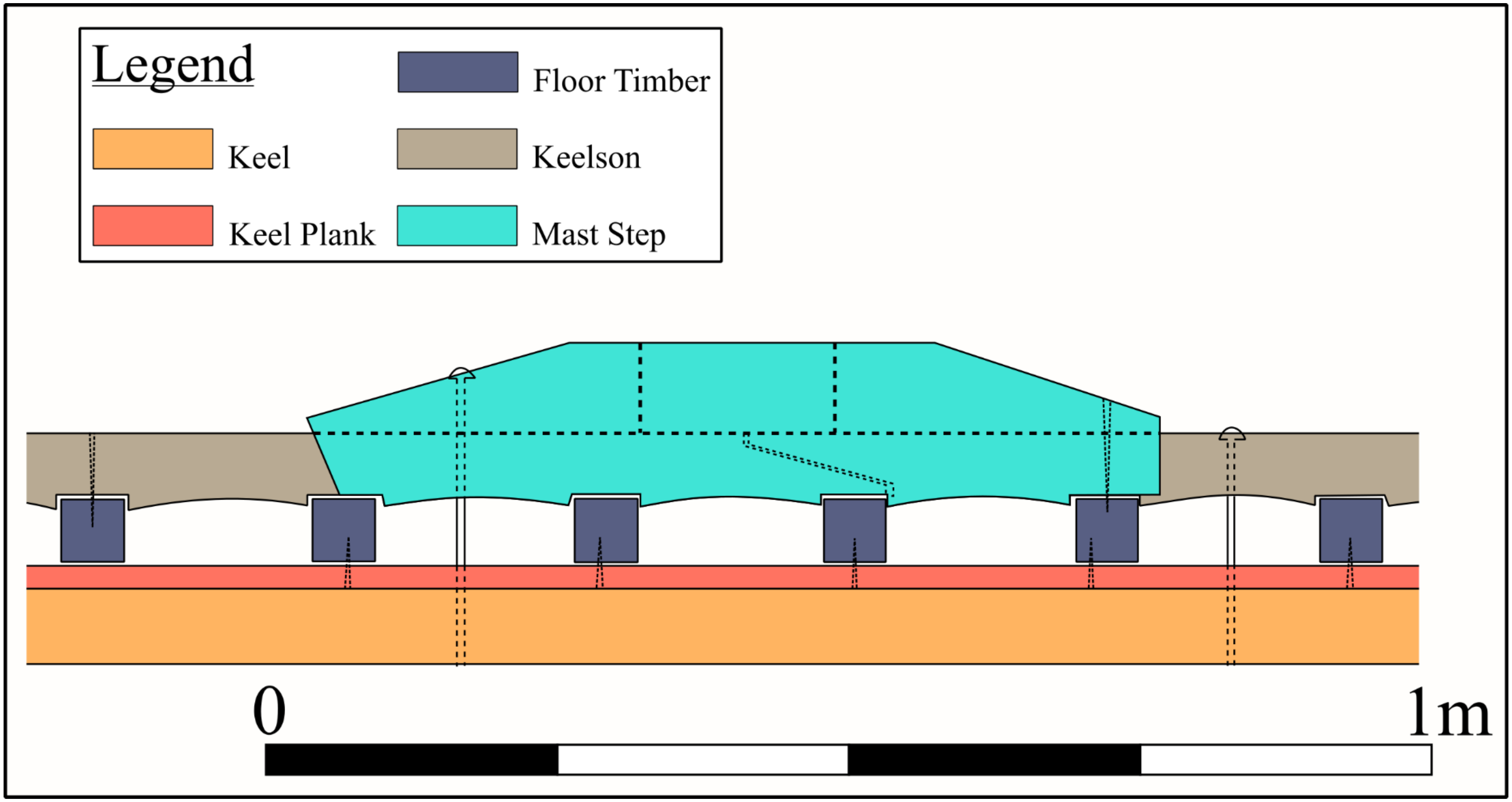

Figure 61 Mast step from Les Sorres X. (after Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries)', 290, fig. 7)

associated well. Mariposa B presents an altered version of this mast step complex by being much shorter and using heavy mast step partners with the keys separated from small wedges acting as the fore and aft walls of the mast mortise (figure 60).[618] Compared to the larger Ligurian examples, Mariposa B is also a much smaller vessel, which might explain the shorter length for this particular step.

Almost every surviving keelson indicates a preference by shipbuilders to refrain from cutting a mortise for the mast into this timber (although mortises for stanchion tenons are frequent). West Turtle Shoals is an anomaly with a mast step mortise carved into the top face of a rectangular keelson in a very similar manner to the earlier ships at the transition between shell- and frame-based construction.[619] The much smaller Les Sorres X includes a wooden block mast step that is recessed to fit over the keelson at its scarf connection (figure 61).[620] Both the weight of the mast step and the mast inserted into the mortise directly over the scarf provided additional reinforcement. Bacàn 1 is the exception to the rule with its expanded keelson features a mortise cut into the top for the mast heel.[621] Whether the decision to utilize an expanded keelson for the mast step is a Northern European or associated bottom-based influence is unclear.

Surviving evidence from Boccalama A suggest bottom-based construction preferred the medieval Mediterranean approach for a thin keelson reinforced by buttresses and a mast step mortise built of composite pieces.[622] Remains from Rhodes 1 also include a thin rectangular keelson without any evidence for an expanded section and possible fragments of a buttress.[623]

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[618] Riccardi, 'The Wrecks off the Camping Site "La Mariposa", Alghero, Sassari, Sardinia, Italy', 136, fig.9.
[619] Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 7.
[620] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 288-9, fig. 5, 7
[621] Medas, 'Due relitti con carichi lapidei rinvenuti al Bacàn (bocca di Porto di Lido, laguna di Venezia)', 121
[622] Romanelli, *La galea ritrovata*, 47.
[623] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 481.

Precenicco has a small short mast step without any associated keelson installed over several frames and above the keel plank.[624] The expanded keelson on Bacàn 1 could be another reinforcement associated with its intended use carrying heavier loads. The typical mast step on medieval Mediterranean vessels could take up too much room in the hold on the much smaller Bacàn ships. A timber that was thinner (except for the expanded keelson section) required less space and could handle minor damage inflicted by shifting cargo.

Ceiling strakes appear in two different configurations throughout the Mediterranean, either as transversal or longitudinal. Transversal-related ceiling features include additional stringers and rebates along the upper surfaces of the keelson for the ends of the planking to rest on. Serçe Limanı shipbuilders used the additional stringers to install transversal ceiling creating a raised platform away from the bilge.[625] Rhodes 4, Camarina, and Cadiz-Delta II include rebates on the upper corners of the keelsons to support transverse ceiling.[626] Sveti Pavao has a stringer (or sister keelson) situated against the mainmast partner to fit the inboard ends of the transverse ceiling.[627] Absence of any fasteners holes or concretions along the top faces of the adjacent floor timbers seem to also support this scenario.

Transverse ceiling on Mortella III, Cadiz-Delta II, Ribadeo, and Saint-Honorat 1 suggest longer strakes that covered the keelson and with their outboard ends supported at the bilge stringers.[628] Most of the other contemporary ships with evidence for ceiling have the planking

[624] Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 132.
[625] Steffy, 'The Reconstruction of the 11th Century Serçe Liman Vessel: A Preliminary Report', 25
[626] Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck in the Port of Rhodes: A Preliminary Report', 9-10; Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87-8; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880.
[627] Beltrame, 'The ship, its equipment and the crew's personal possessions', 48-9.
[628] Cazenave de la Roche, *The Mortella III Wreck*, 84; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880; Borrero et al., '*Santiago de Galicia* 1590 - Field Notes', 44; L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 134-6

running longitudinally. Several ships, including the Bacàn wrecks and Saint-Honorat 1, have ceiling fastened with iron nails and treenails.[629] Neither ship is reported with any treenails to attach the outside planking to the frames. Transverse ceiling appears related to hull form or intended operation, as Serçe Limanı and Rhodes 4 have a similar profile with flat floors and straight sides. Camarina was possibly a horse transport that required a level surface for animals to stand.[630] No clear argument is apparent for the choice in transverse ceiling on Sveti Pavao but the combination of other unusual traits (keel plank, double planking, etc.) may suggest a unique purpose for this vessel. Villefranche, Mortella III, Cadiz-Delta II, and Saint-Honorat 1 were reported with transverse ceiling creating a flat hold surface for vessels with either a wineglass or round profile. Villefranche's ceiling is slightly more complex, as transverse beams and ledges cover the keelson, mast step complex, and bilge stringers with longitudinal boards laid down afterward (in a manner as seen for upper deck assemblies).[631] Longitudinal ceiling strakes were installed at the turn of the bilge on Mortella III and Cadiz-Delta II, even though both vessels have transverse platforms.[632] Surviving hull structure from Boccalama B and Villefranche include longitudinal ceiling planks running from the bilge stringers to the upper deck.[633] Calvi 1 has ceiling between the keelson and bilge stringers. After the second bilge stringer on Mortella III and Calvi 1, a crenulated sill was installed with filler pieces between first futtocks to seal off

[629] Stefano Medas, pers. comm.; L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 134
[630] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 90-1
[631] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 69-71, figs. 34-5
[632] Cazenave de la Roche, *The Mortella III Wreck*, 84; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880.
[633] Romanelli, *La galea ritrovata*, 67-70; Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 67

the bilge from debris.[634] Sills seem to be used extensively for hulls without complete ceiling, but there are few examples to know more about their original provenience on earlier vessels.

Upper Hull Assembly (Shelf Clamps, Beams, Ledges, Waterways, etc.)

Only a handful of shipwrecks include remains from the upper hull assembly and this is mainly from later western Mediterranean examples (Table 7). Most of the earlier eastern ships are only preserved up to the turn of the bilge with minimal findings for round ships. Reconstructions of Boccalama B and Lake Garda are a product of archaeology and documentary sources.[635] These sources suggest that single-decked longships included shelf clamps rebated for consecutive beams that ran across the hull. Above the keelson, a central carling supported by stanchions was rebated to receive the midpoint of each beam. Beam ends were fashioned into a diamond pattern to fit into the shelf clamp and an accompanying wale. The shelf clamp was recessed to fit over the futtocks, while the wale was flush but supported by another thick recessed wale directly beneath. Every third futtock pierced a chamfered toe rail that ran directly over the beam, shelf clamp, and wale. Above this area was the outrigger assembly as part of the propulsion system for these vessels.

Remains from *Kadırga* and the original plans drawn by Le Bas in 1861 appear to support a similar upper hull assembly for smaller longships.[636] The original ship plans include stanchions fitted over the keelson holding up a rebated central carling for the beams. Beam ends were fitted into a robust shelf clamp but not into the corresponding wale. The wale is much smaller than the

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[634] Cazenave de la Roche, *The Mortella III Wreck*, 84; Villié, 'L'épave Calvi 1 (1990)', 88-9
[635] Romanelli, *La galea ritrovata*, 64-5; Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 87.
[636] Basch, 'A Galley in Istanbul: The Kadırga', 134; Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 245, fig. 36.7.

Table 7 Measurements from upper assembly

Shipwreck	*Date*	*Beams width, thickness(cm)*	*Ledges width, thickness (cm)*	*Shelf Clamp width, thickness (cm)*	*Deck Planking width, thickness (cm)*	*Waterway width, thickness (cm)*	*Stern Panel*
(1) Marinières	1420-1430	10-14 x 9+		26 x ? -crenulated for beams			
(2) Contarina I	1460s			30-40 x ? -upper stringer			
(3) Contarina II	1475s	10 x 10	10 x 6	29 x 4	30 x 4	17 x 12 -recessed over futtocks	
(4) West Turtle Shoals	1550-1600			11 x ?			**Planking:** 25-34 cm width -50° chevron angle **Header:** 1.10 m (2.2 m originally) **Fashion Piece:** 2.06 m
(5) Villefranche	1516	**Main:** 9-20 x 10-12 **Orlop:** Double beams (20 x 20) Single beams 14-18 x 20	**Main:** 14-18 x 13-15 **Orlop:** None	**Main:** 20 x 22 **Orlop (stringer):** 18 x 15 -recessed over frames -crenulated for beams	10 cm thick	30 x 10	
(6) *Kadırga*		10 cm thick	None	14 x 10 -recessed over frames	25 x 3.5	19 x 6	
(7) Calvi 1	1575	11.5 x 8	None	16.5 x 13.5 -crenulated for beams (3-6 x 7-9)	16-19 x 2.5-3.8	None	**Planking:** 21 x 6 cm -30° chevron angle **Header:** 2.22 m (4.44 m overall) **Fashion Piece:** 3.84 m length **Deck space:** 1.58 m
(8) Ribadeo	1590 (1597)			24 x 24			

(1) Daeffler, 'L'Epave des Marinières'; (2, 3) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (4) Russo, *West Turtle Shoals Wreck (8MO142)*; (5) Guérout, 'Le navire Génois de Villefranche'; (6) Arcak, 'Kadırga'; (7) Villié, 'L'épave Calvi 1'; (8) Borrero et al., *Santiago de Galicia 1590 – Field Notes*

shelf clamp and appears to be a half log. *Kadırga*'s current hull structure includes a shelf clamp that matches the same width as the accompanying wale (the latter appears to be original). Les Bas' drawing presents the planking as the same thickness throughout the hull, while the current ship includes a recessed thicker plank fitted directly below the wale. Deck planking covered the shelf clamp, while upper futtock ends are exposed above the beams as part of the lower assembly for the outrigger.

Similarities between the Boccalama B, Lake Garda, and *Kadırga* suggest a continued eastern methodology in longship construction over four centuries. Differences from earlier vessels imply whomever constructed *Kadırga* omitted the beam ends from also fitting into the wale. The smaller size of the later longship might also be a reason why this feature is not present, as the *Kadırga* carried fewer rowers and was not intended for long, open-water passages. Boccalama B's reconstruction does not include any knees to support the beams, while Lake Garda evidently had lodging knees at every fourth beam. No knees are indicated as part of the deck assembly on *Kadırga*. Installation of knees as additional reinforcement might be a concern when trying to keep longships lightweight or the much shorter distance between beams compared to round ships may have reduced their necessity.

The two Contarina shipwrecks represent the only other examples of surviving upper hull structure for eastern Mediterranean vessels from this period. The upper structure from Contarina I includes a stringer clamping the overlap between the first and second futtocks; no further information is included about beams or deck placement.[637] Photographs taken of Contarina I

[637] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 14, fig. 4

after it was exposed show a single beam near the bow with a recess to fit between futtocks and another on a different face possibly for the missing shelf clamp.[638]

Contarina II's remains include structure aft of amidships and above the turn of the bilge (figure 62). The shelf clamp is represented by a wide plank with a similar thickness as the accompanying stringers. Beam ends are inserted into the shelf clamp and accompanying wale with two sets of dovetail connections. Ledges simply fit into rectangular rebates on the shelf clamp and butt against the wale. Beams and ledges are installed at every third frame station; ledges are fitted over the heads of first futtocks, while beams are inserted between frame stations. A chamfered waterway is installed directly over the crossbeams. Exposed beam ends along the wale are covered with a thin plank.[639] The overall construction of exposed through-beams along the outside of the vessel for the longships and Contarina II is considered a shell-oriented technique carried over to frame-based shipbuilding until the sixteenth century.[640] Western examples of deck assembly do not have the beam tenon piercing the outside wale.

Villefranche's lower deck assembly provided internal reinforcement for the wineglass shape of the hull. The orlop consists of consecutive beams between double stacked beams rebated into stringers covering the first and second futtock overlap. The outboard end of the lower half of the double beams is recessed over the first stringer and includes a mortise along the top face for a knee that is part of the accompanying beam above. This knee is recessed over the second stringer and ceiling, while its inboard end includes a hook scarf for a continuation of the beam to the other side of the hull.[641]

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[638] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', pl. 8.
[639] Ibid., 35-8.
[640] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 20-1
[641] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 48-54

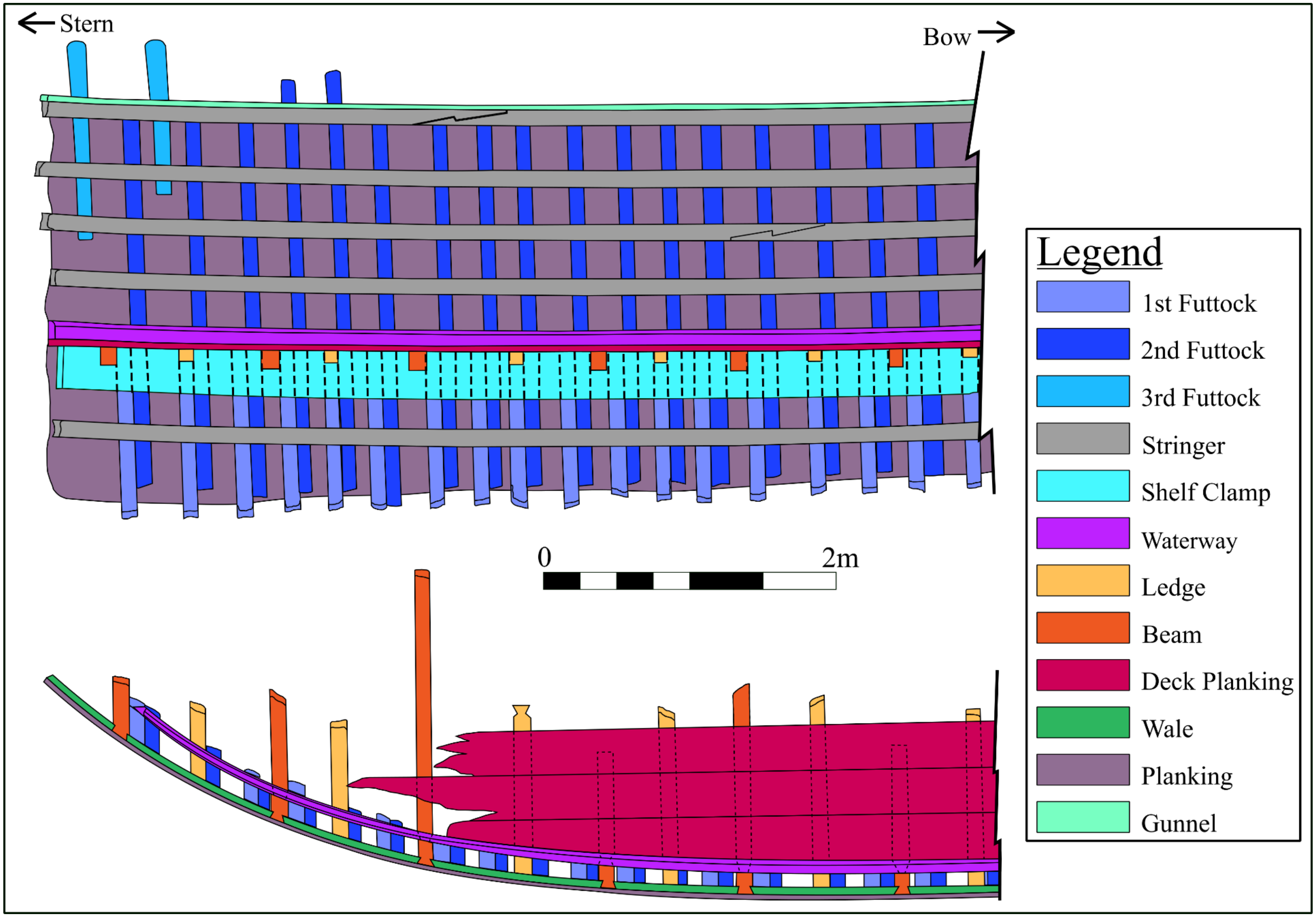

Figure 62 Hull remains from Contarina II shipwreck with surviving deck structure. (after Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 18, fig. 7)

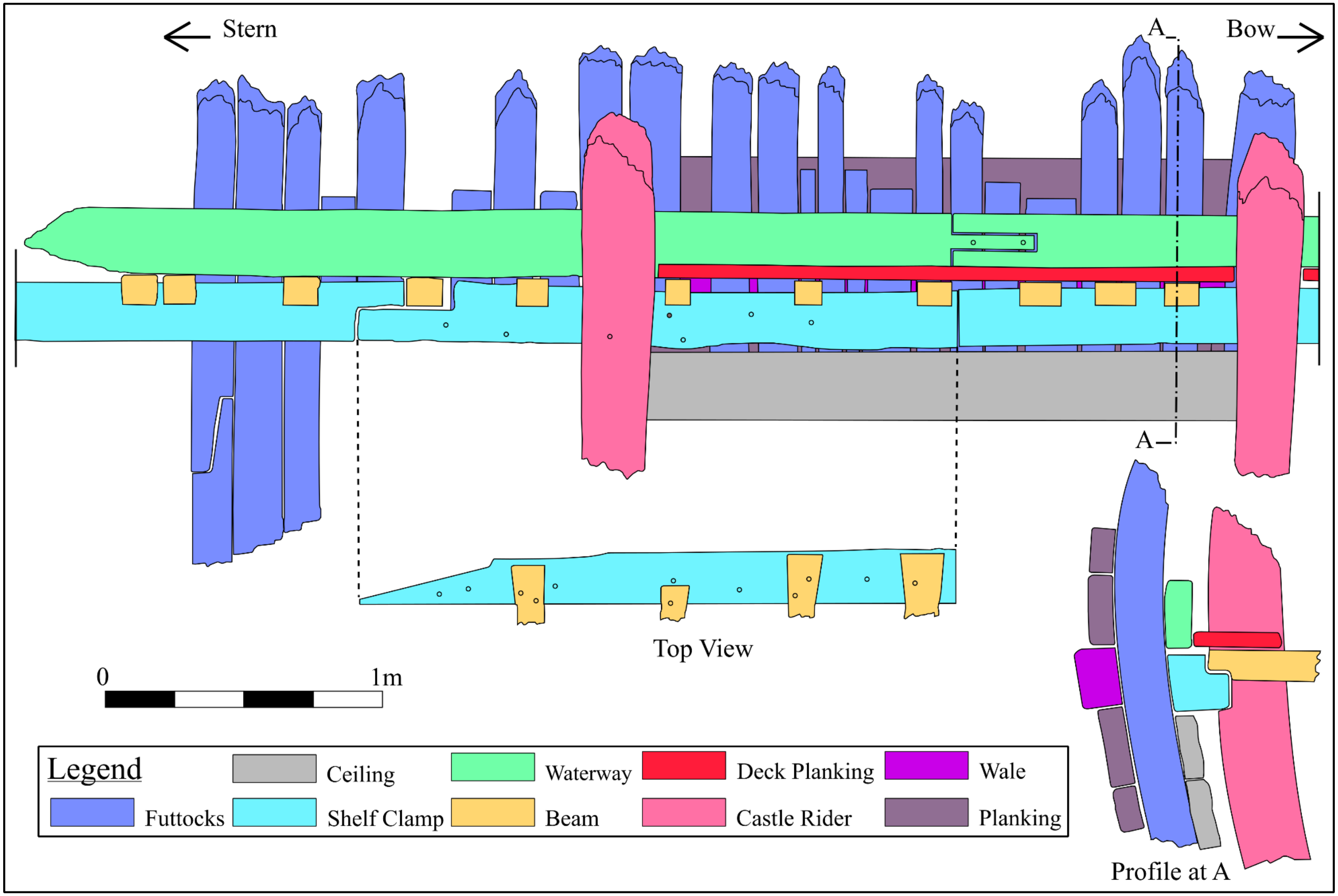

Figure 63 Layout for the main deck on the Villefranche shipwreck. (after Guérout et al., 'Le navire Génois de Villefranche', 55, fig. 25)

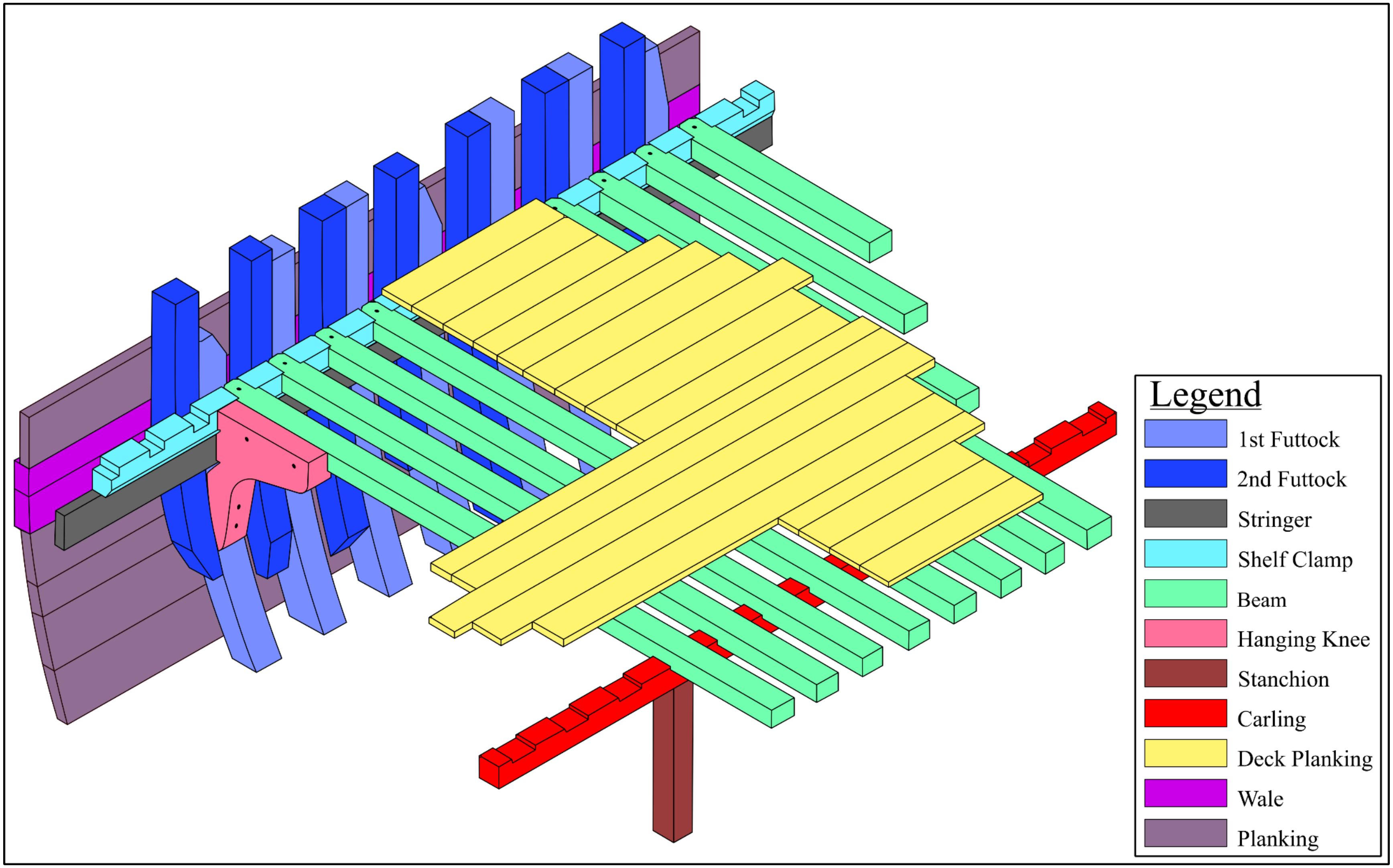

Figure 64   Deck plan from Calvi 1 shipwreck (No scale). (after Villié, 'L'épave Calvi 1', 31)

Remains from the main deck are similar to Contarina II with a shelf clamp (in this case much more robust) rebated for dovetail tenons from the beam ends (figure 63). The dovetail tenons do not pierce the shelf clamp and the positioning of the beams is dependent on their location. Deck planking runs longitudinally and a waterway slightly thicker than the surrounding ceiling sits directly above the shelf clamp. There is an accompanying wale running along the outside of the hull at the same level as the shelf clamp, but the only interaction between these two pieces is the fasteners connecting them together.[642] The upper deck presumably included a similar system with more robust beams crossing the hull. Each deck is held up by stanchions with longitudinal carlings recessed to fit the underside of the beams.

Only minor differences in deck assembly are noted from the surviving remains on Calvi 1 (figure 64). The beam ends are mainly fitted into rebates along the top face of the shelf clamp with a chamfered tenon that pierces the whole timber. Beam ends fitted against the inboard faces of the accompanying overlapping first and second futtocks. Below the shelf clamp is a wide stringer acting as support and there are two accompanying wales on the outside of the hull.[643] There is no surviving evidence for a waterway on Calvi 1. Another difference in deck construction is the use of knees. Villefranche includes standing knees built into the double beams at the orlop and robust versions sitting above the deck planking on the main deck. Calvi 1 includes recessed hanging knees to support beams at key stations and lodging knees at the stern transom. West Turtle Shoals includes a similar placement for lodging knees at the stern as part of the transom assembly.[644]

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[642] Ibid., 54-9.
[643] Villié, 'L'épave Calvi 1 (1989)', 30-2
[644] Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 7.

Limited remains uncovered so far from Ribadeo suggest a similar lower deck assembly with a square shelf clamp and a slightly smaller square stringer running directly underneath.[645] An accompanying wale is present for the shelf clamp. A fragment of a shelf clamp with rebates for the beams also survives on Marinières.[646] Several places along this shelf clamp are without rebates and it seems the accompanying futtocks were cut instead. Villefranche was originally the only example with two sets of castle riders fitted over the ceiling and between decks.[647] Max Guérout concluded that these pieces were only present beneath the castles as additional internal support and it appears this is further reinforced by similar pieces present near the stern on Ribadeo.[648]

Toward the end of the fifteenth century, iconography suggests shipbuilders began to incorporate a flat or square transom as part of round ship construction.[649] West Turtle Shoal and Calvi 1 are the only two ships with surviving stern panels. The West Turtle Shoal example is relatively simple, two long fashion pieces created the curved edge and transom pieces cross in between. Chevron planking is attached to the fashion piece, transom, and the rabbet cut into the sternpost running along the centerline of the assembly.[650] Calvi 1's stern panel is much more complex, with a sternpost and an internal sternpost with framing installed. Several centered frame elements are recessed to fit over the inner sternpost, while the remaining timbers are cut to create the overall shape. The fashion piece is composed of two or three segments chamfered along the outside edge. On either side of the sternpost are filling timbers, and a reinforced

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645 Borrero et al., '*Santiago de Galicia* 1590 - Field Notes', 41.
646 Daeffler, 'L'épave des Marinières', 39, fig. 6.
647 Guérout, 'Epave de la Lomellina (1516) - Structures internes de soutien des châteaux avant et arrière',
648 Borrero et al., '*Santiago de Galicia* 1590 - Field Notes', 34, 40.
649 Loewen, 'The Square Tuck Stern: A Renaissance Innovation?', 132-3.
650 Russo, 'Florida Master Site File, West Turtle Shoals Wreck (8MO142)', 7.

transom port was present toward the centerline. Several dagger knees are installed on top of the stringers to reinforce the lower half of the transom and the internal framing of the stern panel is covered with planking. The outside face is also covered with chevron planks fastened to all the framing pieces.[651]

Calvi 1 features reused timbers such as the stern knee that does not match the exact curvature of the keel. When compared to the West Turtle Shoal stern panel, or the similarly constructed sixteenth-century Iberian example from Red Bay 24M, Calvi 1 is overly complex and appears to use much more timber and fasteners than necessary. There is no evidence for a transom port like the one seen on the West Turtle Shoal wreck. Red Bay 24M is larger than West Turtle Shoals and includes ports installed between transom pieces directly beneath the main deck, although the vessel's use transporting whale oil seemingly discounts the need for a robust stern panel.[652] Calvi 1's stern port may actually be a gunport that required additional reinforcement, which explains its complex construction. The location of the port supports this conclusion, as its position is less than a meter above the corresponding deck.

Outer Hull

Smaller coastal vessels include recessed bilge keels bolted to internal stringers, providing a solid longitudinal connection at the lower frame overlap. Bilge keels also protected hulls when they grounded at low tide, either allowing them to keep upright or to lean against this reinforced spot. This system allowed small vessels to temporarily beach to offload cargoes. Camarina is an exception from the other eastern longships due to the presence of bilge keels, presumably because the ship was a horse transport intended for loading and unloading by beaching.[653] Culip

[651] Villié, 'L'épave Calvi 1 (1989)', 32-44
[652] Loewen, 'The Square Tuck Stern: A Renaissance Innovation?', 132-3.
[653] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 90-1

VI, Les Sorres X, Contarina I, and Sardinaux all include bilge keels and these ships are interpreted as coastal traders operating in shallow water environments.[654] Most large ships operating exclusively in deep water do not include bilge keels. Evidence from Calvi 1 and *Kadırga* suggest a legacy of bilge keel usage from earlier ships, as these later examples include a *massane* (stern wale) girdling the transition from the lower half of the hull as it expands outward to incorporate the upper deck(s).[655] Calvi 1 and *Kadırga* represent different ship morphologies, yet the *massane* is in the same position and similarly transitions into a plank towards amidships as the central strake that covers the overlap between the floor timbers and futtocks.

Planking dimensions vary greatly throughout the Mediterranean although the general trend was for earlier ships to use thinner strakes, and later ships to have thicker strakes. Thickness is dependent on the general size of the ship and is much greater on seafaring vessels intended for longer voyages. Sveti Pavao stands out as the only example of a double-planked ship from this period.[656] Double planking is not a new or adopted phenomenon, the first century BC shell-built Madragues de Giens for example utilized double planking.[657] Ribadeo appears to have thicker planking (15 cm) when compared to other similar sized vessels and this might be due to its intended purpose as a warship.[658] In comparison, Villefranche and Mortella III include planking that is slightly thinner (10-12 cm and 8-10 cm respectively) than Ribadeo.[659]

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[654] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 134-5; Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 35-6; Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 25-6; Joncheray, 'Un navire de commerce de la fin du XVII[e] siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 46
[655] Villié, 'L'épave Calvi 1 (1990)', 115; Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 246.
[656] Beltrame, 'The ship, its equipment and the crew's personal possessions', 48.
[657] Pomey, 'Le navire romain de la Madrague de Giens', 139-40
[658] Casabán, '*Santiago de Galicia* and the Illyrian squadron: Characteristics, dimensions and tonnages of Mediterranean-built galleons for Philip's II Atlantic fleets (1593–1597)', 243; Borrero et al., '*Santiago de Galicia* 1590 - Field Notes', 41.
[659] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 65; Cazenave de la Roche, *The Mortella III Wreck*, 85.

Other vestiges of earlier shell-oriented construction are evident in the Z- and similar scarf types seen on Serçe Limanı, Rhodes 2, and Boccalama B.[660] None of the scarfs include fasteners connecting the two planks together, they are simply fastened to the framing underneath. The shaping of complex planks ends takes more time and additional caulking than butting the ends together. The use of scarfs for planking on Serçe Limanı was perplexing for the original investigators and suggested anachronistic shell-oriented practices present even as frame-based construction was taking hold across the Mediterranean. Hook scarfs present in the ceiling and planking on Boccalama B may highlight some concern by the builders about longitudinal stresses to the hull. But these scarfs are among flat scarfs and other examples that contain no relation between either plank besides the overlap itself.

Rieth's previous observations about the predominant use of iron nails for attaching the planking to the frames remains true.[661] Serçe Limanı's builders used four to six nails per frame station, while the contemporaneous Marsala A followed the two or three nail trend used in earlier shell-based ships and subsequent Mediterranean construction.[662] Most frame stations included two nails, while a third is only prevalent at the butt ends of each strake. Round-shanked nails are present as part of the construction for Villefranche, Mortella III, Calvi 1, and *Trinidad Valencera*. Archaeologists working on Villefranche state that the nail sections recorded near amidships are between 1-1.5 cm for the planking or 2 cm for stringers.[663] Fasteners on Mortella

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[660] Steffy, 'Construction and Analysis of the Vessel', 162; Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 482; Romanelli, *La galea ritrovata*, 65.
[661] Rieth, 'Consruction navale a franc-bord en Mediterranee et Atlantique (XIV^e-XVII^e siecle) et 'signatures architecturales'', 187.
[662] Matthews and Steffy, 'Serçe Limanı', 106-8; Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 302, fig. 18
[663] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 65, 69

III were quadrangular or circular and Villefranche likely used similar nails.[664] Most of the planking fasteners on Calvi 1 were square, although a section of the garboard had round nails.[665] The use of square nails on the interior of this vessel was both sparse and temporary prior to the installation of numerous drift pins or through bolts. Images and drawings of surviving planking from *Trinidad Valencera* suggest the fasteners had cross sections similar to those of Mortella III.[666]

Both Contarina wrecks had their framing assembled using round nails, but the planking was fastened to the framing by square fasteners.[667] Calvi 1 and *Trinidad Valencera* also include round fasteners as part of the connection between frame components.[668] Precenicco does not necessarily conform to the exclusive iron nail preference, as most of its construction is with treenails. Only the overlapping frames include iron fasteners.[669] Cavoli and Marinières planking was attached with a combination of iron fasteners and treenails.[670] Culip VI and Les Sorres X used treenails for connecting the stringers and bilge keels. Cavoli, Mortella III, and Calvi 1 reportedly had clenched nails for the planking fasteners to add further strength to the hull.[671]

Surviving elements for wales vary greatly due to differences in preservation and those that survived are often wales fitted below the waterline. These timbers varied in dimensions and were dependent on the overall size of the vessel. Many of the surviving examples include

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[664] Cazenave de la Roche, *The Mortella III Wreck*, 86, 155, tbl. 14.
[665] Villié, 'L'épave Calvi 1 (1991)', 78-82
[666] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 30
[667] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 25, 35-6.
[668] Villié, 'L'épave Calvi 1 (1990)', 104-8; Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 29-31, fig. 14
[669] Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 132.
[670] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 63; Daeffler, 'L'épave des Marinières', 17.
[671] Martin-Bueno, *La nave de Cavoli y la arqueologia subacuatica en Cerdeña*, 78; Cazenave de la Roche, *The Mortella III Wreck*, 86; Villié, 'L'épave Calvi 1 (1989)', 30

recesses to fit over the outer faces of the framing and many were positioned outbound of internal stringers. Lower wales/stringers often overlapped the first and second futtocks and contributed longitudinal reinforcement at this position. Surviving remains from Contarina II, and the reconstructions of Boccalama B and Lake Garda, suggest that wales played an important structural role in association with the deck beams.[672]

As stated above, the system of through-beams seen on eastern wrecks is reminiscent of earlier shell-based construction. Wales in antiquity were part of the mortise and tenoned planking that comprised the hull, while through-beams acted as the platform for the deck and helped to reinforce the overall shape. The presence through-beams on Contarina II suggests conservative shipbuilding practices were maintained on smaller vessels. Contemporary iconography suggests their widespread use on round ships until the sixteenth century.[673] Attaching the beams to the wales on Boccalama B resembles a shell-based solution to frame-based problems, due to the longitudinal torsion encountered on longships.[674] The reconstruction of Lake Garda and *Kadırga* suggest through-beams were phased out by the sixteenth century.[675] Most longships also include evidence for recessed planking that supported the traditional wales in preventing torsion and provided the foundation for the outrigger assembly installed directly above.

[672] Bonino, 'Lateen-rigged medieval ships. New evidence from wrecks in the Po Delta (Italy) and notes on pictorial and other documents', 18, fig. 7; Romanelli, *La galea ritrovata*, 64-5; Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 87.

[673] For an example of a large contemporary round ship with through-beams, see Rieth, 'Les illustrations d'un livre de recettes techniques d'architecture navale du millieu du XV^{e} siecle; le libro de Zorzi Trombetta de Modon', 92, fig. 1

[674] Christensen, 'Lucien Basch: Ancient wrecks and the archaeology of ships, a comment', 143

[675] Bondioli and Penzo, 'Teodoro Baxon e Nicola Palopano proti delle galee sottili. L'influsso Greco nelle costruzioni navali Veneziane della prima metà del XV secolo', 67, fig. 1; Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 87.

Caulking and sealant were reported for some sites. Serçe Limanı, Marsala A, Camarina, Les Sorres X, Marinières, and Ribadeo had caulked seams.[676] Church Rocks and Sardinaux have no caulking present in the seams.[677] Most ships in this period, including Serçe Limanı, Culip VI, Les Sorres X, Villefranche, Mortella III, Yassıada 3, Calvi 1, and *Trinidad Valencera*, are described as having pitch covering both the inside and outside of the hull. The hulls of Culip VI and Villefranche were payed with tallow before the application of pitch.[678] Marinières and Cap Lardier 1 are described as only having external pitch with the former reported as approximately 6 cm thick.[679] Covering the inside and outside of the hull with pitch appears to be a practice continued from earlier shell-first shipbuilding.

Lead caulking or sheathing reappears by the fifteenth century with Marinières described as having strips inserted between the keel and garboard.[680] Calvi 1 has lead sheathing protecting the keel and garboard connections, while Villefranche, Cadiz-Delta II, Ribadeo, and Agropoli are described as lead sheathed.[681] Similar to pitch practices, lead sheathing was also present throughout antiquity.[682] Absence of lead sheathing during the medieval period could either be

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[676] Matthews and Steffy, 'Serçe Limanı', 111; Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 298-300, fig. 14; Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87-8; Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 37; Daeffler, 'L'épave des Marinières', 18; San Claudio Santa Cruz et al., 'El precio de Ribadeo, un excepcionalmente bien conservado pecio español del siglo XVI', 212.
[677] Preece, Burton, and McElvogue, 'Evidence for High Status at Sea: The Church Rocks Wreck', 112; Joncheray, 'Un navire de commerce de la fin du XVII^e siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 58
[678] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 126-7; Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 60
[679] Daeffler, 'L'épave des Marinières', 17; Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVI^e siècle', 25
[680] Daeffler, 'L'épave des Marinières', 18.
[681] Villié, 'L'épave Calvi 1 (1990)', 84; Guérout, 'Epave de la Lomellina (1516) - Doublage de la coque', 6; Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto delta', 880; San Claudio Santa Cruz et al., 'El precio de Ribadeo, un excepcionalmente bien conservado pecio español del siglo XVI', 211; Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 73.
[682] Hocker, 'Lead hull sheathing in antiquity', 201; Kahanov, 'Some aspects of lead sheathing in ancient ship construction', 219; Rosen and Galili, 'Lead Use on Roman Ships and its Environmental Effects', 301

related to the cheaper practice of applying thick layers of pitch to the hull or that relatively few deep-water vessels are archaeologically reported until the fifteenth century. Except for the longships, most of the earlier vessels are coastal traders that did not necessarily travel long distances with cargos that could offset the price of lead sheathing.

Dendrochronology

Dendrochronology originally focused on tree-ring growth patterns to learn about historic atmospheric and climate conditions. Samples are collected from living trees, archaeological sites, historic architecture, and wooden artifacts. Collecting and reporting about the annual ring growth from hundreds of trees within a regional context provides a dataset for statistical analyses. Results can provide average predicted ring growths during specific years that form the master chronologies against which new samples are compared.[683] Master chronologies should not be considered static and the infusion of new datasets continue to refine the predictability of growth patterns.

Dendroarchaeology focuses on understanding the applications of wood within a historic context. This subdiscipline continues to apply the traditional dendrochronological techniques to find absolute dates for the construction of objects and structures from archaeological sites.[684] Timber is also examined to learn about the conversion process and craftsmanship of individual builders. On more complex materials (such as ships), this research also focuses on the builder’s choices of wood species, understanding the forest management practices, and the origins of

[683] Farrell and Baillie, 'The Use of Dendrochronology in Nautical Archaeology', 48
[684] Domínguez-Delmás, 'Seeing the forest for the trees: New approaches and challenges for dendroarchaeology in the 21st century', 1

timbers. Taxa identification from the ship timbers or wood cargo could also provide information about the timber-harvesting industry and shipyards.[685]

Several caveats and challenges should also be considered with dendrochronological studies. Sampling from underwater sites often includes limitations on visibility, tools, and time.[686] Researchers prefer timbers with greater amounts of tree-rings and limited amounts of damage by marine borers. The latter can effectively be overcome by archaeologists excavating hull sections under greater overburden, hopefully in an undisturbed context that left timbers in an anerobic environment.[687] At least 50 cm overburden is considered necessary for significant reduction in oxygen levels.[688] Samples can be identified at the genus level, but it is much harder to provide a specific species. Many shipwrecks include oak throughout their construction. The wide geographical distribution of common oak species (*Quercus robur* and *Quercus petraea*) across Europe prevents identifying an exact origin.[689] Other issues include the presence of repairs on ships with longer lifespans. Each repair may include different species and date to a later period than the original construction.

Simplified anatomy of a typical tree includes the central heartwood, sapwood, and the bark protecting the latest growth (figure 65). Sapwood represents the living layer of the tree transferring water and food throughout the organism, while the heartwood is the conversion of older sapwood into a "dead" skeletal structure. Shipbuilders throughout history recognized

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[685] Pomey and Rieth, *L'archéologie navale*, 51.
[686] Domínguez-Delmás et al., 'Selecting and Sampling Shipwreck Timbers for Dendrochronological Research: Practical guidance', 232
[687] Ibid., 237.
[688] Gregory, 'Re-burial of timbers in the marine environment as a means of their long-term storage', 344; Björdal and Nilsson, 'Reburial of shipwrecks in marine sediments: A long-term study on wood degradation', 871; Nyström Godfrey, Bergstrand, and Petersson, eds., *Reburial and Analyses of Archaeological Remains: The RAAR project, Phase II - Results from the 4th retrieval in 2009 from Marstrand, Sweden*, 31.
[689] Haneca, Čufar, and Beeckman, 'Oaks, tree-rings and wooden cultural heritage: A review of the main characteristics and applications of oak dendrochronology in Europe', 2

sapwood as prone to rot and whenever possible chose to remove this layer as part of fashioning each timber for installation. Removal of the sapwood prevents dendrochronologists from accurately dating the felling of a tree. Statistical estimates may provide a date range, and this is mostly successful with species (such as oak) that provide a constant new layer of growth regardless of atmosphere, climate, or anthropogenic factors. Other species, including walnut (*Juglans regia*) or poplar (*Populus sp.*), are more difficult to date due to individual changes by single trees, short lifespans, and management for fruit or nut production.[690]

Comparative dendrochronological analyses on ancient Mediterranean shipwrecks mainly includes work focused on the French coastline. Previous studies were comprised of 28 shipwrecks with samples collected and studied on most of the hull structure.[691] Preliminary findings suggest that ships built with few tree species highlighted a shipyard's access to quality materials. Heterogeneity throughout the hull structure could indicate less timber availability or shipbuilders preference for specific species as ideal for individual components.[692] Several wrecks included a few timbers with similar chronologies specifying resources from the same tree or forest. Hulls with species homogeneity could be traced to a possible coastline for their original production.[693] Recent studies in ancient shipwrecks continue to add to this initial study. No master chronology is available for this period or throughout the medieval era. Several issues for compiling a master chronology in this geographic area include the major deforestation from

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[690] Domínguez-Delmás et al., 'Selecting and Sampling Shipwreck Timbers for Dendrochronological Research: Practical guidance', 234

[691] Guibal and Pomey, 'Essences et qualité des bois utilisées dans la construction navale antique: L'aaport de l'étude anatomique et dendrochronologique', 93

[692] Guibal and Pomey, 'Timber Supply and Ancient Naval Architecture', 38-41.

[693] Giachi et al., 'The wood of "C" and "F" Roman ships found in the ancient harbour of Pisa (Tuscany, Italy): The utilisation of different timbers and the probable geographical area which supplied them', 271-2

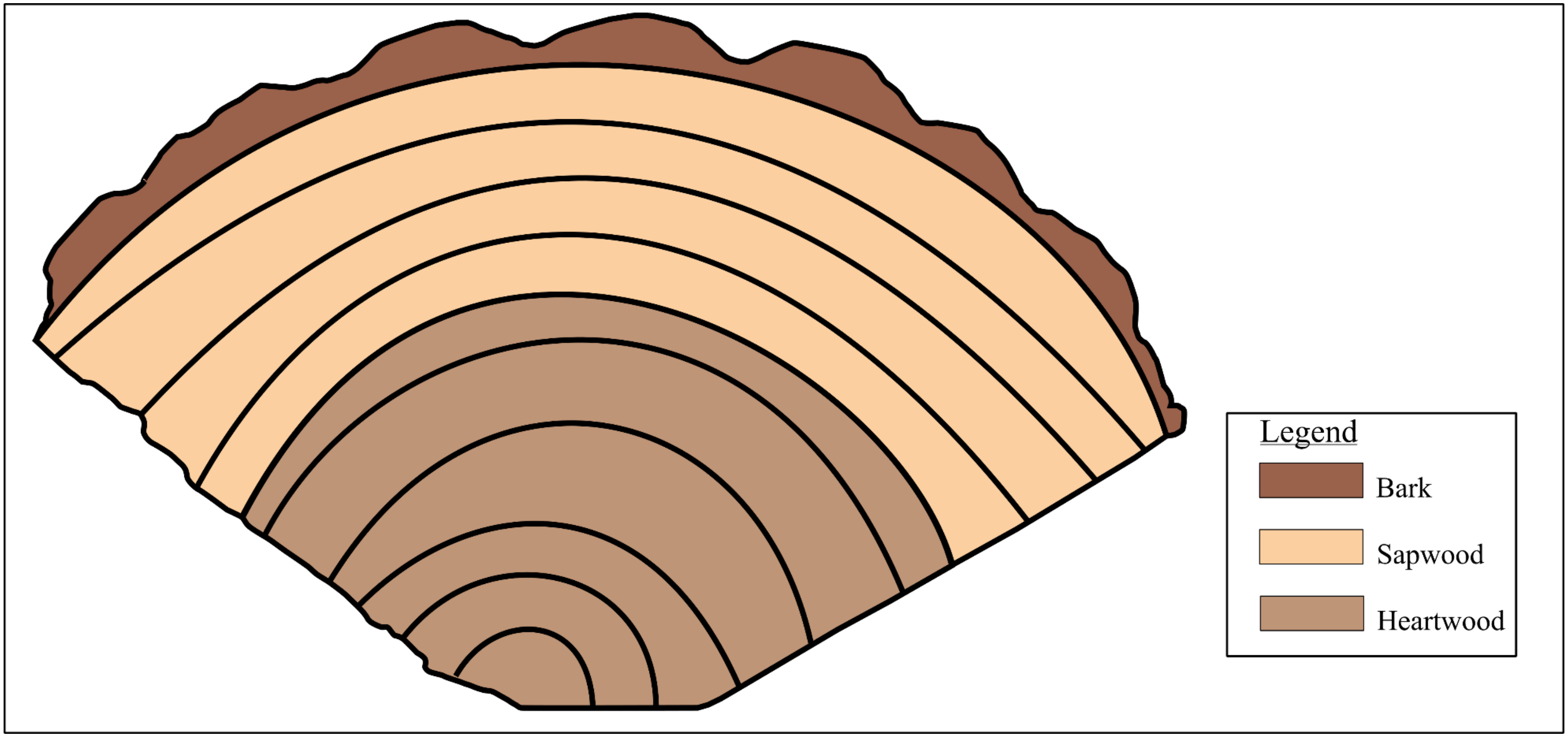

Figure 65   Rudimentary example of a tree cross section. (Author's drawing)

continual human occupation across the Mediterranean and lack of available samples from shipwrecks.

Ships excavated from the late medieval and early modern periods included timber sampling for species identification. Investment in dendrochronological research on these projects varies, as the earlier excavations only report wood typology. Developments in dendroarchaeology over the last decade highlight greater concerns to include additional sampling of individual timbers with the promise of further insights into common practices within shipyards and forestry management. Early archaeological excavations, such as *Trinidad Valencera*, which was investigated in the 1970s, includes limited information beyond identifying the wood recovered as oak (*Quercus*).[694] Recent excavation projects, like Mortella III, include not only species identification, but contributions from skilled dendrochronologists describing timber morphology, recording cross-sections of individual timbers, and building new site chronologies from recovered samples.[695]

Trinidad Valencera also represents another issue. Few remains survive from Mediterranean sites and the smaller dimensions of these timbers might also have reduced ring-growth potential providing limited opportunities for building chronological sequences. Out of the 41 shipwrecks presented in Chapter 2, 31 sites include wood identification as the only recorded dendrochronological dataset. Table 8 presents the wood typology available from shipwrecks. Most sites report only the genus for a specific sample, while recent projects (or revisits) have provided specific species.

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[694] Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 28

[695] Cazenave de la Roche, *The Mortella III Wreck*, 31, 177-95.

Table 8 Mediterranean shipwrecks with wood species identification

Shipwreck	*Date*	*Axial Timbers*	*Framing*	*Internal Longitudinal Components*	*Upper Assembly*	*Outer Hull*
(1) Serçe Limanı	1025	**Keel:** Elm (*Ulmus*) **Stem/Sternpost:** pine (*Pinus*)	Pine (*Pinus*)	Pine (*Pinus*)	Pine (*Pinus*)	Pine (*Pinus*)
(2) Marsala A	1050s	**Keel:** Elm (*Ulmus*)	**Floor-timbers:** Elm (*Ulumus*) Chestnut (*Castanea sativa*) Oak (*Quercus*) Walnut (*Juglans regia*)	**Keelson:** Poplar (*Populus*) **Ceiling:** Chestnut (*Castanea sativa*)		**Planking:** Silver Fir (*Abies alba*)
(3) Marsala B	1100s	**Keel plank:** Silver Fir (*Abies alba*)	**Floor-timbers:** Elm (*Ulumus*) Oak (*Quercus*) Birch (*Carpinus*)	**Ceiling:** Maritime Pine (*Pinus pinaster*), Silver Fir (*Abies alba*)		**Planking:** Silver Fir (*Abies alba*)
(4) Rhodes 4	1175-1200s	Turkish Pine (*Pinus brutia*) or Aleppo Pine (*Pinus halepensis*)	Turkish Pine (*Pinus brutia*) or Aleppo Pine (*Pinus halepensis*)	Turkish Pine (*Pinus brutia*) or Aleppo Pine (*Pinus halepensis*)		Turkish Pine (*Pinus brutia*) or Aleppo Pine (*Pinus halepensis*)
(5) Precenicco	1180-1300	**Keel plank:** Elm (*Ulmus*)	Oak (*Quercus*)	Oak (*Quercus*)		Oak (*Quercus*) Elm (*Ulmus*)
(6) Çamaltı Burnu I	1200-1225		Elm (*Ulmus*)			Pine (*Pinus*)
(7) Culip VI	1290-1300	**Keel:** Oak (*Quercus*) **Stem:** Pine (*Pinus*)	**Framing:** Holm Oak (*Quercue ilex*) **Filler floors:** (*Quercus*)	**Keelson:** Beech (*Fagus sylvatica*), Maple (*Acer*) **Ceiling:** Scots Pine (*Pinus sylvestris*) **Stringers:** Holm Oak (*Quercus ilex*), Poplar (*Populus*) **Stanchion:** Holm Oak (*Quercus ilex*) **Mast Step Buttresses:** Poplar (*Populus*), Holm Oak (*Quercus ilex*)		**Side keels:** (*Quercus*) **Planking:** Pine (*Pinus sylvestris* and *Pinus nigra*)
(8) Camarina	13th ca. (1301?)		**Floor-timbers:** Oak (*Quercus*)	**Keelson:** Conifer (*Pinus* or *Cupressus*)		
(9) Les Sorres X	1390s	**Keel:** Cypress (*Cupressus sempervirens*)	**Floor-timbers:** Holm oak (*Quercus ilex*)	**Keelson:** Elm (*Ulmus campestrys*) **Stringers:** Umbrella Pine (*Pinus pinea*) **Ceiling:** Umbrella Pine (*Pinus pinea*)		**Bilge Keels:** Cypress (*Cupressus sempervirens*) **Planking:** Umbrella Pine (*Pinus pinea*)

Table 8 Continued

Shipwreck	*Date*	*Axial Timbers*	*Framing*	*Internal Longitudinal Components*	*Upper Assembly*	*Outer Hull*
(10) Olbia Wreck 10	1405-1440	**Keel:** Pine (*Pinus*)	**Framing:** Oak (*Quercus robur*)			**Planking:** Oak (*Quercus robur*)
(11) Bacàn 2	1420s	**Keel:** Turkey oak (*Quercus cerris*)	**Framing:** Oak (*Quercus robur*)	**Ceiling:** Spruce (*Picea abies*)		**Planking:** Turkey Oak (*Quercus cerris*)
(12) Cavoli	1440s					
(13) Bacàn 1	1450s	**Keel:** Oak (*Quercus*)	Oak (*Quercus*)	**Keelson:** Oak (*Quercus*) **Ceiling:** Spruce (*Picea abies*)		**Planking:** Oak (*Quercus*)
(14) Contarina I	1460s	**Everything:** Oak (*Quercus*)	**Framing:** Oak (*Quercus*)	**Keelson:** Oak (*Quercus*) **Stringers:** Larch (*Larix*)		**Bilge Keels:** Oak (*Quercus*) **Planking:** Oak (*Quercus*) **Wales:** Oak (*Quercus*)
(15) Contarina II	1475s		**Framing:** Oak (*Quercus*)		**Deck Planking:** Larch (*Larix*)	**Planking:** Fir (*Abies*) **Gunwale:** Spruce (*Picea*)
(16) Mariposa A	1475-1525	**Keel:** Pine (not *P. cembra, sylvestris or mugo*)	**Framing:** Oak (*Quercus*)			
(17) Lake Garda	1509	**Keel:** Oak (*Quercus robur*)	**Floor-timbers:** Elm (*Ulmus*)	**Keelson:** Oak (*Quercus robur*) **Stringers:** Oak (*Quercus robur*) **Ceiling:** Larch (*Picea/Larix*) **Mast Step Partners:** Turkey Oak (*Quercus cerris*)		**Planking:** Oak (*Quercus robur*)
(18) Villefranche	1516		**Framing:** Oak (*Quercus*)	**Ceiling:** Oak (*Quercus*), Beech (*Fagus*) **Stringers:** Oak (*Quercus*)	**Shelf Clamp:** Oak (*Quercus*)	**Planking:** Aleppo Pine (Pinus halepensis), Stone Pine (Pinus pinea), and Oak (Quercus)
(19) Mortella III	1527	**Keel:** Deciduous Oak (*Quercus*) **Rider Keel:** Willow (*Salix*)	**Framing:** Sessile Oak (*Quercus petrae*)	**Keelson:** Sessile Oak (*Quercus petrae*) **Ceiling:** Beech (*Fagus sylvatica*) **Pump Well:** Chestnut (*Catanea sativa*) **Buttresses:** Juniper (*Juniperus communis*)		**Planking:** Sessile Oak (*Querus petrae*)
(20) Sardinaux	1500-1550 (1540s?)	**Keel:** Holm Oak (*Quercus ilex*)	**Framing:** Oak (*Quercus*)			**Planking:** Maritime Pine (*Pinus pinaster*)
(21) Chrétienne K	1500-1550 (1540s?)	**Keel:** Holm Oak (*Quercus ilex*)	**Framing:** Oak (*Quercus*)			**Planking:** Holm Oak (*Quercus ilex*)

Table 8 Continued

Shipwreck	*Date*	*Axial Timbers*	*Framing*	*Internal Longitudinal Components*	*Upper Assembly*	*Outer Hull*
(22) Calvi 1	1575	**Keel:** Oak (*Quercus*) **Stern Kee:** Oak (*Quercus*)	**Framing:** Oak (*Quercus*)	**Keelson:** Oak (*Quercus*) **Ceiling:** Beech (*Fagus*) **Stringers:** Maritime Pine (*Pinus pinaster*)	**Beams:** Oak (*Quercus*) **Deck Planking:** Beech (*Fagus*) **Knees:** Pine (*Pinus*)	
(23) Sveti Pavao	1580	**Keel Plank:** Stone Pine (*Pinus pinea*)?	**Framing:** Oak (*Quercus robur*)	**Keelson:** Oak (*Quercus robur*) **Mast Step Partners:** Ash (*Fraxinus excelsior*)		**Planking:** Stone Pine (*Pinus pinea*)
(24) *Kadırga*	1575-1625		**Original Framing:** Turkey Oak *(Quercus cerris*)		**Beams:** Turkey Oak (*Quercus cerris*) **Deck Planking:** Black Pine (*Pinus nigra*), Turkish Pine (*Pinus brutia*) **Central Gangway:** Cedar (*Cedrus libani*) **Kiosk:** Walnut (*Juglans regia*)	**Planking:** Black Pine (*Pinus nigra*) **Wales:** Turkish Pine (*Pinus brutia*)
(25) Yassi Ada 3	1572+	**Keel:** Sessile Oak (*Quercus petraea*), Turkey Oak (*Quercus cerris*) **Apron:** Turkey Oak (*Quercus cerris*) **Sternpost:** Turkey Oak (*Quercus cerris*)	**Framing:** Sessile Oak (*Quercus petraea*), Turkey Oak (*Quercus cerris*), Oriental Beech (*Fagus orientalis*)			**Planking:** Sessile Oak (*Quercus petraea*), Turkey Oak (*Quercus cerris*), Oriental Beech (*Fagus orientalis*), Maple (*Acer pseudoplatanus*), Turkish Pine (*Pinus brutia*), Cypress (*Cupressus sempervirens*) Repair Planks: Beech (*Fagus*) **Wale:** Elm (*Ulmus campestris*)
(26) Agropoli	1575-1625	**Keel:** Oak (*Quercus robur*) **Sternpost:** Oak (*Quercus robur*) **Inner Sternpost:** Oak (*Quercus robur*)	**Framing:** Oak (*Quercus robur*)	**Keelson:** Oak (*Quercus robur*)		**Garboard:** Oak (*Quercus robur*) **Planking:** Oak (*Quercus*)
(27) Cap Lardier 1	1575-1600	**Keel:** Oak (*Quercus*)	**Framing:** Oak (*Quercus*)			**Planking:** Oak (*Quercus*), Maritime Pine (*Pinus pinaster*)
(28) Cadiz-Delta II	1573 (1587)	Oak (*Quercus*)	Oak (*Quercus*)	**Bulkheads:** Conifers **Everything else:** Oak (*Quercus*)	Oak (*Quercus*)	Oak (*Quercus*)

Table 8 Continued

Shipwreck	*Date*	*Axial Timbers*	*Framing*	*Internal Longitudinal Components*	*Upper Assembly*	*Outer Hull*
(29) Church Rocks	1582+	**Keel:** Oak (*Quercus*)? **Sternpost:** Oak (*Quercus*)?	**Framing:** Oak (*Quercus*)?			**Planking:** (*Quercus*)?
(30) *Trinidad Valencera*	1588		**Framing:** Oak (*Quercus*)			**Planking:** Oak (*Quercus*)
(31) Saint-Honorat 1	1637	**Keel:** Oak (*Quercus*)	**Framing:** Oak (*Quercus*)	**Keelson:** Oak (*Quercus*) **Stringers:** Oak (*Quercus*) **Ceiling:** Cork Oak (*Quercus suber*) **Bulkhead:** Cork Oak (*Quercus suber*)	**Beam:** Holm Oak (*Quercus ilex*) **Shelf Clamp:** Cork Oak (*Quercus suber*) **Lodging Knee:** Elm (*Ulmus campestris*)	

(1) Matthews and Steffy, 'The Hull Remains'; (2, 3) Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala'; (4) Koutsouflakis and Rieth, 'A Late 12th-Century Byzantine Shipwreck'; (5)Capulli, 'Il Relitto di Precenicco'; (6) Günsenin, 'The construction of a monastic ship'; (7) Rieth, 'L'Arquitectura Naval'; (8) di Stefano, 'La galea medieval di Camarina'; (9) Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries)'; (10) Riccardi, 'I relitti del porto di Olbia'; (11) Medas, 'Due relitti con carichi lapidei rinvenuti al *Bacàn'*; (12) Martin-Bueno, *La Nave de Cavoli*; (13) Medas, 'Due relitti con carichi lapidei rinvenuti al *Bacàn'*; (14, 15) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (16) Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo; (17) Capulli, *Le navi della Serenissima*; (18) Guérout, 'Le navire Génois de Villefranche'; (19) Cazenave de la Roche, *The Mortella III Wreck*; (20)) Joncheray, 'Un navire de commerce de la fin du XVIIe siècle; (21) Lopez, Joncheray, Brandon, 'L'épave post-médiévale Chrétienne K'; (22) Villié, 'L'épave Calvi 1'; (23) Beltrame, 'The ship'; (24) Liphschitz, 'The *Kadırga* galley in Istanbul'; (25) Liphschitz, 'Three Yassı Ada shipwrecks'; (26) Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli'; (27) Joncheray, 'L'épave dite «des ardoises», au cap Lardier'; (28) Manuel Higueras-Milena Castellano and Gallardo Abárzuza, 'Proyecto Delta'; (29) Preece, Burton, and McElvogue, 'Evidence for High Status at Sea'; (30) Martin, '*La Trinidad Valencera*'; (31)) L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes'

Most keels are either oak or elm (*Ulmus*), which are known for their strength durability, and ability to work with while green.[696] Rhodes 4, Olbia Wreck 10, and Mariposa A include pine keels, although the framing on the latter two ships is exclusively oak. Les Sorres X is an anomaly with a cypress keel (*Cupressus sempervirens*), while a rider keel from Mortella III is identified as a willow trunk (*Salix*). [697] Bottom-based ships, such as Marsala B, include a silver fir plank keel. Precenicco's plank keel is elm and the plank keel from Sveti Pavao is assumed to be stone pine like the rest of the planking.

Few endposts survive in the archaeological record. Evidence from Serçe Limanı and Culip VI identified these components as pine, while subsequent examples are exclusively oak. Elms and common oaks were ubiquitous across most of Europe, which makes their usage ubiquitous in shipbuilding. Stone, maritime, or Aleppo pine grow along the coastal regions of the Mediterranean and were easily accessible for nearby shipyards.[698] The inherent flexing properties of pine could be a consideration by shipbuilders when choosing this wood for axial timbers and planking. Silver fir commonly grows in mountains regions, its use in earlier shipbuilding was described as possibly a consequence of poor timber supply.[699] The wood used to build Marsala B varies and all originates from local sources that grew across Sicily.[700]

Although Serçe Limanı's keel is identified as elm, the remainder of the ship is built exclusively of pine (genus level identification only). The decision to build the ship without any other hardwoods is curious, especially when most of Anatolia and the Balkans include groves of

[696] Caudullo and de Rigo, 'Ulmus - elms in Europe: Distribution, habitat, usage and threats', 186.
[697] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 298, fig. 8; Cazenave de la Roche, Milanese, and Ciacchella, 'Rapport de fouille programmée pluriannuelle du site de la Mortella III (St-Florent, Haute-Corse), campagne 2019', 21-3.
[698] Bonari, Acosta, and Angiolini, 'Mediterranean coastal pine forest stands: Understorey distinctiveness or not?', 19
[699] Guibal and Pomey, 'Timber Supply and Ancient Naval Architecture', 36.
[700] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 304-6

Turkey oak (*Quercus cerris*).[701] Earlier shell-based construction primarily relied on pine as the ideal material for its strength and flexing capabilities. Whether Serçe Limanı's shipbuilders were following that earlier tradition for timber selection with a new construction methodology is not clear. It is possible there was an abundance of surrounding pine near the construction site compared to available hardwoods. Rhodes 4 shows a similar trend in Eastern Mediterranean timber selection, as the exposed remains recorded by archaeologists are all reported as pine.

Marsala A's framing is a mix of elm, chestnut, oak, and walnut suggest a localized construction along Sicily's coastline. Selection of chestnut and walnut as framing timbers might be due to poor timber supply or replacements, as neither of these timbers provided the necessary transverse strength for the hull.[702] Marsala B's framing is similar with elm, oak, and birch. Çamaltı Burnu I and Lake Garda relied exclusively on elm for their framing, while all other ships record some species of oak. Yassıada 3 is an exception with oriental beech (*Fagus orientalis*) identified amidst the predominantly oak frames. Beech is easier to work and resists splitting, but it is prone to rot and is not ideal as a heavy structural support.[703]

The trend of oak becoming the predominant choice for axial timbers and framing is also true for longitudinal components. Marsala A's keelson is recorded as poplar, while Culip VI's was beech (*Fagus sylvatica*). Since no direct evidence for Serçe Limanı's keelson survives, Camarina is the only example from Table 1 that is identified as pine or cypress. Les Sorres X's

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[701] Bagnoli et al., 'Combining molecular and fossil data to infer demographic history of Quercus cerris: Insights on European eastern glacial refugia', 682

[702] Giachi et al., 'The wood of "C" and "F" Roman ships found in the ancient harbour of Pisa (Tuscany, Italy)', 279; Pasquale et al., 'Reworking the idea of chestnut (*Castanea sativa* Mill.) cultivation in Roman times: New data from ancient Campania', 866

[703] Bektaş, Güler, and Altay Baştürk, 'Principal Mechanical Properties of Eastern Beech Wood (*Fagus orientalis* Lipsky) Naturally Grown in Andırın Northeastern Mediterranean Region of Turkey', 150-1; Malakani et al., 'Influence of Fungal Decay on Chemi-Mechanical Properties of Beech Wood (*Fagus orientalis*)', 102

keelson is the only elm example, while the stringers from this ship are reported as pine. Calvi 1 also has pine stringers and the examples found from Contarina I are identified as larch (*Larix*). Larch is an interesting choice due to its presence mainly in mountainous regions; this wood required additional transportation efforts and cost.[704] The timber is tough and has rot-resistant properties, which is why it continues to be in demand for the modern yachting industry.

Ceiling also varies between pine, oak, larch, or beech. In addition to its use in Marsala A's framing, chestnut was selected for the ceiling rather than a more typical hardwood. Both Bacàn wrecks ceiling are spruce (*Picea abies*), another species that grows in mountainous regions and throughout northeastern Europe at colder latitudes.[705] Spruce has poor durability and not as naturally rot-resistant compared to other timbers. Lake Garda, Mortella III, and Sveti Pavao include wood identification for the mast step complex. Mast partners on Lake Garda are made of oak and Sveti Pavao's examples are ash (*Fraxinus excelsior*). Ash is commonly found throughout Europe beyond the coastline in mountains and higher latitudes.[706] It is highly flexible and shock resistant, but it does not have the same level of rot resistance as oak. Mortella III's buttresses are identified as juniper (*Juniperus communis*), a species with a growing region similar to that of ash. Juniper is a common shrub that is a heavy and dense wood with a high durability, which might explain the decision to use this specific wood type for the buttresses.[707]

Almost all of the surviving upper assemblies from the archaeological record suggests shipbuilders chose hardwoods such as oak and elm for key components. The only differences shown in Table 1 are choices in deck planking, as Mariposa A has larch, Calvi 1 beech, and

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[704] Saulnier et al., 'Climate-growth relationships in a *Larix decidua* Mill. network in the French Alps', 560-2
[705] Fyllas et al., 'Tree growth-climate relationships in a forest-plot network on Mediterranean mountains', 395
[706] Kerr and Cahalan, 'A review of site factors affecting the early growth of ash (*Fraxinus excelsior* L.)', 225
[707] Cazenave de la Roche, *The Mortella III Wreck*, 96.

Kadırga pine. Bilge keels on Les Sorres X and Contarina I are reported as cypress and oak respectively. Planking varied between ships with most vessels covered in pine or oak. Marsala A and B, along with Contarina II, are the exceptions, as all three of these ships used fir instead. As mentioned above for Marsala A, the decision to use fir might be related to the availability of resources near the shipyard.

Only the framing, deck planking, outer hull planking, and the gunnel for Contarina II include wood identification. The framing is described as oak, while the deck planking, outer planking, and gunwale are all softwoods (larch, fir, and spruce). Contarina I is slightly older than Contarina II and most of the hull is described as oak, including the planking. In this case, it seems that whoever built Contarina II may have struggled with obtaining ideal wood for construction compared to the economic conditions taking place slightly earlier in the same region. Treenails reported from Precenicco, Les Sorres X, and Sardinaux are made from shock resistant woods (*Viburnum*, black poplar, and willow), while those found on Yassıada 3 are oak.[708]

Summary

Shipbuilding throughout the Mediterranean between late antiquity and the early modern era underwent major changes, both in construction methodologies and sailing technologies. Ships from antiquity and the early medieval period were constructed shell-first with the axial timbers and thick planking attached to each other using pegged mortise and tenons. Framing installation was limited, and these timbers only played a supportive role. Toward the end of the

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[708] Capulli, 'The Precenicco Shipwreck: An 11th-13th-century vessel from the River Stella', 133; Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 291; Joncheray, 'Un navire de commerce de la fin du XVII^{e} siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44; Liphschitz, 'Three Yassı Ada shipwrecks: A comparative dendroarchaeological investigation', 205

first millennium, societal changes and major events presumably shifted economic pressures that led shell-based construction transitioning to reliance on transversal framing. The alternating of floor timbers between half-frames typical of shell building was phased out in favor of long-armed floors with short-armed futtocks. Floor timbers and half frames were arranged in a continuous row with associated futtocks, while later frame-oriented construction relied on a staggered overlap between components.

Planking thicknesses reduced as they became secondary elements on the construction of the vessel and iron fastening were the standard with few treenails. The connection between the keel and garboard was less of a concern. Attachment of floor timbers to the axial timbers took precedence as part of the frame-oriented methodology. Frames took on a greater role in design and on later vessels they were the first components erected prior to any planking. Shell-built vessels relied on the thicker planking to swell up to seal seams and the entire hull was covered in pitch for additional waterproofing. Thin planks in frame-based construction butted against each consecutive strake along the curved hull leaving long narrow seams in between that required caulking to fill.

When exactly frame-oriented construction began and which surviving archaeological finds represent the earliest frame-based assembly is still debated. Serçe Limanı’s remains and its date close to the beginning of the new millennium is often used as a benchmark for when true frame-based construction became the main methodology (at least for the Eastern Mediterranean). Comparison of shipwrecks dated between the late medieval and early modern period indicates a new transitional methodology in use that maintains its presence (in different forms) throughout the Mediterranean until the introduction of ship plans at the end of the seventeenth century that could dictate all frame stations prior to construction. Most ships identified from this period represent a frame-based approach for the center of the hull, while shell-oriented practices were continued at either end and for the upper assembly.

Limited remains of the endposts suggests that most ships incorporated a round stem and earlier ships were mainly double ended. Iconography indicates the adoption of the stern rudder and straight sternpost in the Mediterranean basin by the fourteenth century. Archaeological examples indicate a connection between the heel timber (or keel) and sternpost was supported by a stern knee with associated deadwood. Sternpost angles and the application of a flat transom by the beginning of the sixteenth century affected the overall cargo capacity and deck height of the ship.

Significant preservation of keels throughout this period suggests straight timbers on round ships that were rockered on longships to improve sailing capabilities for their shallower hulls. Connection of the garboard with the keel via a keel rabbet is seen as a shell-oriented construction feature. The absence of the keel rabbet on Serçe Limanı or Culip VI is unnecessary for flat floored vessels where the transverse framing supplies the overall strength to the hull. The presence of the keel rabbet for Marsala A is either an anachronism among adoption of frame-based methodology into central Mediterranean shipbuilding or as part of the garboard providing support between axial timbers due to these components simply butting together.

Keel rabbets (or chamfered keels) on later ships seem to be present only as a consideration by the builder on whether the vessel being built was for carrying heavier cargoes or provided greater strength along the center axis due to a complex wineglass shape or to counteract sagging. Scarf connections between axial timbers rarely survive. Serçe Limanı's reconstruction suggests simple flat scarfs, while subsequent ships only butt these components together. Marsala A may include butted axial timbers, while Culip VI is the next earliest example. The reinforcement of axial timbers by scarfing was important for longitudinal construction. Transition to the transverse strength inherent in frame-based construction seems to reduce the necessity for scarfing axial timbers together.

Serçe Limanı, both Marsala wrecks, Precenicco, and Çamaltı Burnu I represent a tradition of shipbuilding that continued to practice framing in a shell-built manner with long-armed floor timbers overlapping with short-armed futtocks. This technique disappears by the thirteenth century in favor of central floor timbers with overlapping futtocks. Connection between transverse framing timbers is absent on most eastern ships and appears first on the earliest western vessel Culip VI. This construction characteristic suggests the adoption of frame-oriented practices from the east to the west. Shipbuilders in the western Mediterranean were less familiar with this approach and relied on hook scarfs to correctly align floor timbers and futtocks prior to their installation on the keel.

The shallow rebate recorded for most scarfs should be seen as a factor in the assembly process aligning floor timbers and upper futtocks together before inserting fasteners and adding longitudinal reinforcements (stringers, ceiling, planking, wales, etc.). If these scarfs subsequently provided transversal strength to the framing during a ship's working life, it should be viewed as supplemental rather than a necessity. Much shallower hook scarfs seen on later eastern ships suggests the practice was accepted as part of the industrialized process for frame-based construction (western practices transferred east). Framing dimensions throughout this period remain relatively square near amidships and change toward the endposts, due to the rising and narrowing of the hull. The overall scantlings appears consistent with shell-oriented framing, while their size increased in the sixteenth century alongside the general dimensions for vessels.

Spacing between frames also becomes standardized and follows a design procedure often related to the linear unit used by the shipbuilder.

Installation of internal longitudinal components (keelsons, stringers, etc.) on earlier eastern ships did not usually include fastening these components to the framing. Bolts are present between frames to connect the keelson to the keel or a stringer to an accompanying bilge keel. This practice also carried over to the west as the shipbuilders only connected the keelson with the frames using smaller nails. When and where shipbuilders chose to begin driving bolts through floor timbers is unresolved, although it took place by the fourteenth century. Stringers appear intermittently on earlier shell-built construction as a longitudinal reinforcement that held the frames in place. These components become much more important and prevalent on frame-based hulls by clamping down the frame overlaps, while separate sets held the central section of each futtock in place.

Ceiling appears on most vessels to protect the framing from shifting ballast or cargo. Many Mediterranean ships across this period included raised transverse flat platforms above the bilge rather than traditional ceiling attached directly to the frames. This aspect is explicitly adopted for ships with wineglass profiles, so a flat surface in the hold could accommodate cargo. Mast step complexes originate from earlier shell-built assemblies comprised of sister keelsons supporting an unfastened keelson or mast step timber. This assemblage is modified during the medieval period to create a composite mast step built over the keelson. The morphology of the mast step is dependent on the size of the vessel, although most versions include similar components comprised of buttresses (sometimes built into molded frames), mast step partners, and wedges (or keys) to create the fore and aft part of the mast mortise.

Mediterranean bottom-based construction appears to originate also in earlier antiquity and might be a contributing factor in the transition to frame-based construction. The handful of surviving examples from the subsequent periods suggest a common characteristic relying on a plank keel and two or three accompanying strakes to compose the bottom of the hull (Boccalama A is the exception with five strakes). Marsala B, Precenicco, and Rhodes 1 are described with similar profiles, even though the two earlier ships share the same framing pattern as contemporary keel-based vessels. Rhodes 1, Boccalama A, and Sveti Pavao fit in with later construction relying on floor timbers with overlapping futtocks. Boccalama A is also markedly different due to its exclusive use as a riverine or lagoon craft not suited to coastal or open sea voyaging. Sveti Pavao is also unusual, as it is a larger merchant vessel used for sea voyages that is double planked. This small sample set only provides suggestions for vessels constructed based on environmental hazards, while the shipbuilders themselves followed the common patterns utilized for general shipbuilding at the time of their construction. Additional examples of bottom-based vessels that operated the coastal or open water environments are warranted for deeper analyses.

Much less is known about the upper assemblies of earlier hulls. Round ships seem to include shelf clamps supporting beams and ledges to create each deck. Through-beams from Contarina II and contemporary iconography suggest reliance on this shell-oriented construction practice. Similar construction on longships support this anachronism, since their assembly is frame-based but the vision for these ships is longitudinal. Connecting the beams with the wale provided additional reinforcement for the long narrow hull shape and supported the outrigger situated above this point. The preference for through-beams falls out of style by the beginning of the sixteenth century. Western sixteenth-century round ships suggests that additional lower reinforcement was necessary to support wineglass profiles and additional riders that overlapped different decks were needed to support the large castle assemblies.

Bilge keels were installed on ships operating in shallow water environments across the Mediterranean. The same strake holds equal importance on round ships and longships, its presence continues as a short wale at the stern to supplement the drastic change between the bottom of the hull with the upper deck(s). Dimensions for planking and wales were dependent on the overall size of the hull and the amount of time devoted to refining their appearance (i.e.: chamfered, rounded, etc.). Fastening patterns for the planking installation also suggest familiarity with the construction technique. Serçe Limanı suggests that earlier shipbuilders used additional fasteners per frame station, while Marsala A and subsequent ships show a standardization in using two or three nails only. Culip VI indicates additional nailing and perhaps a remnant of the transition by western shipbuilders toward the frame-based approach, while Iberian shipwrecks indicate preference for mixed fastening with iron nails and treenails.

Treenails present in the assembly of Yassıada 3 are not as easily explained without additional eastern shipwreck comparisons. Either a coastal, bottom-based, or western influence might explain their temporary use for securing the keelson prior to the installation of iron bolts. Caulking became ubiquitous for frame-based shipbuilding, while the decision to apply sealant to both the outside and inside of the hull is clearly an earlier shell-oriented practice still applied even in the modern period. Several western ships indicate this practice was later utilized for the external hull only and that lead sheathing was possibly reintroduced as a practical measure for larger sailing ships. Whether lead sheathing stopped being used is unclear and will require further archaeological work in the future to locate larger sailing ships from the late medieval period.

Dendrochronological data retrieved from most ships discussed in Chapter 2 suggests that earlier shipbuilders relied on local sources of timber. Studies comparing earlier shell-built ships along the French coastline clearly show that carpenters were aware of the different qualities between wood types. Marsala A and B suggest that shipbuilders relied on hardwoods when available, but also depended on lesser quality materials that grew in the vicinity. Most of the later ships in this dataset suggest a preference for different species of oak for the framing, while the planking was composed of pine or other softwoods that were resinous and bendable. The occasional application of fir in shipbuilding is discussed as an inferior material that might suggest difficulty in obtaining better resources. Recent investigations are beginning to incorporate greater concern for dendrochronological analyses on hull remains that will provide additional information about timber selection, shipyard practices, and lumber procurement.

CHAPTER IV

ROOTS OF SHIPBUILDING OR COMMUNITIES OF PRACTICE?

Shipwrecks from the modern era include cultural histories developed partly by available documentary resources often missing from earlier periods. Sometimes this historical evidence is also correlated with assumptions that domestic tableware found on board ties the crew and the ship to the same place of origin.[709] This concept might apply to sites from antiquity or the early medieval period but becomes much more ambiguous later due to rapid globalization. When Matthew Harpster reviewed nautical archaeological publications less than a decade ago, he noted a common trend by researchers to rewrite histories for individual sites by fitting them into an ideal narrative.[710] His counter argument at the time was to remove this idealized culture-history approach and produce a scientific lexicon for a nomothetic study. Harpster's argument is not a new one and has remained a critique for the subdiscipline since early in its foundation.[711] Over the last several decades, several approaches were proposed with few attaining widespread adoption.[712]

Studying hull remains by using an operational process provides a solid methodology during excavation and analysis. Premeditation by shipbuilders is sometimes identified from construction details and the overall assembly. Pomey and Rieth envisioned building a multiscale organization scheme based on overlapping construction signatures.[713] This paradigm may

[709] Bass, *Cape Gelidonya: A bronze age shipwreck*, 165.
[710] Harpster, 'Shipwreck Identity, Methodology, and Nautical Archaeology', 611, 615
[711] For arguments towards a more anthropologically focused approach, see Gould, ed., *Shipwreck Anthropology*, 13; Gould, *Archaeology and the Social History of Ships*, 4.
[712] For an approach that has gained greater attention than many others, see Westerdahl, 'The Maritime Cultural Landscape', 5
[713] Pomey and Rieth, *L'archéologie navale*, 35.

showcase where signatures were strongest or if there was greater overlap in a geographic context. At the same time, it does not explain how the signature was originally absorbed into a shipbuilding community, reapplied over time, or how it changed. This chapter answers some of these questions by taking the construction dataset discussed previously and applying it to two approaches. The first approach explores a separate proposal by Rieth (and followed up by Pomey, Kahanov, and Rieth) for organizing shipbuilding by different culture-historical communities throughout the Mediterranean based on hull forms.[714] Afterward, the remainder of this chapter explores practice and social learning theories to explain the development of shipbuilding as communities of practice which reinforced social norms, although these norms were eventually challenged by outside influences or changed to meet new circumstances.

Hull Forms as Community Roots of Shipbuilding

In 2008, Rieth published a preliminary examination discussing construction details and geometries of hull cross-sections in the Mediterranean between shell- and frame-based shipbuilding.[715] His analysis suggested that the wineglass profile was utilized by both shell and frame shipbuilders based on its continual usage, as seen on the Kyrenia, Dramont E, Yassıada I, and Saint-Gervais II shipwrecks. This collection represented a Greco-Roman tradition that covered late antiquity into the early medieval period. Rieth also grouped early frame-based ships such as Bataiguier, Agay A, Dor 2001/1 and Tantura A, Serçe Limanı, and Marsala A as sharing a flat bottomed and sharp bilge profile without an earlier shell-constructed equivalent. This observation led Rieth to argue that the hull profile between these vessels could originate from an

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[714] Rieth, 'Géométrie des formes de carène et construction «sur membrure première» (V^{e}-XII^{e} siecles). Une autre approche de l'histoire de l'architecture navale méditerranéenne au moyen age?', 65-7; Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 301-5

[715] Rieth, 'Géométrie des formes de carène et construction «sur membrure première» (V^{e}-XII^{e} siecles)', 45-6

eastern fluvial tradition. His initial thoughts were to tie the earlier eastern ships from Tantura lagoon with a Nilotic fluvial origin that transferred into axial-frame construction. The appearance of the far west ships Bataiguier and Agay A having similar profiles were hypothesized as transferring this hull shape during the early Islamic conquest, while the same profile seen on Serçe Limanı suggests a penetration into Byzantine practices.[716]

Pomey, Kahanov, and Rieth revisited hull forms in their subsequent 2012 article discussing the transition between shell and frame shipbuilding. Hull profiles and associated assemblies were organized around ‘Roots’ to emphasize the origins and non-linear development of shipbuilding across the Mediterranean.[717] These roots were also divided based on the concept and construction of each vessel (Table 9). Pomey et al. recognized five separate categories and associated most with cultural-historic communities that existed at the time the ships operated. Shipwrecks from the Western Mediterranean fell into two main types, based on either a flat floor and round bilge or wineglass profile associated with Roman culture. Later Eastern Mediterranean ships relied on a shallow wineglass profile that was associated with the Byzantines. The last two roots are the only categories linked with a geographic region and environment rather than a cultural context, as these are the eastern ships Rieth emphasized in his earlier article associated with a Nilotic fluvial tradition.

Several of the ships uncovered from the Yenikapı harbor project in Istanbul, Turkey share a similar flat-bottom profile with this eastern riverine root but are separated in their own categories due to their mixed construction techniques.[718] The takeaway for our current discussion

[716] Ibid., 65-8.
[717] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 239
[718] Ibid., 301-6, tbl. 4.

Table 9 Roots of construction and hull form across the Mediterranean during antiquity and early medieval periods[a]

Root	*Origin*	*Original Construction*	*Date (century AD) of main steps*	*Evolution*	*Examples of Shipwrecks*
1. Western Roman Imperial	Western Roman Imperial type	Shell concept and process. Flat frames, round bilge. Overlapping half-frames, bolted floor timbers, longitudinal components. Tight mortise-and-tenon joints.	2nd to 5th	From shell concept and process to shell concept with partially mixed processes (2nd c. AD); then to entirely mixed concept and process (5th c. AD) Loosening of mortise-and tenon joints, then unpegged tenons. Strong framing and longitudinal components.	St-Gervais 3 La Bourse Dramont F Fiumicino Parco di Teodorico
2. Western with Continental influence	Western Hellenistic / Roman Republican type	Shell concept and process. Wine-glass cross-section, round bilge. Alternating floor-timbers and half-framers. Central longitudinal timbers. Tight mortise-and-tenon joints.	5th to 7th	Late evolution of the framing and longitudinal timber under western Roman Imperial type influence (5th c. AD); then sudden evolution (break) to frame concept and process under possible continental influence (7th c. AD). Disappearance of mortise-and-tenon joints	Dramont E St-Gervais 2
3. Byzantine	Eastern Hellenistic type	Shell concept and process. Wine-glass cross-section, round bilge. Alternating floor-timbers and half-frames. Central longitudinal timber. Tight mortise-and-tenon joints.	4th to 7th, 9th to 11th	From shell concept and process to shell concept with mixed processes (4th c. AD), to mixed concept and process (7th c. AD), then to frame concept with mixed process (9th c. AD). Loosening of mortise-and-tenon joints until unpegged tenons or coaks.	Yassıada 2 Yassıada 1 Bozburun Yenikapı 3, 16 and 18
4. Eastern Riverine	Riverine/Nilotic tradition (?)	Bottom-based construction (?). Flat floor-timbers, hard chine, rectilinear sides.	End of 5th/ beginning of 6th 10th to 11th	Frame concept and process. Flat floor-timber cross-section with keel, sharp turn of bilge and rectilinear sides. Longitudinal timbers. No mortise-and-tenon joints (or coaks).	Dor/Tantura (Dor 2001/1) Bataiguier Agay A Serçe Limanı
5. Eastern Flat-Bottomed	Unknown	Flat-bottomed	9th to 11th	Frame concept and mixed process. Flat floor-timbers, hard chine. Coaks.	Yenikapı 6-9, 12
Or 5a (?) Eastern Branch of Root 1	Sub-root of 1	cf. Root 1	9th to 11th	As above	Yenikapı 6-9, 12
Or 5b (?) Byzantine Riverine	Sub-root of 4	cf. Root 4	9th to 11th	As above	Yenikapı 6-9, 12

[a]after Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: analysis, problems, and future research', 306, tlb. 4

Table 10 Roots of construction and hull form across the Mediterranean during late medieval and early modern periods

Roots	*Example Shipwreck(s)*	*Range*	*Construction and Transition*
1. East Flat floor, sharp bilge, flat sides (Riverine Origin)	Serçe Limanı Marsala A Çamaltı Burnu I Rhodes 4	1025-1200	Axial timbers scarf. Alt. long-armed floor-timbers to full floor-timbers and futtocks. Overlapping frame elements with minimal scarfs. Longitudinal components. Keelson bolted between frames.
2. East Flat floor, round bilge (Round Ships)	Marsala A Bacàn 2 Bacàn 1 Contarina I Contarina II Yassi Ada 3 Trinidad Valencera	1050-1588	Keel rabbets to none. No axial timber scarfs. Alt. long-armed floor-timbers to full floor-timbers and futtocks. Overlapping frame elements with no scarfs to hook scarfs. Longitudinal components. Keelson bolted between frames to through all or patterned.
3. East Flat floor, round bilge (Longships)	Camarina Boccalama B Lake Garda *Kadırga*	1300-1625	Keel rabbet or chamfered. Axial timbers scarfed. Floor-timbers and futtocks. Overlapping frame elements to hook scarfs. Lighter scantlings. Longitudinal components. Keelson bolted between frames to through. Wales recessed.
4. East Bottom-Based	Marsala B Precenicco Rhodes 1 Boccalama A Sveti Pavao	1100-1580	Plank keel mainly same thickness as rest of strakes. Alt. long-armed floor-timbers to full floor-timbers and futtocks. Mainly flat floor with round bilge and sides. Overlapping frame elements to hook scarfs. Longitudinal components. Keelson bolted between frames to through.
5. West Flat floor, round bilge (Round ships)	Cap Lardier 1 Rodinara Sardinaux Chrétienne K West Turtle Shoals Agropoli	1500-1625	Keel rabbet. Axial timbers mainly butted. Floor-timbers and futtocks. Overlap to either hook scarfs or tapered/recessed. Longitudinal components. Keelson bolted through frames.

Table 10 Continued

Roots	*Example Shipwreck(s)*	*Range*	*Construction and Transition*
6. West Wineglass (Round Ships)	Villefranche Calvi 1 Saint-Honorat 1	1516-1637	Keel rabbet. Axial timbers scarfed or butted. Floor-timbers and futtocks. Frame joints mixed: dovetail, hook scarf, recessed. Longitudinal components. Keelson bolted through frames. Thicker planking.
7. West Half Circle (Round Ship)	Mortella III	1527	Keel rabbet. Axial timbers scarf or butted. Rider keel. Floor-timbers and futtocks. Frame joints hook scarf or carved recess. Longitudinal components. Keelson bolted through frames. Thick planking.
8. West-Iberian Flat floor, round bilge (Round ships)	Culip VI Les Sorres X Cavoli	1290-1440	No keel rabbet. Axial timbers butted. Floor-timbers and futtocks. Frame joints hook scarf or recessed. Longitudinal components, secured with treenails. Keelson bolted between frames. Planking attached with iron fasteners and treenails (Cavoli).
9. West-Iberian Shallow Wineglass (Round Ships)	Marinières Mariposa B	1420-1525	No keel rabbet. Axial timbers butted. Counter-keel sometimes present. Floor-timbers and futtocks. Frame joints dovetail or hook scarf (connected using iron fasteners and treenails on Marinières). Longitudinal components, secured with treenails. Keelson bolted through frames. Planking attached with iron fasteners and treenails.

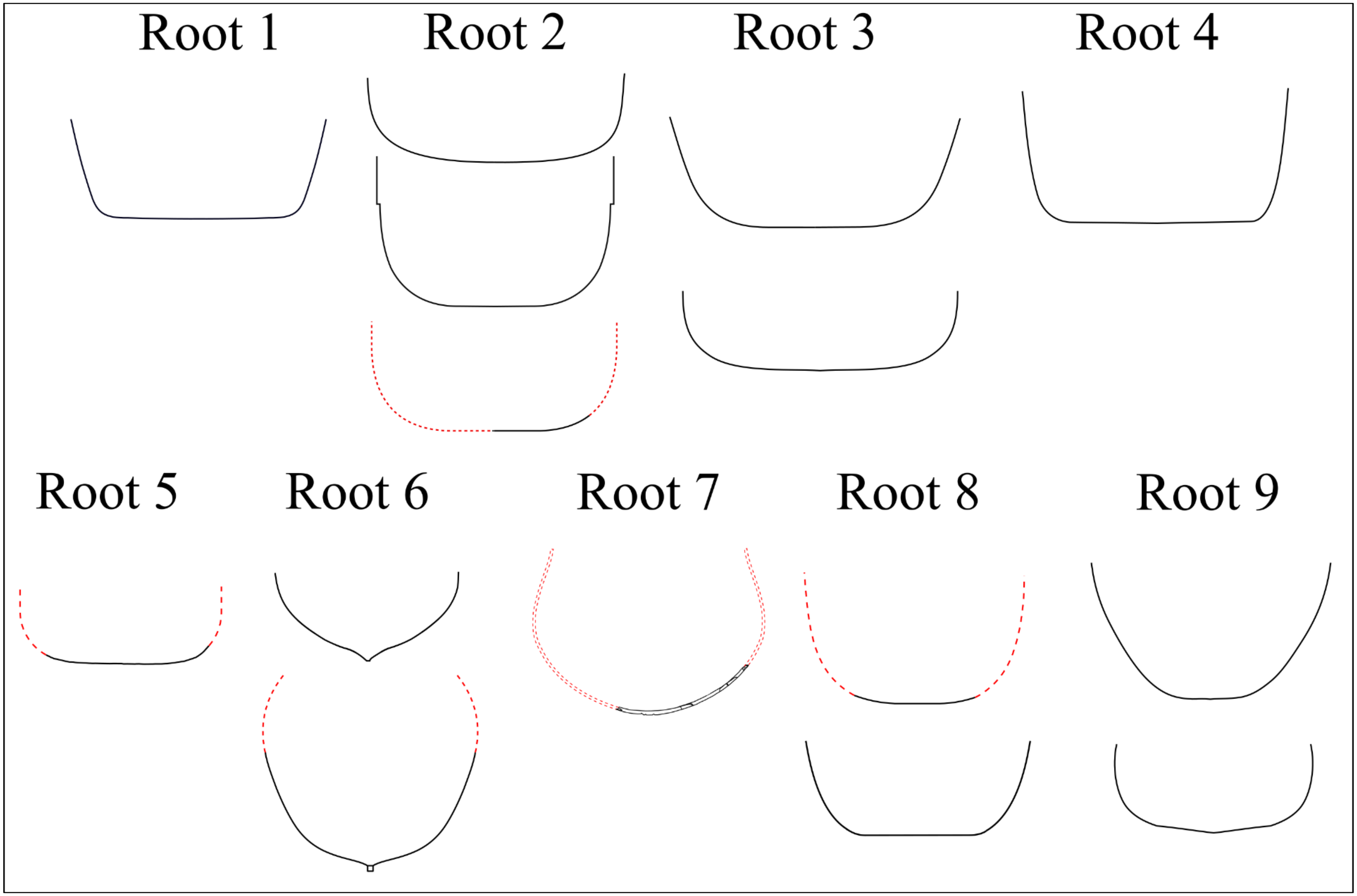

Figure 66 Published hull forms organized into "Root" categories. Not to scale, all red is conjecture. Root 1 - Serçe Limanı; Root 2 – Marsala A, Contarina I, Yassi Ada 3; Root 3 – Lake Garda, Kadirga; Root 4 – Marsala B; Root 5 – Sardinaux; Root 6 – Villefranche, Calvi 1; Root 7 – Mortella III; Root 8 – Culip VI, Sorres X, Root 9 – Marinières, Mariposa B. (Author's drawing)

is that different communities throughout the Mediterranean relied upon similar hull geometry applied to ships built with different construction techniques. These same shapes were also identified on late medieval and early modern vessels and suggest another aspect of continual practice between communities and as an organizational scheme for this dissertation's dataset that covers a *longue durée* in shipbuilding.

Organizing shipwreck hull shapes based on the Pomey et al. studies is one approach to examining each vessel based on common features. This follows trends in other archaeological subdisciplines away from the culture-historical approach. Pomey et al. also continued to ascribe a cultural status to their roots, such as their association to Roman, Byzantine, or ascribing the diffusion of shapes to the religious expansion of Islam.[719] Table 10 represents my interpretation of the late medieval and early modern period by borrowing the root organization described by Pomey et al. This period is one of constant fluctuation between rival political groups and the periodic influx of outside cultures into the Mediterranean. Applying any specific root to a cultural complex would not match what the archaeology indicates.

Ships from the current dataset with published profiles (figure 66) are divided into nine roots between the East and West halves of the Mediterranean. Root for our purposes does not denote origin but provides a categorical value to subdivide the dataset based on hull form. Several of the roots are duplicates that share the same hull shape but include differences in construction practice that divide them between each end of the Mediterranean. Thus, Root 2 hulls are eastern ships with a flat floor and round bilge, which Roots 3, 5, and 8 also include. Similarly, Root 6 represents western ships with wineglass hulls, and this is also tied to Root 9.

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[719] Rieth, 'Géométrie des formes de carène et construction «sur membrure première» (V^{e}-XII^{e} siecles)', 67; Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 236

Roots 8 and 9 could either be viewed as part of Roots 5 and 6 respectively but are represented here as part of an Iberian group that contains construction practices not seen on all other examples. Since Chapters 2 and 3 already provide the construction and comparative information between shipwrecks, the following is mainly a discussion on the reasoning for grouping certain sites together. The aim of this subsection is to discuss the correct approach toward organizing shipwrecks based on a typology separate from culture-historical practices.

Root 1 represents ships with a flat floor, sharp bilge, and straight sides. This root includes Serçe Limanı and represents the oldest group in the overall dataset. Previous studies that include Serçe Limanı suggest this hull form stems from a riverine or possibly bottom-based approach that was borrowed and used in axial-frame construction.[720] Serçe Limanı, Marsala A, and Çamaltı Burnu I include evidence that their frames relied on long-armed floor timbers matched with short-armed futtocks. Overlaps between these framing elements rarely included any scarfs or fastening between them. Rhodes 4 is the exception, though not enough of the hull was uncovered to know the exact framing pattern. The exposed futtocks and floor timber wrongheads, along with the larger size of the ship, all suggest this vessel relied on full floor timbers and futtocks. No other ships after Rhodes 4 include a similar profile and it remains unclear whether shipbuilders continued to use this hull form or there was a conscious decision to rely on the more seaworthy flat floor and round bilge instead.

Ships with a flat floor and round bilge in the Eastern Mediterranean are represented in Root 2. Marsala A is shown in both Root 1 and 2 due to the differences between the reconstructions suggested by the archaeological report and the later reconstruction. If Marsala

[720] Rieth, 'Géométrie des formes de carène et construction «sur membrure première» (V^{e}-XII^{e} siecles)', 65-6

A’s profile is definitely flat floored and round bilged, then there is additional evidence for a transition in framing within Root 2. Earlier ships include the long-armed floor timbers overlapping with short-armed futtocks that are later replaced with full floor timbers and futtocks. Root 2 also includes other transitional details, including the preference by eastern shipbuilders to overlap framing elements without scarfs. Yassıada 3 and *Trinidad Valencera* represent two different occurrences when the hook scarf was later used in eastern shipbuilding. Fasteners also seem to change over time in this root, especially with earlier vessels reporting traditional square nails that are described as round (or possibly quadrangular) on the Contarina wrecks.[721]

The four eastern longships are considered Root 3, although based on hull shape alone this group might be considered a sub-root of Root 2. As stated in Chapter 3, longship construction is somewhat different from the many round ships in this study. There is a clear indication in the construction practices of longships that frame-based shipbuilders relied partly on a longitudinal vision presumably originating with earlier shell construction.[722] Boccalama B is considered the only thin galley of this group, but there are limited construction characteristics available in published sources.[723] What can be identified between the longships are additional measures to include stringers or wales that are recessed to fit onto the frames. This may reflect a shared concern about the greater overall length to breadth ratio on these vessels.

Shipbuilders clearly were concerned with keeping these vessels light weight and thus draft, since Boccalama B’s frames toward amidships are similar in scantlings to the much smaller Lake Garda hull. Several transitional elements noted between these ships include the preference by the earlier Camarina shipbuilder to install the keelson bolts between frames, while

[721] Occioni-Bonaffons, 'Sulla scoperta di due barche antiche nel comune di Contarina (Rovigo)', 25, 35-6.
[722] Steffy, 'Ancient scantlings: The projection and control of Mediterranean hull shapes', 422.
[723] Romanelli, *La galea ritrovata*, 63.

the other examples connect the two longitudinal components through the floor timbers.[724] Most of the eastern longships do not rely on any scarf connections between framing, it seems that this was adopted around the time when *Kadırga* was built in the second half of the sixteenth century.[725] Earlier connections were also made with several nails between the floor timber and futtock, while *Kadırga* also showcases double clenching in its construction.

Root 4 is the only category organized based on the construction approach (bottom-based) rather than hull form. The original interpretation for Marsala B suggests a flat bottom, sharp bilge, and straight sides similar to the keel-based equivalents in Root 1. Surviving remains from Boccalama A suggest a similar profile and the original investigators believe that it was a barge unsuited to open sea travel.[726] Marsala B may also reflect a similar hull-profile depicted for Marsala A in the later reconstruction, with a flat bottom (without a true keel) and a round bilge. Marsala B was found in the same vicinity as Marsala A, directly off the coast of Sicily, suggesting it was a ship that could operate in a coastal environment. The same argument and profile are suggested in Precenicco and Rhodes 1, both with flat bottoms and round bilges.

Rhodes 1 is interpreted as some form of a bottom-based longship, due to its length and hull that tapers at either end. Sveti Pavao remains the separate example for its larger size and the double hull planking not seen on any other vessels from this period. There is still a possibility this ship is axial based, but the published remains have a profile similar to the other wrecks. Shared construction practices suggest similar tendencies through time as mentioned for the previous roots. Evidence from Marsala B and Precenicco include long-armed floor timbers with short-armed futtocks that transitions on later ships to full floor timbers and futtocks. The keelson

[724] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 87
[725] Dönmez Yakarçelik, 'Deniz Müzesi'nde Sergilenen Tarihi Kadırga', 174
[726] Romanelli, *La galea ritrovata*, 44.

on Marsala B and Rhodes 1 was fastened between frames, while this connection included the floor timbers on Sveti Pavao. Scarfs between framing elements are absent except for shallow hook scarfs on Sveti Pavao. Ship sizes hover between earlier and smaller examples and later larger ships with scantlings that also reflect this divide. Further studies locating bottom-based construction throughout the Mediterranean in the future would presumably divide this root into further groups.

Examples of western ships with a flat floor and round bilge are compiled into Root 5, which is equivalent to Root 2 in the Eastern Mediterranean. There is a sub-division in size between Cap Ladier 1, Rondinara, and Sardinaux representing ships that presumably operated in a littoral zone compared to the larger Chrétienne K, West Turtle Shoals, and Agropoli that worked offshore. The fact that West Turtle Shoals was found in the Americas also proves that medium sized hull with this shape is adequate for oceanic travel. This root is also composed currently of ships that existed mainly in the sixteenth century and there is not enough information to identify any long-term changes in practice. All the ships share the same frame morphology of floor timbers paired with futtocks. Except for Cap Ladier 1, each ship includes a keel rabbet that either suggests long thin shapes that required additional longitudinal reinforcement or lingering shell-based practices in frame construction.

Several ships in this group also share practices in scarfing the stem and keel together, while the remainder of the axial timbers were simply butted. All frames are either bolted or nailed to the keel. There are greater differences between ships on how the floor timbers were connected to the futtocks. Interestingly, most ships in this root do not include any scarf and their frame elements are simply overlapped. Chrétienne K is an exception with its tapered or recessed overlaps between frame segments. West Turtle Shoals and Sardinaux are the only two examples with hook scarfs. Fastening also varies between square or round nails that were either blind or were clenched on the opposite face of each joint. Another observation is that the scantlings for the frames were very similar regardless of hull proportions, while the planking thickness was dependent on the size of each ship.

Root 6 represents Western Mediterranean wineglass shaped vessels, including Villefranche, Calvi 1, and Saint-Honorat 1. These ships represent a seafaring class that presumably was dedicated to carrying larger cargoes over long distances. Each of these ships include keel rabbets that were either part of an earlier shell tradition carried over into frame construction or simply a necessary component for the complex profile. Villefranche's deeper wineglass shape included thicker carved garboards and a deeper keel toward the sternpost. Calvi 1 and Saint-Honorat 1 showcase a shallower wineglass profile that did not necessitate a carved garboard. Saint-Honorat 1's keel being chamfered rather than rebated also implies less concern for this connection than in the other two examples. Villefranche and Calvi 1's stern assemblies imply differences in construction practices but similar overall key features. The different angles of the sternposts appear based on hull size rather than number of decks. Every ship was composed of floor timbers with overlapping futtocks and the keelson bolted through the frames to the keel.

Differences appear in the use of scarf connections between elements. Villefranche includes dovetails and an arrangement of scarf types for upper assemblies. Calvi 1 on the other hand presents a single dovetail amongst mainly hook scarfs for the lower assembly and either half lapped or recessed overlaps between futtocks. Round nails are present on both ships. Villefranche and Saint-Honorat 1 also provide evidence that complex hull shapes in the Western Mediterranean required flat platforms built in the hold that fit over stringers and keelsons. This root is also fortunate for having additional surviving material from the upper hull, showcasing differences in the extent of their ceiling. Similarities do exist with the use of dual stringers over framing overlaps and how beams were fitted into shelf clamps. Other differences include the use of treenails, which seems to be more common for internal construction and avoided as a plank fastener. Calvi 1 presents evidence that the wineglass shape did not inhibit shipbuilders from employing new concepts like a flat transom.

Mortella III is put into a separate root category (Root 7), due to my belief that this ship represents the first example which will be augmented by additional finds in the future. Many features from Mortella III also could place this ship with the wineglass profiles. It is a large seafaring type with a keel rabbet and relies on the frame-based system of floor timbers and futtocks. Its lower frame assemblies rely on hook scarfs with carved recesses between futtocks. Every identified floor timber is bolted to the keel rather than in a repetitive pattern seen on other ships. The keel and a rider keel connect together and increase in thickness toward the sternpost. Fasteners identified on this vessel were round or quadrangular in section instead of the more traditional square profile. The half-circle hull profile requires transverse ceiling installed in the hold and the mast step complex is similar to many other Mediterranean examples regardless of hull shape. A re-examination of Mortella II in 2021 may reveal another ship with the same profile to start expanding this root.[727]

Culip VI, Les Sorres X, and Cavoli together comprise Root 8, which is the first of two groups representing a Western-Iberian influence. Some shared consistencies with these wrecks include the absence of any keel rabbet or scarfs connecting the axial timbers. Frames consist of

[727] Arnaud Cazenave de la Roche, pers. comm.

floor timbers overlapping with futtocks. This overlap includes hook scarfs for Culip VI or diagonal butts and recesses on the futtocks for floor timbers from Les Sorres X. Cavoli provides some evidence of a dovetail scarf possibly replaced with unrelated frame repairs sometime during its life. Frames are connected by outside-driven fasteners through the keel on Culip VI and Les Sorres X. Both ships share practices of using treenails to install longitudinal components, such as the keelson on Les Sorres X or the stringers on Culip VI. Compared to the larger ships found elsewhere, both Les Sorres X and Culip VI include only a single stringer over the lower frame overlap. Not enough survives from Cavoli to know more about its longitudinal elements, but it fits this group due to the explicit use of treenails as part of installing the hull's planking.

Root 9 represents a secondary wineglass hull form associated with Iberian influence from Marinières and Mariposa B. Axial timbers are different for each ship, as Marinières includes a counter keel while none is reported for Mariposa B. The counter-keel and keel on Marinières created a keel rabbet for a carved garboard, but it remains unclear whether Mariposa B also has a rabbeted keel. Sternpost assembly on Marinières is no different than recorded on other Mediterranean ships, except the inclusion of an inner sternpost beginning at the counter keel. Marinières' axial timbers are also butted against each other without any evidence for scarfs. The sternpost angle appears to be unrelated to the size, as both are not far off from each other.

Both ships are frame-based with floor timbers overlapping the futtocks. This overlap on Marinières includes single and double dovetail scarfs, while Mariposa B has hook scarfs. The scarf connections are made with nails and treenails for Marinières, while Mariposa only uses nailed clenched on the opposite side. Most floor timbers are bolted to the keel on both ships with toenailed examples at the endposts. Besides the hull profiles, the ships share the use of iron fasteners and treenails to assemble the planking to the hull. For Mariposa B, the retrieved apotropaic eye includes square fastener holes and round holes presumably for the treenails.[728]

The approach outlined by Rieth (and expanded upon in conjunction with Pomey and Kahanov) to organize shipwrecks by hull shape and define different trends on how shell to frame construction took place across the Mediterranean seems to be a challenging approach for subsequent periods. As described above, the late medieval and early modern shipwrecks were organized into nine roots based on hull shape, construction method, or some shared practice. The result emphasized multiple roots with the same hull shape separated either by region or influence. Many of the roots include similar construction practices that were shared even if the overall hull shape was different.

Even with over 40 shipwrecks in various states of preservation and publication, many more examples are needed to flesh out this first attempt at expanding hull shape categories. Several of the roots described above can also be tied to the earlier organization by Pomey et al., such as Roots 2 and 8 being the successors to the “Western Roman Imperial” type. Root 6 would be the continuation of ships from the “Western with Continental influence”, while there are no currently reported ships from the subsequent period in the Eastern Mediterranean with a wineglass profile to fit the “Byzantine” type. Serçe Limanı and the other examples from Root 1 are the continuation of the “Eastern Riverine” and “Eastern Flat-Bottom”. Rhodes 4’s remains suggest that this shape continued its use on much larger ships until possibly the thirteenth century and was later abandoned for a round bilge and sides. Similar statements could also be made with the surviving eastern longships when compared to the earlier wineglass equivalents

[728] Virgilio Gavini, pers. comm.

recorded from the Yenikapı harbor project.[729] The wineglass shape appears reserved for open-water seafaring vessels with the depth of the shape dependent on the overall size of the ship.

Other differences from the earlier studies includes the half-circle profile from Mortella III, which is not shared by any previous examples. The question arises whether other half-circle hulls were adopted after antiquity from a coastal or inland tradition that has not shown up in the archaeological record until now or whether this shape existed previously. Ships associated with Iberian influences rely on similar hull shapes seen on vessels built elsewhere. The presence of treenails as essential components in construction and the unusual character of counter-keel (or counter-plank) on at least two examples raise questions about how much frame-based construction took hold in the Western Mediterranean and whether additional examples reported from the Iberian coastline will provide contrary evidence. The limitations of current dendrochronological studies on this last group of ships leaves lingering impressions on whether the larger examples may be Atlantic-built ships lost in the Mediterranean. Dovetails joints are often utilized as an Atlantic signature and remain enigmatic chronologically without earlier examples to trace their origin. These considerations will continue until further research on the Iberian-Mediterranean coast can provide additional sites with more information.

Lastly, there are shared practices between ships with different hull profiles that originated in the same region or coastline. This last observation implies that shipbuilders chose hull shapes not because they were only taught one form, but because their selection was dependent on the intended operation area for the ship. In theory, the same builder would know how to produce vessels of different forms and the only clear way for archaeologists to acknowledge a similarity

[729] Pulak, 'Yenikapi Shipwrecks and Byzantine Shipbuilding', 70, fig. 23.

would be based on the construction sequence and individual practices that are shared. Chapter 3 includes several examples where ships built along the Iberian, French Riviera, and Ligurian coast share the technique to clench nails that does not appear on any eastern ships until the end of the sixteenth century (Yassıada 3). The technique of organizing wrecks into separate roots may be more ideal for discussions of earlier origins and transitions of shipbuilding rather than for informing scholars about construction practices organized around hull shape throughout late medieval and early modern eras.

Practice and Social Learning in Shipbuilding

Few documents discuss the social organization of ship construction during the late medieval period. Most knowledge is piecemeal and consists of surviving building estimates and later documents associated with the Venetian arsenal.[730] Analysis of the transition from shell- to frame-based construction suggest that carpenters on earlier projects needed to be competent in most aspects of ship assembly, including creating seamless butting of the planking or precise cutting of mortises for the tenons. Frame-based construction reduced the knowledgeable workforce by requiring only a few members of a building project to be familiar with how the ship was designed.[731] Everyone else involved could be assigned specific tasks that were important for the completion of the project but did not require knowledge of the whole. This division resulted in a social organization within ship carpentry that produced specialists like sawyers to cut the planking and caulkers to attach them to the frames and seal the seams.[732]

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[730] Fourquin, 'A Medieval Shipbuilding Estimate (C. 1273)', 23-4; Fourquin, 'Un devis de construction navale de *ca.* 1273', 264-9; Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 1-2

[731] Harpster, 'Designing the 9th-Century-AD Vessel from Bozburun, Turkey', 311-2; Pujol i Hamelink, *La construcció naval a la Corona d'Aragó, Catalunya (segles XIII-XV)*, 99-100.

[732] Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 73.

Shipbuilding and many other artistries during the medieval period developed guild associations as a social and regulating entity for a particular craft within a defined area. Guilds often advocated on behalf of its members with authorities and collected dues towards celebrations, such as maintaining holy sites for patron saints, welfare coverage for elderly members, or other benefits to the community.[733] Venetian shipbuilders' dues were partially used to provide dowries for their daughters.[734]

How knowledge was conveyed is often described as part of a generational apprenticeship system. During the late medieval and early modern period, this system became more regulated with levels that consisted of apprentice, journeyman, and master.[735] Apprentices in shipbuilding were often sons of master craftsmen pursuing the family career and learning alongside their fathers. Outside apprentices were common, although the level of their mastery of the craft compared to a blood-relative of the instructor varied. If the master was not teaching his own relative, sometimes he would advance the education of a star pupil to the detriment of the rest. These actions led in managed shipyards to a surplus of carpenters who were familiar with the general practices, but unable to fully comprehend vital design aspects reserved for a select few.[736]

Apprentices learned the craft beginning at a young age, and were presumably assigned menial tasks to become familiar with all aspects of the trade before being given greater responsibilities. This type of learning required apprentices to acquire their new skillset through mimicking their master's abilities and participation in the construction process. As apprentices

[733] Ogilvie, *The European Guilds: An Economic Analysis*, 19-20.
[734] Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 76.
[735] Wendrich, 'Archaeology and Apprenticeship: Body of Knowledge, Identity, and Communities of Practice', 11.
[736] Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 81-4.

aged and required less direct supervision, the individual might advance to the rank of journeyman. The journeyman held a middling position and its specific requirements were somewhat subjective.[737] Journeymen traveled and practiced their trade until they passed a set of instructions imposed by their guild or an oral examination in front of a committee of master carpenters and associated administrators if they were connected to a state shipyard.[738] Once the level of master craftsman was attained, the ship carpenter could establish his own shipyard and become a teacher to a new generation.

Similar apprenticeships still occur today in traditional wooden shipbuilding and many other industries. Modern instructional methodology requires practitioners to learn their trade through the same repetition of important tasks. This repetition reinforces conservative tendencies, due to the apprentice learning to complete an assignment in the same manner as originally instructed.[739] Shipbuilding and other crafts should be viewed as conformist, due to the lack of variation in the final product when compared directly with previous or subsequent examples. Differences appear based on outside factors, such as fluctuations in economics, migrations, environmental changes, or foreign cultural influences.

Pomey, Kahanov, and Rieth apply the operational process as a methodological approach highlighting the gradual changes in shipbuilding and recognizing that outside forces could contribute to the transition in hull construction.[740] Drawbacks of the operational process is that it is mainly a methodological analysis and does not necessarily provide theory beyond identifying

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[737] Croix, Doepke, and Mokyr, 'Clans, Guilds, and Markets: Apprenticeship Institutions and Growth in the Preindustrial Economy', 14-15
[738] Unger, 'The Technology and Teaching of Shipbuilding, 1300-1800', 185-6.
[739] Mokyr, 'The Economics of Apprenticeship', 24.
[740] Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 236

the assembly patterns of individual builders (or groups of craftsmen in the case of shipbuilding). Archaeologists studying material culture produced by other craft masteries also use this approach to explain practice and social learning theories. Both theoretical paradigms could be beneficial when applied to understanding the social dynamics of shipbuilding communities based on archaeological remains and surviving documents.

Practice and Social Learning Theories in Archaeology

Pierre Bourdieu and Anthony Giddens postulated that individual practice creates social structures within society.[741] Giddens emphasized that there is a continual feedback loop between these aspects.[742] Practice not only reaffirms existing structure, its recreation based on the same repetition produces habitual disposition. Habitus is considered both a conscious and unconscious product of structure, where the daily practice of meaningful actions by participants is constrained by existing societal expectations.[743] Social structures are dual natured by not only allowing production of individual practice but can also lead to transformations in society.[744]

Practice based approaches vary considerably over the last several decades.[745] Debate between practice theorists is often based on the level of agency invoked by the participant and whether specific action or all activities should be considered.[746] Common themes between studies emphasize the need for a multiscalar view toward understanding practices at various

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[741] Giddens, *Central Problems in Social Theory: Action, Structure, and Contradiction in Social Analysis*, 117; Bourdieu, *The Logic of Practice*, 54.
[742] Giddens, *The Constitution of Society: Outline of the Theory of Structuration*, 27.
[743] Bourdieu, *Outline of a Theory of Practice*, 78.
[744] Giddens, *Central Problems in Social Theory*, 47.
[745] Dobres and Hoffman, 'Social Agency and the Dynamics of Prehistoric Technology', 224-5; Lightfoot, Martinez, and Schiff, 'Daily Practice and Material Culture in Pluralistic Social Settings: An Archaeological Study of Culture Change and Persistence from Fort Ross, California', 201-3; Pauketat, 'Practice and history in archaeology: An emerging paradigm', 86-8
[746] Dornan, 'Agency and Archaeology: Past, Present, and Future Directions', 320; Joyce, 'PostScript: Doing Agency in Archaeology', 368

levels and that the operational process provides the methodological impetus towards understanding behaviors during different stages in the production of technology. Most examples reaffirm the connection between agency and structure, while avoiding any further breakdown of either concept.[747]

Recent scholarship has also tied social learning theory with practice theory to explain the differences between the nature of social structure produced by individual actions and their inherent social identity. Jean Lave and Etienne Wenger re-envisioned learning apart from the traditional view of a situated relationship between student and instructor by viewing education as a social process.[748] Situated learning is no longer viewed as the confines of a specific location and instruction, such as modern school systems with educators (seen as “learning in situ”). Apprentices involved in a “legitimate peripheral participation” learn not only from traditional observation and mimic learning in an historical-apprenticeship system but also the mannerisms, performances, and social networks of those around them as part of an inherent social structure for them to emulate. [749]

Legitimate peripheral participation is considered non-binary opposition (unlike structuralism in traditional practice theory).[750] There is no such thing as illegitimate participation, core members (versus peripheral), or non-participation. Legitimate peripheral participation is simply terminology referring to all involved and the discussion of new members learning and eventually gaining admittance to full participation. In this sense, journeyman and masters act alike in supplying instruction or cues for apprentices (peripheral members) to learn before they

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[747] Ortner, 'Theory in Anthropology since the Sixties', 148
[748] Lave and Wenger, *Situated Learning: Legitimate Peripheral Participation*, 29.
[749] Wenger, *Communities of Practice: Learning, mearning, and identity*, 100-2.
[750] Lave and Wenger, *Situated Learning: Legitimate Peripheral Participation*, 35.

are replaced by the latter group in the future. Members within a legitimate peripheral participation are part of a community of practice, which implies a system where everyone involved reaffirms the process of production taking place.[751] Communities of practice share attributes within their craft regardless of the social networks formulated based on communal identities from language, migration history, religion, kinship, or other social processes.[752] Communities of practice do not necessarily fit the same limits as communities of identity, and it is often the former that covers a larger population throughout a geographic landscape.[753]

Archaeologists have applied social learning when analyzing their data. For example, scholars studying ceramic production across the Southeastern United States noted a common method of manufacture practiced by female Native Americans.[754] Groups of potters used differences in decorations imprinted on finished surfaces to signify communities of identity. Jill Minar explores this topic by identifying the finish twist for cord manufacture that was applied to the outside surfaces of Alachua ceramics.[755] Through a combination of archaeological analysis and ethnographic research, Minar observed that cord manufacture is a developed motor skill that requires less attention by practitioners as they become more adept at its manufacture. Learning through imitation and verbal instruction often leads to an identical final twist pattern in the

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[751] Wenger, *Communities of Practice: Learning, mearning, and identity*, 63-71.
[752] Worth, 'What's in a Phase? Disentangling Communities of Practice from Communities of Identity in Southeastern North America', 146.
[753] Stark, 'Glaze Ware Technology, the Social Lives of Pots, and Communities of Practice in the Late Perhistoric Southwest', 25; Eckert, *Pottery and Practice: The Expression of Identity at Pottery Mound and Hummingbird Pueblo*, 3, 58; Eckert, 'Choosing Clays and Painting Pots in the Fourteenth-Century Zuni Region', 55; Eckert, Schleher, and James, 'Communities of identity, communities of practice: Understanding Santa Fe black-on-white pottery in the Española Basin of new Mexico', 1-2
[754] Sassaman and Rudolphi, 'Communities of Practice in the Early Pottery Traditions of the American Southeast', 416; Semon, 'Late Mississippian Ceramic Production on St. Catherines Island, Georgia', 211; Sanger, 'Coils, slabs, and molds: Examining community affiliation between Late Archaic shell ring communities using radiographic imagery of pottery', 104
[755] Minar, 'Motor Skills and the Learning Process: The Conservation of Cordage Final Twist Direction in Communities of Practice', 382

finished product of apprentices.[756] Once the verbal instruction and visual cues are identified, apprentices could in turn teach a new participant to produce the same result.[757]

John Worth found similarities between ceramic production between Native American groups during the Spanish Mission period (1566-1763). His analysis describes a landscape of practice that can be tied to earlier archaeological chronologies developed by culture historians as "phases" of ceramic manufacture.[758] Communities of practice act within this landscape through daily interactions by constituent members and develop due to changes in the social interplay of continuity and change. Worth also discusses domains of practice, which are considered functional categories for vessel fabrication or surface treatment.[759] He also discusses horizons of practice, viewed as contour-like maps that highlight the spatial distribution of a practice and its frequency within the same field as other choices. Rachel Hensler examines roughly the same period as Worth, focusing on a comparative analysis of ceramic production in coastal and interior sites.[760] Her study involves the development of Altamaha pottery and argues for a constellation of practice where the tools utilized for decorative styles moved between social groups. Continuous interaction between coastal and interior groups that were earlier divergent in practice before the arrival of European colonization eventually converged through time in the Contact and Mission periods, which led to the adoption of Altamaha pottery across the landscape.[761]

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[756] Minar and Crown, 'Learning and Craft Production: An Introduction', 373-4
[757] Minar, 'Motor Skills and the Learning Process', 396
[758] Worth, 'What's in a Phase?', 138.
[759] Ibid., 148-9.
[760] Hensler, 'Using *chaîne opératoire* and communities of practice to identify interaction in the Contact and Mission periods in southern Georgia, AD 1540-1715', 110-2
[761] Ibid., 119.

Similar observations were also identified for Southwestern United States ceramic manufactures. Suzanne Eckert examined fourteenth and fifteenth century ceramic production in Central New Mexico and found the continual use of similar decorations on the exterior of bowls to be a reflection of different migration histories that involved incorporation or segregation among Pueblo society.[762] Miriam Stark suggests that the arrival of new producers due to migration led to the experimentation with and adoption of unfamiliar raw materials and changes in technological traditions.[763] Stark also recognized that certain manufacturing steps in the shaping of pottery are greatly resistant to changes when compared to the stylistic decoration applied. This observation is reinforced by Olivier Gosselain's research on ceramics across sub-Saharan Africa. Gosselain observes communities of practice that contain a similar operational process throughout the region tied to earlier Bantu migrations.[764] Several communities of practice sharing the same manufacture methods were scattered without any homologous sections across the geographic landscape. Decorations by using roulettes along the upper surface of ceramics indicated a practice that was influential between adjacent communities of identity and confined to specific geographic areas in Africa.[765]

Patrick Fazioli also indicates similar conclusions for ceramic production in the Balkans between late antiquity and early medieval period. Coastal and interior communities shared similar practices in manufacture and decoration techniques.[766] By the early medieval period there

[762] Eckert, 'The Dynamic Nature of Cultural Identity during the Fourteenth and Fifteenth Centuries in Central New Mexico', 277-8.
[763] Stark, 'Glaze Ware Technology, the Social Lives of Pots, and Communities of Practice in the Late Perhistoric Southwest', 24.
[764] Gosselain, 'Materializing Identities: An African Perspective', 204-6
[765] Ibid., 199-200.
[766] Fazioli, 'Rethinking Ethnicity in Early Medieval Archaeology: Social Identity, Technological Choice, and Communities of Practice', 32.

is a continual practice by coastal settlements in the same operational process, while the interior locations indicate a different methodology. Modifications in the ceramic production found at interior settlements suggested a later influx of migrants with differing ceramic techniques.[767]

Recent research by Francesca Fulminante and Mukund Unavane also apply communities of practice to the study of Archaic bronze votive figurines from Central Italy. Their conclusions indicate a difference between the metal content of the objects compared to the stylization.[768] The inclusion of metallic iron in the final product provides a signature for a community of practice following similar smelting practices for votives originating in Latium Vetus when compared to Umbrian examples from Central Italy.[769] Even though the metallic composition of the objects differs, the stylizes of figures are similar indicating application within the same cultural system (or community of identity).

Gwendolyn Kelly examined stone bead and ornament production in South India by suggesting that within the community of practice there are differences between orthodox and heterodox methodologies.[770] Bourdieu was the first to discuss the differences between doxa, orthodoxy, and heterodoxy in anthropology and sociology. Doxa is considered the unacknowledged awareness of self-evident principles in the natural organization of social orders. When power struggles manifest, those seeking to maintain their elevated positions will enhance mechanisms that secure the social order. Those following orthodox patterns intend to follow an explicit set of beliefs and/or practices to maintain the social structure. Others who challenge

[767] Ibid., 38.
[768] Fulminante and Unavane, '"Community practices" and "communities of practice" in smelting technology by XRF analysis of Archaic bronze votive figurines in central Italy (6th - 5th centuries BC)', 10
[769] Ibid., 8-9.
[770] Kelly, 'Heterodoxy, orthodoxy and communities of practice: Stone bead and ornament production in Early Historic South India (c. 400 BCE-400 CE)', 32

vested interests create heterodoxy by increasingly diverse practices. Heterodoxy is the state of affairs when various social practices co-exist within the same area and are accepted.[771]

Kelly's examination of bead and ornament production in Early Historic South India focused on the operational process beginning with the raw material, shaping of the object, drilling the hole, and polishing of the final product (not necessarily in this order).[772] She noticed that the manufacturing process was dissimilar between examples and suggest that there was a general heterodox community of practice. Within this heterodox, there was a smaller sample between sites of a specific operational process and different material usage that suggested an orthodox practice taking place. The orthodox community was viewed by Kelly as possibly traveling bead makers who shared their knowledge of a specific set of practices with new groups. Sharing their methodology, alongside other outside orthodox groups, led to diverse practices and the general heterodox community identified in the archaeological record.[773]

Communities of Practice in the Mediterranean

Shipbuilding should be viewed as another example of how practice and social learning were applied in a traditional craft environment. Often viewed as a conservative profession, shipbuilding includes a traditional social community that is slow to adopt new technological features. Master molds and designs for framing were kept secret and only shared with trusted apprentices. Families pursued shipbuilding as a generational business with children not only learning how to design and build a ship but also becoming indoctrinated into the community through participation in the guild and other social activities. These aspects highlight the inherent habitus where the shipbuilders guild provided the social structure that is reaffirmed through

[771] Bourdieu, *Outline of a Theory of Practice*, 169.
[772] Kelly, 'Heterodoxy, orthodoxy and communities of practice', 36-9
[773] Ibid., 47.

participation by its individual members. Shipyards also represent another aspect of this habitus during construction of a vessel and how the axial timbers, framing, planking, and longitudinal elements were assembled based on a routine sequence specific to a shipbuilding tradition.

Preferences towards fastening, scarfing, or other specifics showcase the agency at work by craftsmen with the continual reaffirmation of the general habitus. At the same time, everyone who is involved with a shipyard, guild, or other social entities where ship constructors were present are members of legitimate peripheral participation. Individuals with greater responsibilities or knowledge provide peripheral members the opportunities to gauge, learn, and adopt appropriate practices within the community. Apprentices learned the methods to construct a ship while also observing how journeyman and masters acted, behaved, or networked within social circles. Eventually, peripheral participants reached full participation and replaced the journeyman or masters who came before them.

Identifying the products of an apprentice or journeyman compared to those of a master craftsman in the archaeological record is problematic. Mistakes were presumably corrected, and any unusable practice material was either discarded or reused in a different manner.[774] Limited documents about the daily lives of shipbuilders throughout the Mediterranean during the late medieval period adds to the difficulty. Most of what we know about apprenticeships, guilds, and similar structures is available in greater detail by the early modern era.[775] Shipbuilding treatises appear by the 15th century, but as will be discussed in the following chapter, these are often composed by an emerging middle class interested in understanding or explaining professions in

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[774] Wendrich, 'Recognizing Knowledge Transfer in the Archaeological Record', 255-6.
[775] Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 75; Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 1-2

which they were not necessarily members.[776] Nevertheless, what survives of hull remains from archaeological sites provides construction signatures and overall shapes that suggest overlapping communities of practice.

Fernand Braudel referred to the Mediterranean and its coastal communities as separate from those beyond the mountains in Northern Europe or the Atlantic coastline.[777] Coastal groups communicated and shared technological development more frequently than hinterland inhabitants.[778] This observation explains how quickly the general adoption of frame-based construction took hold, while construction signatures from earlier shell-based assemblies were still featured. Borrowing the lexicon laid out by the researchers described above, the shipbuilding traditions (shell or frame construction) represent horizons of practice used within a geographically bounded area. The Mediterranean is the bound environment in this case, although the adoption of frame-based practice migrated from this region into the Atlantic by the beginning of the early modern era. Practitioners of a tradition represent the social landscape of practice and could be the same group influenced by overlapping horizons. Communities of practice throughout the Mediterranean are identified as orthodox or heterodox groups following similar operational process in the assembly of the ship with differences on how this was carried out. Overlapping communities of practice are more prevalent than horizons and should be studied through a multiscalar analysis to identify different shipbuilding groups throughout the basin.

Shipwrecks in this dissertation are predominantly representations of a frame-based horizon of practice. The construction similarity throughout this landscape is the technique where

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[776] McGee, 'The Shipbuilding Text of Michael of Rhodes', 240-1.
[777] Braudel, *The Mediterranean and the Mediterranean World in the Age of Phillip II*, 23-5, 276-7.
[778] Westerdahl, 'The Relationship between Land Roads and Sea Routes in the Past - Some Reflections', 61-2; Westerdahl, 'Traditional zones of transport geography in relation to ship types', 224-8.

in the design and assembly the framing is installed on axial timbers before any planking. Five sites (Marsala B, Precenicco, Boccalama A, Rhodes 1, and Sveti Pavao) also provide evidence for a bottom-based construction horizon currently seen in the eastern half of the Mediterranean.[779] This horizon focuses on keel planks with the first associated strakes providing a flat foundation from which framing and additional planking is subsequently installed. Les Sorres X and Marinières represent another horizon possibly composed of a blending between bottom-based and frame-based construction.[780] The following analysis also divides the Mediterranean into two regions (East vs. West) based on an approximate line between the Straits of Sicily and Messina. This division will become clear as we discuss signatures comprising communities of practice between associated shipwrecks. Future research may change this division based on new archaeological discoveries or may determine that it is untenable.

The hull remains demonstrating the connections between axial timbers suggest a long practice of scarfing these elements together. Butting of axial timbers without any scarf connections is suggested on Marsala A but is explicit on western ships beginning with Culip VI.[781] Practitioners of the earliest frame-based approach originally followed a shared heterodox practice where dual master frames were installed amidships supplemented by tailframes near the endposts. Sometime around the beginning of the fourteenth century, dual master frames were replaced with a single master frame relying on double futtocks (figure 67). Dual master frames

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[779] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 296; Capulli, 'Il relitto di Precenicco', 113; Romanelli, *La galea ritrovata*, 44; Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 481; Beltrame, 'The ship, its equipment and the crew's personal possessions', 48.
[780] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 34; Daeffler, 'L'épave des Marinières', 19-20.
[781] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 298, fig. 3; Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 184, fig. 4; Rieth and Pujol i Hamelink, 'L'arquitectura naval', 118-9.

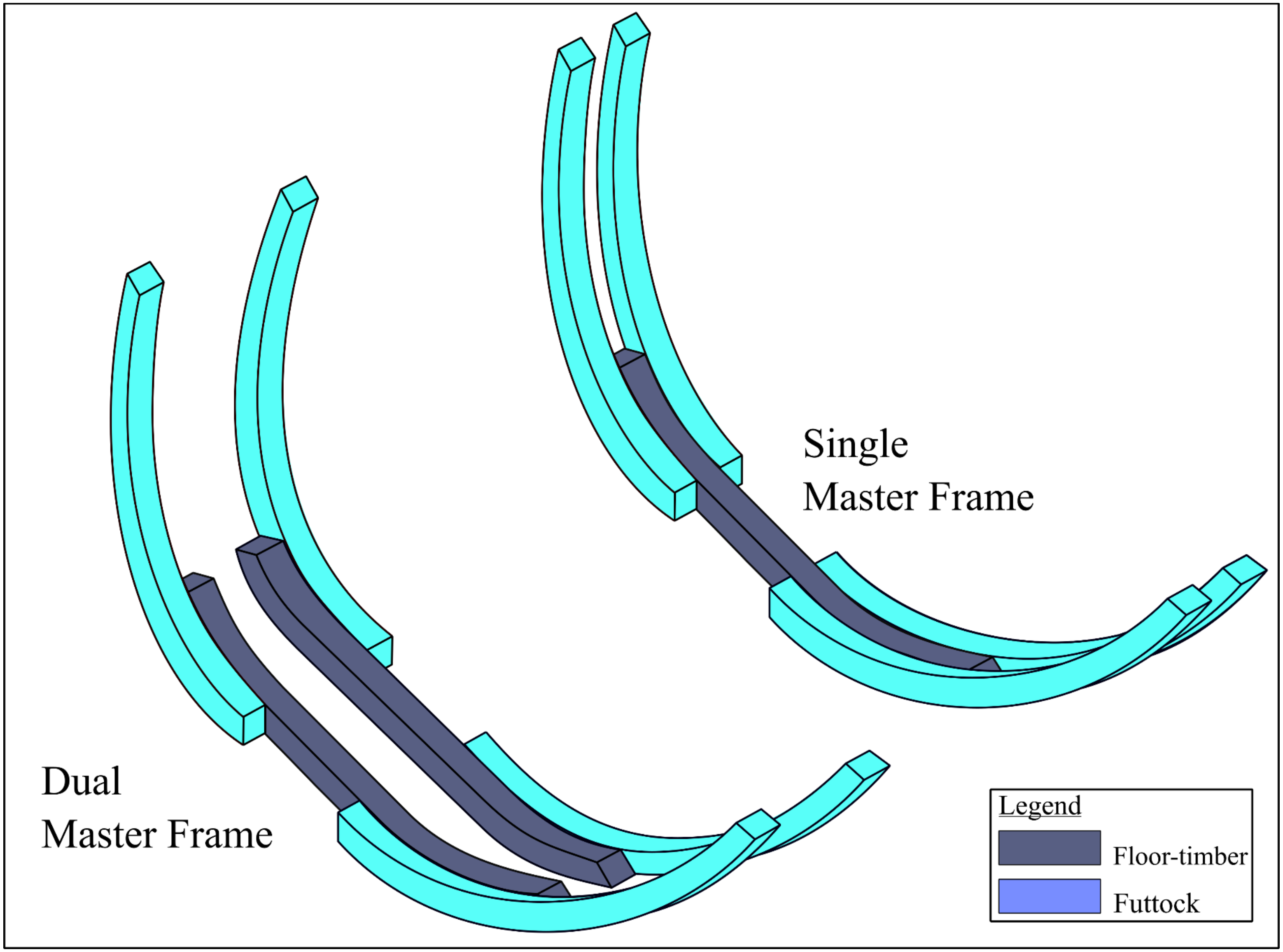

Figure 67 Examples of double master or single master frames. (Author's drawing)

refer to a pair of futtocks on a single face of twin floor timbers, while the single master frame is a floor timber that includes double futtocks attached at each wronghead. Based on the archaeological material, the earliest appearance of the single master frame is on Boccalama B and other vessels associated with the Adriatic as an orthodox community. It was later carried over to the west, specifically along Ligurian coastline. Explicit use of dual master frames on Yassıada 3 and on a few later period western wrecks suggests that there is currently no clear transition point for this practice, only that the dual master frame pattern is older. The single master frame started in the Adriatic enclave before its adoption by certain western shipyards.

There is some evidence that the adoption of the frame-based approach was misinterpreted regarding the pattern for attaching futtocks to floor timbers. Most examples indicate the preference for futtocks to be attached on the faces of floor timbers away from amidships, while a minority of western vessels showcase the opposite.[782] Only the construction on Rhodes 4 suggests a similar issue in the east with reverse attachment of the futtocks, perhaps a testament toward the earlier transition adopting the frame-based approach from shell-based methodology.[783] Subsequent Atlantic-Iberian transition to the frame-based approach relying predominantly on a single master frame might pertain to a constellation of practice between this coastline and shipwrights who employed this signature technique in the Mediterranean. Similar constellations of practice occurred previously between Venetian and Greek shipbuilders, when the former sought out masters from the east to take over leadership roles in the state arsenal.[784]

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[782] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 43; Joncheray, 'L'épave dite «des ardoises », au cap Lardier. Un caboteur ligure de la fin du XVI[e] siècle', 23
[783] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 486-7.
[784] Gertwagen, 'Byzantine Shipbuilding in Fifteenth-century Venetian Crete: War Galleys and the Link to the Arsenal in Venice', 120-2.

Comparable changes in practices are seen with the original preference for alternating long-armed floor timbers with short-armed futtocks. The original community of practice is centralized with eastern vessels, while the later and more common full floor timbers becomes ubiquitous. Other common practices include mast step complexes and sealing hulls with pitch. As described in the previous chapter, the latter practice is a carryover from the earlier shell-first construction. Mast step complexes may have developed from earlier period, but their system of intricate construction remains consistent regardless of whether the ship is identified as a round ship or longship. Where there are greater contrasts is in the floor timber to futtock connection that develops throughout the later period. Earlier practices avoided using any scarfs, except for key frame installations that were also nailed together for support. Culip VI remains the earliest example for the use of hook scarfs that Rieth originally identified as an important signature indicating Mediterranean construction.[785] Eastern contemporary wrecks around the same time as Culip VI include no hook scarfs. Hook scarfs are mostly found on western vessels. When hook scarfs appear on eastern ships, they are shallow in comparison. Yassıada 3 is again an outlier with robust hook scarfs when compared to the shallower ones identified on *Trinidad Valencera* or Sveti Pavao.[786] Near the beginning of the early modern period, two overlapping western groups also utilized either dovetail joinery or cutting recesses into one of the corresponding frame elements to fit snuggly against the other. Due to the prevalence of dovetail joinery found

[785] Rieth, 'Consruction navale a franc-bord en Mediterranee et Atlantique (XIV^{e}-XVII^{e} siecle) et 'signatures architecturales'', 184-6.
[786] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 57-8; Martin, '*La Trinidad Valencera*: An Armada invasion transport lost off Donegal. Interim site report, 1971-76', 29-31

on most early modern Iberian shipwrecks, there is a previous suggestion that this practice in the Mediterranean is an outside influence.[787]

Fastener preferences also represent different scales for communities of practice. There is a consistent orthodox practice across most of the Mediterranean for exclusive use of iron fasteners with a ratio of two or three per frame station (albeit with a few using additional nails on some wrecks) when attaching the planking. Most ships associated with the Iberian Peninsula include heterodox communities, where treenails were installed alongside iron fasteners with a standard ratio for the planking or were used in key longitudinal components. The only other significant treenail use noted on Mediterranean ships is often tied to internal assembly not directly exposed to the outside hull. For instance, treenails were used to fasten ceiling on the Bacàn wrecks, Saint-Honorat 1, and in a single example from Calvi 1.[788] Another group of shipbuilders between the Adriatic and Ligurian coasts began utilizing round (or quadrangular) nails instead of the traditional square fasteners for hull assembly.[789] Several ships from the Iberian, French Riviera, and Ligurian coasts clenched fasteners. Only Yassıada 3 and *Kadırga* include this practice for contemporary eastern vessels.[790] Connection between the keelson and keel is another practice where bolts were originally installed between frames. None of the later western ships includes this practice and contemporary eastern ships eventually adopt bolting the keelson through floor timbers to the keel. Yassıada 3 provides another interesting anomaly with

[787] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 43; Rieth, 'Consruction navale a franc-bord en Mediterranee et Atlantique (XIV^{e}-XVII^{e} siecle) et 'signatures architecturales'', 186-7.
[788] Stefano Medas, pers. comm.; L'Hour and Richez, 'Sondage sur un site sous-marin de la Baie de Cannes, Saint-Honorat 1. L'épave d'un galion espagnol incendié en 1637?', 134; Villié, 'L'épave Calvi 1 (1989)', 25
[789] Cazenave de la Roche, *The Mortella III Wreck*, 154-5.
[790] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 57; Arcak, 'Kadırga, A Technical Analysis of the Sultan's Galley', 244.

the presence of treenails temporarily installed between floor timbers prior to the installation of bolts through them.[791]

Even within the frame-based horizon, there are still practices that do not necessarily contribute to this construction technique. Planking scarfs on eastern vessels, such as Serçe Limanı, Boccalama B, and Rhodes 2, suggest anachronisms from the earlier shell-first horizon fulfilling habitus without providing actual construction benefit.[792] The same observation can be said about the use of keel rabbets and carved garboards, which are shell-based techniques that usually need to be installed prior to the frames. This assembly practice is due to hull shape and the application of keel rabbets was often based on a ship's overall design. Ships with an increased length to breadth ratio or without scarfs between axial timbers include keel rabbets, while this practice remained unnecessary for most other frame-based vessels. Recesses fitting the keelson onto the frames is a universal trait, but its application on stringers, wales, or other longitudinal components suggest practices that were longitudinally focused within a transversal hull methodology.

Comparisons of hull construction discussed in detail throughout the previous chapter and summarized above, represent multiple shipbuilding communities that operated in varying ways throughout the Mediterranean. The overlapping traditions left behind practices from the earlier shell-built horizon that were maintained in subsequent frame-first construction, sometimes without any obvious added benefit to the architectural project. Overlapping horizons also meant that shipbuilding in the Mediterranean was already a heterodox community of practices following the general operational process for assembling a frame-based hull with differences on

[791] Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 55.
[792] Steffy, 'Construction and Analysis of the Vessel', 162; Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 482; Romanelli, *La galea ritrovata*, 65.

how this was achieved depending on where the ship was built. Several wrecks tied to specific coastlines included practices that appear confined to these areas and suggest orthodox communities within a heterodox environment (single master frame serves design as a pivotal example). Limited finds from earlier western shipbuilding or later eastern shipbuilding is problematic to understand how frame construction was embraced. This limitation does not yet allow us to know when and how practices originating in the west were adopted by eastern shipbuilders, such as the presence of scarfs between framing elements or the clenching of nails.

There is clearly a constellation of practice shared between shipbuilding communities. For instance, Venice went beyond its borders to lure Greek master shipbuilders with the promise of pay and status to work within its arsenal. Venetians recognized Greek master shipbuilders were producing superior vessels compared to their local craftsmen or that shared design knowledge for narrow longships were inferior in the upper Adriatic. The fact that these outsiders could work efficiently in the arsenal suggests a connection between eastern communities on how ships were built. Similarly, constellations of practice between Ligurian and Adriatic groups with those operating along the Iberian-Atlantic coastline exist through the application of single master frame designs. Although this latter topic is outside the current scope of research, it should be investigated in the future under this theoretical paradigm.

Domains of Practice in Shipbuilding

Ships can be divided into four structured aspects: liveworks (the submerged hull portion), deadworks (or upperworks, as they as sometimes described), rigging, or decorations. Each aspect should be viewed as a domain of practice. Worth defined domains of practice as categories of functionally related practices within an operational process.[793] Domains of practice in shipbuilding are somewhat hierarchical. Liveworks represents the first sequential domain, although when elements of any domain were installed might overlap during actual construction. Most of what is represented in the archaeological record is mainly information about the liveworks. Few wrecks within this study include surviving hull structure from the deadworks and it remains difficult to discern important information without referring to contemporary iconography.

Between the late medieval and early modern period historians suggest at least two overlapping nautical revolutions (1400-1550) took place. Most of the earlier revolution stemmed from improvements to navigation with the introduction of the compass and charts.[794] Appearance of the cog and other Northern European ships in the Mediterranean also led to developments in the first domain by the adoption of the straight sternpost and associated rudder.[795] Rigging also developed with more ships relying on square sails rather than the lateen rigs seen on most iconography throughout the earlier medieval period. Near the end of these revolutions, historians comment on the greater complexity of the rigging with additional masts on larger vessels and more canvas on the medium and small ones.[796] Added masts also suggest an increase in overall dimensions for vessels from this period. Superstructure also varies, as the castles grow in complexity until the introduction of guns (along with improvements to gunpowder) and changing

[793] Worth, 'What's in a Phase?', 150.
[794] Lane, *Venice: A Maritime Republic*, 119-24.
[795] Mott, *The Development of the Rudder: A Technological Tale*, 110-3.
[796] Unger, *The Ship in the Medieval Economy, 600-1600*, 186-7.

naval tactics by the end of the sixteenth century from boarding actions to using artillery to pummel ships from afar.[797]

While none of these domains appear completely static based on the historical and iconographic record, archaeological examples suggest that the first domain is the most resilient against change. Despite the fact that Mediterranean shipbuilders embraced the stern rudder, many ships still sailed with quarter rudders as a failsafe measure.[798] The construction signatures noted between shipwrecks in the previous chapter also suggest that general practices continued without interruption for the liveworks. Most of the vessels featured include similar hull shapes to earlier shell constructed examples without any sudden change.

Superstructure from the second domain suggests that this component altered through time and was more heavily dependent on the intend operations of a vessel. Higher deadworks on large oceanic round ships provided not only cabin space for passengers but also taller platforms to defend against others who wished to prey on shipping.[799] These structures also led to concerns that their increased size affected sailing, as the greater surface area could act as a rigid sail that might lead to disastrous consequences.

The introduction of cannons on ships did not immediately change how the deadworks were constructed because early gun technology did not provide powerful enough broadsides and Mediterranean naval tactics focused on capturing vessels through boarding.[800] Most warships from this period were often longships with a large crew and a smal assortment of artillery pieces

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[797] Rodger, 'The Development of Broadside Gunnery, 1450-1650', 314-5; Gianni Ridella, 'Genoese Ordnance Aboard Galleys and Merchantmen in the 16th Century', 54; Eliav, 'Tactics of Sixteenth-century Galley Artillery', 406-7
[798] For two examples of longships with both types of steering gear, see McGee, ed., *The Book of Michael of Rhodes: A Fifteenth-Century Maritime Manuscript*, 316, f.142a, 325, f.145b.
[799] Unger, *The Ship in the Medieval Economy, 600-1600*, 184-6.
[800] Sicking, 'Naval warfare in Europe, c. 1330-c. 1680', 249-50.

at the bow. By the end of the sixteenth century, naval tactics and improved artillery led to changes in the deadworks. High superstructures became burdensome and no longer a defensive necessity regardless of whether or not a vessel was employed for naval purposes.[801]

Rigging should be considered dual natured regarding domains. It can fit as part of the second domain when a ship keeps the same sail configuration throughout its operational life. On the other hand, rigging is also considered a separate domain due to the static nature of hull shapes through time while sails, masts, and associated rigs varied. Decorations on ships fluctuated the most and should viewed as the domain closely tied to communities of identity. Preferences on figureheads, trims, painting, and other elements were stylistic changes that occurred in smaller social groups that changed through time. Many of the smaller vessels recorded in this study presumably incorporated lesser amounts of decorative elements, as these ships were working coastal craft. Nevertheless, the apotropaic eye and associated arch design recorded from Mariposa B clearly suggests that decorative elements (possibly with symbolic and/or ritualistic connotations) still existed on smaller vessels.[802] Iconography also provides evidence that most longships from this period included elaborate decorative elements on either end of the vessel, while the upper elements of superstructure on round ships could include color or carved ensembles.

Further work exploring iconographic sources throughout the Mediterranean may provide better information about communities of identity associated with specific regions. One example includes the lion of Saint Mark appearing on vessels associated with Venice, while ships tied to

[801] Phillips, 'The Caravel and the Galleon', 114.
[802] Riccardi, 'Evidenze archeologiche di imbarcazioni dell'età di Colombo. I relitti del Camping «La Mariposa» (Alghero - Italia)', 280

Genoa could include dragons alluding to Saint George.[803] Surviving iconographic examples of the Venetian lions are represented on the 1727 *bucentaur* (state galley) on display at the city's Museum of Naval History. In this same vein, several images of an eastern dragon motif tied to the Ottoman sultans are prominent on *Kadırga*.[804] Traditional culture histories tied to archaeological sites should also be viewed as aspects within the third or last domain of practice (depending on how some interpret rigging).

Historic typologies written in documentary sources reflect the perceived outlook of the observer based on their own contemporary communities of identity. Ships with various superstructures, stern tucks, rigging, sail patterns, or the amount of artillery on board could all be identified with the same typology (or could also be ascribed differently between sightings of the same ship). The mainstream trend by nautical archaeologists is to attribute historic typologies upon archaeological sites, which reflects more on the community of identity applied between modern scholars than about the shipwreck under investigation.[805] Historians are also prone to this type of conceptualization when examining the small collection of documents available associated with designs. This aspect is further highlighted in the following chapter regarding hull forms described in shipbuilding treatises, where idealized measurements and/or drawings end up being preferred "identities" for historic ship types.

Summary

Nautical archaeology continues to mature as a subdiscipline with additional findings reported every day around the world. As these findings are published and tabulated, shipwreck studies are becoming more accomplished in examining larger datasets. Shipbuilding in some

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[803]Lane, *Venice: A Maritime Republic*, 88.
[804] Basch, 'The Kadirga Revisited: A Preliminary Re-Apprasial', 47
[805] Harpster, 'Shipwreck Identity, Methodology, and Nautical Archaeology', 613

ways is no different than many other craft trades, except the final product is much more complex and often requires a diversified workforce to produce the final product. Over the past century, archaeologists have debated topics about the manufacture of pottery, beads, figurines, weaponry, and other materials that require developing an operational process from raw materials to finished creation. These discussions provide an avenue for nautical archaeologists to pursue the same level of theoretical debate about shipbuilding.

Several colleagues have already pursued this thought process by adopting the operational process as a methodology for excavation and subsequent analyses. This organization allows researchers to conceptualize the steps necessary for shipbuilders to create the required elements, such as the axial timbers, framing, longitudinal reinforcements, and planking assembled in a specific order leading to the creation of a ship. The logical next step is to decide how to interpret this data and whether the organization involved can be generalized for examining shipbuilding from different geographic areas and periods.

This chapter outlined two approaches to consider for applying the dataset gathered on Mediterranean shipwrecks from the late medieval to early modern period. The first approach involved an examination of operational process divided into roots based on construction technique and hull forms. Shipwrecks were divided into nine different roots with several categories, including similar hull forms from either side of the Mediterranean. The major differences were identified based on techniques, such as the clenching of nails, inclusion of a scarf joint between frame elements, or the addition of treenails as part of the overall construction. Compared to earlier studies in antiquity, which includes a much more diverse and robust dataset, the wrecks presented in this dissertation can only be analyzed in a preliminary fashion.

Many of the hulls include few characteristics, due to a lack of preservation or the limited descriptive material. For hull forms that included additional information, there seems to be a developing pattern indicating that the transition from shell to frame construction was longer than originally supposed. Although most of the ships in this study are frame-based, there were still underlying tendencies to follow earlier shell construction patterns. The “Root” system also showed that ships with similar hull profiles might also be assembled with different sequences within the same region. Framing joints were either without scarfs, included hook scarfs, or some other variation even if all shipwrecks included the same hull form. In this case, it seems more indicative of a non-linear development of western shipbuilders adopting frame construction from earlier eastern practices. For the general approach in question, it also downplays relying on hull forms as an organizational tool toward highlighting individual shipbuilding communities. In the future, archaeologists might benefit from utilizing roots to discuss the more general commonly-held characteristics between ships but refrain from its use when trying to identify smaller group practices between communities of practitioners who utilized the same techniques regardless of hull form.

The other approach introduced in this chapter considered whether nautical archaeologists should view ships as a technological product of a society involved with its own societal structure and individual agency. Practice theory provides the impetus to consider the craftsmen as both reaffirming their own position within the social structures that exist, while also implementing their own personal choices seen in some aspects of the work. This approach also includes social learning theory, which suggests that all participants in a project contribute to a learning environment regardless of where it takes place.

Like many other craft trades in the medieval economy, shipbuilding relied on an apprenticeship system where younger members learned the trade from more experienced craftsmen. Apprentices learned not only the expected structural aspects required to build and assemble ships, but also the social norms based on their interactions and observations with those who interacted within this environment. While we know less about the social interactions between shipbuilders, except for those who participated in state-owned shipyards, archaeologists can still rely on the evidence in the archaeological record to provide some evidence towards communities based on their practices.

Shipbuilding is organized into domains of practice based on the liveworks, deadworks, rigging configurations, and decorations. Most surviving archaeological evidence is mainly found in the first domain of hull assembly below the waterline. Each element in the construction and assembly techniques of a ship is regarded as practices that could be independent or reliant on each other. Organizing these practices and identifying similar operational processes between ships suggests a community of practice; often these groups are widespread and unhindered by geographical region. Thus, shipbuilding in the western Mediterranean includes communities of practice that preferred to use clench fasteners. Ships associated with the Iberian Peninsula show a preference for use of treenails as part of the hull assembly, while most of the Mediterranean relied predominantly on iron fasteners. Communities of practice can also be related and form constellations, due to different groups sharing similar enough techniques that knowledge is shared and understood between them. One example is the determination by the Venetian shipyard to find Greek master builders to hire and teach native Adriatic craftsmen their trade.

Differences in ship design are often seen in the upper domains, including the deadwork, rigging, and especially decorative motifs. These variations are more dependent on the intended purpose and operational area for a vessel. Greater deadworks on a round ship permitted additional housing for passengers and provided defensive platforms. Poor handling due to high flat rigid surface areas, the introduction of new cannon technology, and changes in naval tactics later reduced this superstructure. Rarely found in the archaeological record and more prominent in contemporary iconography, decorations reflect identities of associated societies with specific ships showcasing cultural biases. Communities of identity are associated with cultural and political groups that changed over time and sometimes were outside groups that infused themselves into Mediterranean culture (Normans occupying Southern Italy for example). While societies changed, the archaeology presents a conservative tendency for shared communities of practice that were far less prone to transformations.

CHAPTER V

ARCHIVAL RECORDS AND SHIP DESIGN

Archaeological remains of shipwrecks provide clues to the processes of shaping and assembling individual timbers. Ideally, these surviving hull remains can also inform scholars about the decisions made by shipbuilders when designing and building a vessel. Although the conception of a ship takes place both before and during its actual assembly, this design-focused chapter is deliberately placed after the review of archaeological evidence for construction due to its more abstract nature. Medieval shipbuilders were both designer and manufacturer until naval reforms in the seventeenth century allowed naval architecture to develop as a distinct discipline. Archaeological remains pre-dating the seventeenth century cannot regularly be tied to a specific shipbuilder. Researchers therefore must use combination of available hull remains, documentation, iconography, and ethnography to define and analyze the example under study.[806] The result of this work is a comparative approach that considers a longue durée of shipbuilders, their tools and materials, and the proportions they relied upon when designing and constructing vessels.

The archival record is an important contributor to the archaeologist's comparative approach. Early documents relating to ship design and construction often served as a basis for replication and refinement by later authors. This chapter explores available archival materials while attempting to identify the shipyard concepts that lay behind these records. Observations from this analysis suggest that typology and expectations for standardization were applied to the

[806] Rieth, 'L'Architecture navale médiévale en Méditerranée: Quelques axes de réflexion', 367-9.

creation of vessels for state or private enterprises. Most of the available documentary sources relevant to this dissertation focus on building in the Adriatic, while we have relatively few published examples of hull remains from this region. Evidence suggests that similar methods for controlling hull design were employed across the Mediterranean, but there was significant differences on how various shipbuilding communities conceptualized the approaches that were applied to frames and planking.

Conception in Antiquity (AD 100 – 1000)

The earliest method for hull design in the Mediterranean likely consisted of a series of sketches for guidance and demonstration rather than for practical purposes.[807] Sketches and rudimentary models were presumably used in state sanctioned production as a way to convey ideas about the final product to authorities who were not familiar with the field. Further development of state navies also required some level of standardization, possibly in the overall dimensions, for the benefit of naval tactics and the use of ship sheds in antiquity.[808] Prior to the transition from shell- to frame-based shipbuilding, hull construction mainly relied on a longitudinal vision. This vision is also sometimes classified as a more idiosyncratic approach, where the length and profile of each plank dictated the overall shape. Framing was complementary, providing support to a hull rather than dictating its form.

Archaeological evidence from the sixth-century BC Jules Verne 7 wreck suggests that even in shell-first construction, certain strakes were set at specific heights as a check for providing a uniform hull.[809] State level standardization in shipbuilding is mentioned during the

[807] Pomey, 'On the Use of Design in Ancient Mediterranean Ship Construction', 54-5.
[808] Basch, 'Construction privée et construction d'etat dans l'Antiquité', 35.
[809] Pomey, 'Conception et realization des navires dans l'Antiquite mediterraneenne', 64; Pomey, 'Les épaves grecques du VIe siècle av. J.-C. de la place Jules-Verne à Marseille', 151-2.

Punic Wars with the construction and outfitting of numerous vessels in a short time frame. The third-century BC Marsala wreck provides an example for how this construction was accomplished through a series of painted glyphs from the Phoenician alphabet and other symbols, suggesting preassembly of upper strakes prior to their installation on the axial timbers.[810] Several later Romano-Celtic wrecks in Mainz, Germany also include evidence that molds were installed to provide guidance and later removed after assembly was complete.[811] These examples represent exclusive state sanctioned enterprises where construction was on a limited timetable or required standardization for their use. Contemporary private shipyards did not necessarily follow these parameters and were presumably less regulated.

There is much stronger evidence that regardless of the type of shipyard, most shell-first vessels still followed simple proportions. Marcus Vitruvius Pollio in his *De architectura* specified that the arrangement of proportions relies on symmetry and dimensions based on a standard linear unit.[812] Many reconstructions of shell-based ships suggest that length-to-beam ratios hovered around the standards for later round ships (1:3) and longships (1:7-8). Overall proportions were determined by a linear module, such as the keel length, creating "rules of thumb" during construction.[813] Spaces between mortise and tenon joints were calculated based on ratios and the width of the mortise depended on dimensions of the plank and overall hull size.[814] Analysis from the Kyrenia shipwreck indicates that ratios were used to establish the

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810 Frost et al., *Lilybaeum*, 218-9; 235-6.
811 Bockius, *Die spätrömischen schiffswracks aus Mainz*, 193-7; Bockius, 'Markings and Pegs: Clues to Geometrical Procedures of Roman Naval Architecture?', 85-8.
812 Vitruvius Pollio, *The Ten Books on Architecture*, 13-14.
813 McGrail, 'How Were Vessels Designed before the Late-Medieval Period?', 126.
814 Pomey, Kahanov, and Rieth, 'On the Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, problems, and future research', 296

proportions for the vessel.[815] Similarly, the Romano-Celtic ships from northwestern Europe, including the Mainz wrecks, St. Peters Port, and Barland's Farm indicate a specific linear unit was employed for their construction.[816]

Envisioning Late Medieval Ships (AD 1000-1400)

Shipbuilding in the eastern Mediterranean continued to follow the practice of proportions based on a standard linear unit and later incorporated the use of molds for predicting the shape of key frames during hull assembly. The AD eleventh-century Serçe Limanı wreck currently represents the best example for the early use of this system in an exclusively frame-based hull, although it appears that the methodology was developed during the shell-to-frame transition in vessels that still used plank edge-joinery.[817] Shipbuilders constructing Serçe Limanı relied on a standard unit of 32 cm (Serçe Limanı (SL) feet), which is relatively close to the contemporary Byzantine foot (31.23 cm).[818] The use of this measurement is applied in multiples to dictate the length of the keel, beam, and distance between the endposts. It was also used in determining the eventual height of the sides and presumably was drawn on the ground to create the overall midship design.

Analysis of individual floor timbers suggests that key floors were predesigned based on the use of an adjustable breadth mold and rising tablet (figure 68). The breadth mold provided the profile for half the length of an L-shape floor timber, including the midships flat (10 SL ft) and the curved arm. Markings on the breadth mold coincided with the width of the dual master

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[815] Steffy, 'Seldom discussed features of ancient and medieval ship construction', 168.
[816] Rule and Monaghan, *A Gallo-Roman Trading Vessel from Guernsey: The excavation and recovery of a third century shipwreck*, 29-30; McGrail, 'How Were Vessels Designed before the Late-Medieval Period?', 127-8; Nayling and McGrail, *The Barland's Farm Romano-Celtic Boat*, 198-9; Bockius, 'Markings and Pegs: Clues to Geometrical Procedures of Roman Naval Architecture?', 76.
[817] Harpster, 'Designing the 9th-Century-AD Vessel from Bozburun, Turkey', 302-10
[818] Steffy, 'Construction and Analysis of the Vessel', 154.

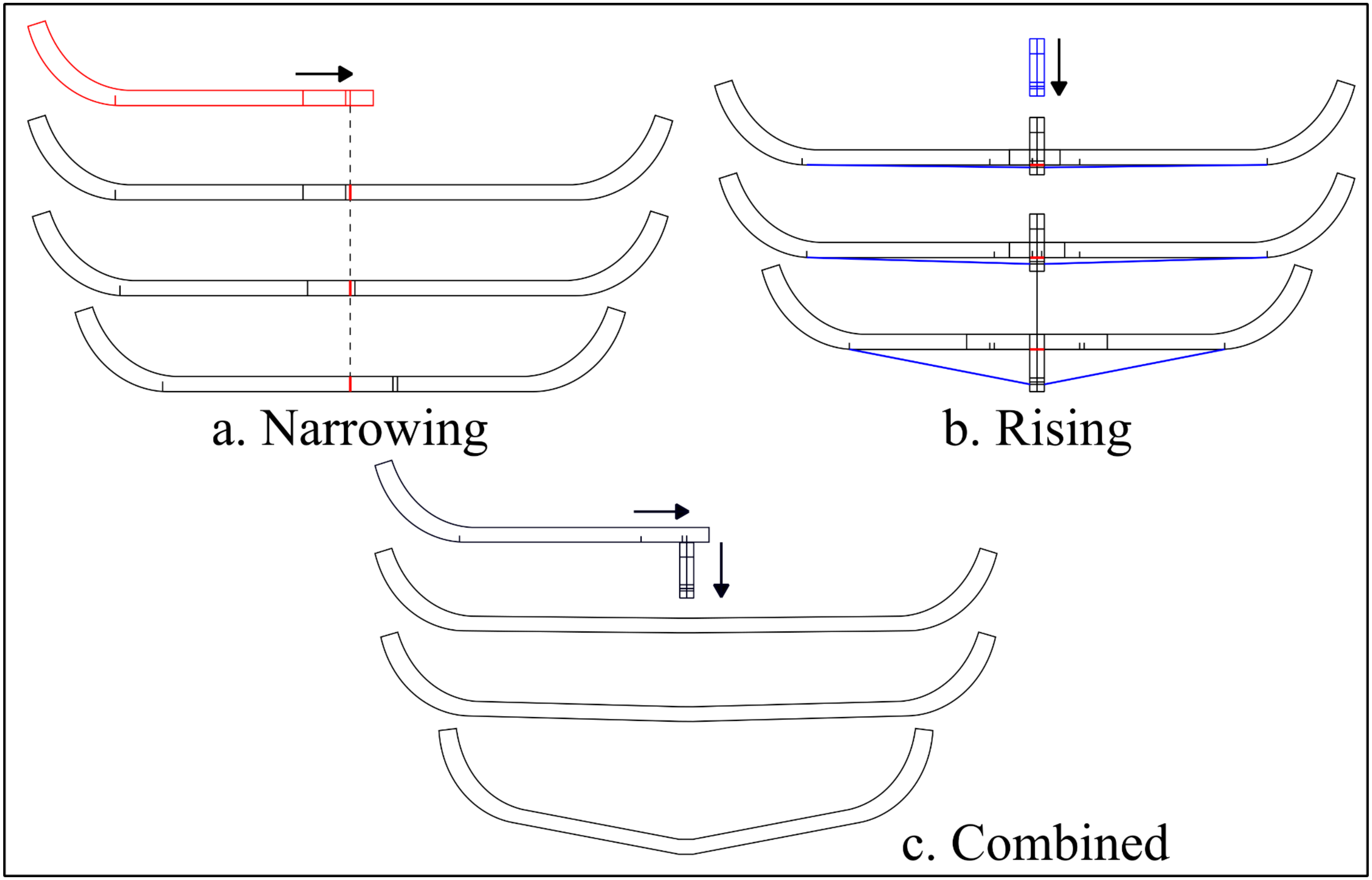

Figure 68   Predetermining the shapes of dual master frames, intermediate frames, and tail frames with a breadth mold (a) and rising tablet (b) and how these are combined to create the final shape (c). (after Harpster, 'Designing the 11th-century-AD vessel', 45, fig. 2)

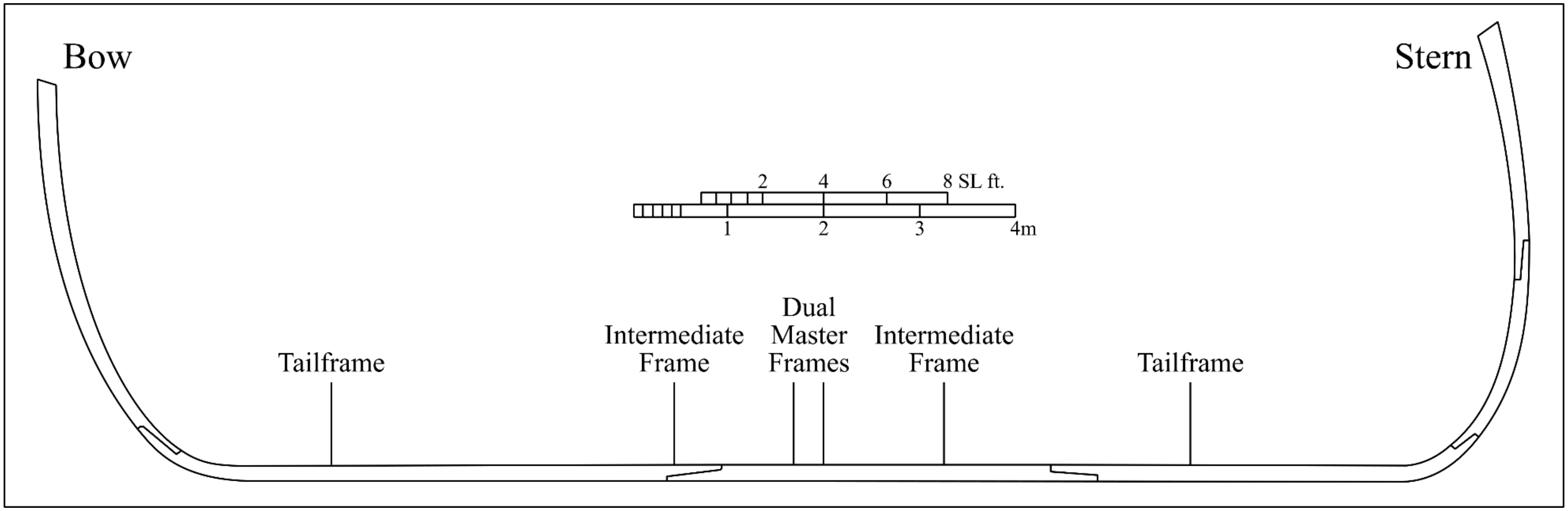

Figure 69   Predesigned frames positions on Serçe Limanı's axial timbers. (after Steffy, 'Construction and Analysis of the Vessel', 155, fig. 10-2)

frames, a pair of intermediate frames, and tailframes near the endposts. Intermediate frames were important for dictating the confines of the "flat" amidships and the beginning of the rising. Tailframes represented the terminal ends of the predesigned hull that helped to define its longitudinal curves and kept a wide profile. A rising tablet was employed with divisions (such as one-sixteenth or three-fourths of the SL ft) that marked the additional amount added to the key floor timbers to increase the deadrise toward the ends of the vessel.[819]

Most of the central floor timbers had a slight amount of deadrise near the keel and the rising did not begin until the intermediate frames. Once the key frames were cut, their positioning on the hull was also dictated by proportions based on the midships flat. The dual master frames were set at amidships, one occupied the direct center of the keel and the other positioned 1 SL ft forward toward the bow (figure 69). Intermediate frames were positioned 5 SL ft from the further dual master frame from their location, while the tail frames were positioned at different distances. The bow tailframe was placed 15 SL ft forward, while the aft tail frame was 12.5 SL ft aft, each positioned based on their distance from the nearest master frame.[820] The remainder of design relied on battens or ribbands (wooden strips) bent around the erected frames. Battens were used to project the design for the rest of the floor timbers and futtocks during the remainder of the assembly. These indicated how the planking curved into the rabbets at the endposts and defined the outside beveling of each frame station.[821] This system was already part of the standard practices of other Byzantine shipbuilders who still relied on edge-joined planking. The methodology employed for constructing the Serçe Limanı hull must have also been widespread, as some evidence from Marsala A testifies.

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[819] Harpster, 'Designing the 11th-century-AD vessel from Serçe Limanı, Turkey', 45-7
[820] Ibid., 47-50.
[821] Steffy, 'Construction and Analysis of the Vessel', 160-1.

Marsala A shares commonalities with Serçe Limanı, as both ships appear to utilize the Byzantine foot in their construction, rely on a dual master frame placed amidship, and have alternating L-shaped floor timbers for the framing. Reconstruction of the limited archaeological remains of the Marsala A wreck does not confirm the use of intermediate frames in the initial construction sequence. In fact, they may have been absent because all framing on Marsala A is relatively square and utilized a single breadth mold.[822] None of the surviving floor timbers suggest the use of a rising tablet to create a foot for the entry or a run toward the after end of the vessel. There is instead minor deadrise from the master frames in either direction that becomes more prominent beyond the tailframes (the 10th frame from either master frame), frames which are positioned on the curving endposts.[823] The same mold also provided the angle for the floor timbers positioned on each endpost.

Marsala A's builders presumably predesigned the master frames and tailframes, while relying on battens to guide the rest of construction. Other frames may have been predesigned, but compared to Serçe Limanı, it is difficult to distinguish since Marsala A's floor timbers have a standard dimension and predictable shape throughout.[824] The lack of other hull remains from this period or associated finds west of Sicily makes it difficult to explain overall changes in shipbuilding. Table 11 presents the available archaeological material from this period related to the key frame assemblies of the hulls. Both Serçe Limanı and Marsala A share a frame-based approach within the same cultural sphere, albeit with lingering aspects of earlier shell-based techniques. On the other hand, the differences in their design indicate convergent practices, where shipbuilders were attempting to answer the same problems with different solutions.

[822] Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 183-4
[823] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 299, fig. 4
[824] Bonino, 'Appunti sul relitto medioevale "A" di Marsala (Lido Signorino)', 184, fig. 4

Table 11 General measurements and frame design

Shipwreck	*Date*	*LOA (m)*	*Beam (m)*	*Depth (m)*	*Ratio*	*Framing Design Method*	*Master Frame Location*	*Cross-Section Amidships*
(1) Serçe Limanı	1025	15.66	5.2	2.4	1 : 3.01	Dual master frame	Center over keel	Flat floor-timbers, hard chine 72° flair outward
(2) Marsala A	1050s	18	5.8	2.9	1 : 3.1	Dual master frame	Center over keel	Slight deadrise, round bilge
(3) Culip VI	1290-1300	18.8	4.8	2.2	1 : 3.92	Dual master frame -Central and bilge markings -Roman Numerals on floors	74 cm Forward from central keel - 7 / 16th bow to forward dual frame	Flat floor-timbers, round bilge
(4) Boccalama B	1300-1325	38	5		1 : 7.6	Single master frame	19.6 m from stern	Flat floor-timbers, round bilge
(5) Les Sorres X	1390s	9.5	1.9	0.9	1 : 5	Dual master frame -Central and bilge markings	62 cm Forward from central keel -3 / 16 from bow to forward dual frame	Flat floor-timbers, slight round bilge
(6) Marinières	1420-1430	25	8.45	2.07	1 : 3	Dual master frame -canted aft frames 5-9° substitute for ramo	1/3 aft from front end of keel	Flat floor-timbers, round bilge
(7) Contarina I	1460s	20.98	5.2	2.46	1 : 4.05	Single master frame (no evidence of rising at endposts)	21.5 cm forward from center of keel (or 1 frame station forward)	Flat floor-timbers, round bilge
(8) Mariposa B	1500-1525	16				Dual master frame	Center of keel (?)	Slight deadrise, round bilge
(9) Lake Garda	1509	39.6	4.9		1 : 8.08	Single master frame	Center of keel	Flat floor-timbers, round bilge
(10) Villefranche	1516	46.45	14	4.4	1 : 3.32	Single master frame -Futtocks attached to floor-timbers inward toward W59 -Rise/Narrow based on circles diam.	5/8ths forward from end of keel	Wineglass - deadrise 35 cm
(11) Mortella III	1527	36.8	10.5	6.15	1 : 3.5	Single master frame - Rise/Narrow based on 5.8 m circle radius	Center over keel	Half-circle - deadrise 33 cm
(12) Sardinaux	1500-1550 (1540s?)	10-12	~1.8		1 : 5	Dual master frame	Center over keel	Flat floor-timbers, round bilge

Table 11 Continued

Shipwreck	*Date*	*LOA (m)*	*Beam (m)*	*Depth (m)*	*Ratio*	*Framing Design Method*	*Master Frame Location*	*Cross-Section Amidships*
(13) West Turtle Shoals	1550-1600					Dual master frame	Forward of center (?)	Flat floor-timbers, round bilge (?)
(14) Yassi Ada 3	1572+	21.2	6	1.2	1 : 3.53	Dual master frame	71.5 cm forward from center of ship (or 2 frame stations forward of center)	Flat floor-timbers, round bilge
(15) Calvi 1	1575	23.4	7.8	2.2	1 : 3	Presumed master frame(s) -Rise/Narrow based on +2.81 m circle radius(?)	Unknown	Wineglass - deadrise 39 cm
(16) *Kadırga*	1575-1625	39.57	5.72	1.34	1 : 6.92	Dual master frame	Center of keel (?)	Flat floor-timbers (slight deadrise), round bilge
(17) Cap Lardier 1	1575-1600	20 ± 2				Single master frame (?) -Futtocks attached to floor-timbers inward to master frame	Center overall length	Flat floor-timbers, round bilge
(18) Agropoli	1575-1625	23	5.75		~ 1 : 4	Butted Dual master frames	10.35 m from bow	Flat floor-timbers, round bilge

(1) Matthews and Steffy, 'The Hull Remains'; (2) Ferroni and Meucci, 'I due relitti Arabo-Normanni de Marsala'; (3) Rieth, 'L'Arquitectura Naval';, (4) Romanelli, *La Galea Ritrovata*; (5) Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc'; (6) Daeffler, 'L'Epave des Marinières'; (7) Occioni-Bonaffons, 'Sulla scoperta di due barche'; (8) Gavini, 'Osservazioni sulla circolazione dei manufatti ceramici'; (9) Capulli, *Le navi della Serenissima*; (10) Guérout, 'Le navire Génois de Villefranche'; (11) Cazenave de la Roche, *The Mortella III Wreck*; (12) Joncheray, 'Un navire de commerce de la fin du XVII[e] siècle; (13) Russo, *West Turtle Shoals Wreck (8MO142)*; (14) Labbe, 'A Preliminary Reconstruction'; (15) Villié, 'L'épave Calvi 1'; (16) Arcak, '*Kadırga*'; (17) Joncheray, 'L'épave dite «des ardoises», au cap Lardier'; (18) Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli'

Most archaeological remains of ships that predate the beginning of the fourteenth century are too fragmentary to learn about the design concept or to identify a separate building tradition. Limited excavation of Rhodes 4's stern suggests that eastern Mediterranean shipbuilders continued to practice the methodology seen on the Serçe Limanı hull. In fact, the shape of Rhodes 4's hull and increased molded dimension of consecutive aft frames support the use of a breadth mold and rising tablet.[825] Rhodes 4 also includes clues that shipbuilders began to employ a greater overlap between floor timbers and futtocks. There is a possible reliance for scarfs at most frame stations that were only present on key frames for Serçe Limanı, but the decision not to dismantle any exposed portion of Rhodes 4's ceiling prevented verification.[826] Although it is not out of the realm of possibility that Rhodes 4's builders followed the earlier practice of diagonally butting individual frame elements, the increase in the overall scantling dimensions for the hull may have required further control between frame stations by designing and pre-assembling each frame before its place next on the keel.

Other ships from this era, including Marsala B, Precenicco, and Rhodes 1 represent a bottom-based building methodology taking place in the eastern Mediterranean. All three vessels have no keel or a keel plank that is only slightly thicker then adjacent planking. Marsala B and Precenicco are much smaller vessels and share similar hull form to Serçe Limanı (relatively flat amidships with the sides angled outward).[827] Marsala B is very fragmentary, while Precenicco is well preserved and suggests a rivercraft that could operate either in the lagoon or temporarily along the coast of the upper Adriatic. These two vessels seem to support the previous hull

[825] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 486-8, figs. 10, 13-14.
[826] Rieth et al., 'The Rhodes 4 Shipwreck: Final report', 18-19.
[827] Ferroni and Meucci, 'I due relitti arabo-normanni de Marsala', 293; 297; Capulli, 'Il relitto di Precenicco (XI-XIII d.C.): Lettura dello scafo e osservazioni sull'uso dei madieri asimmetrici alternati', 80, fig. 4.

classification schemes that place the designs of Serçe Limanı and earlier ships as originating from a riverine environment. Rhodes 1 appears to fit this same group, except that its round bilge might be a later development to make the ship sail better in coastal areas. Unlike to the axial-built ships that take up much of the remainder of this discussion, the bottom-based vessels were constructed by first laying the bottom planking down. Some version of a breadth mold was used to control the narrowing, while none of the watercraft indicate using a rising tablet. The slender long shape of Rhodes 1 may suggest a longship type that was built in a bottom-based manner rather than relying on a true keel.[828]

Some of the earliest documentary evidence which mentions the design process were construction estimates itemizing materials and costs for completing ships. When war broke out between Charles I of Anjou and Genoa in 1272, shipbuilding estimates for personnel and horse transports were compiled by master carpenter Gartia of Naples. Gartia was mainly concerned with costs and only briefly explained each timber's use in the ship. He noted that timbers should be bought to make molds and battens during construction.[829] Another Angevin document from 1275 consists of a list of measurements for the key timbers from a red galley of Provence to be copied by Neapolitan shipbuilders when creating a fleet for invasion of the Dalmatian coast.

Compared to the 1272 construction estimate, the 1275 red galley document is significantly more detailed, naming most timbers and providing scantlings. Design conceptualization is alluded to when it mentions that the framing timbers were square in dimension and that there are *corve de sexto* (molded frames) for 95 frames situated along the center of the hull that were predesigned prior to their assembly. Frame stations beyond the

[828] Koutsouflakis, 'Three Medieval Shipwrecks in the Commerical Port of Rhodes', 480-1.
[829] Fourquin, 'A Medieval Shipbuilding Estimate (C. 1273)', 23-4; Fourquin, 'Un devis de construction navale de *ca.* 1273', 266-7.

molded frames were designated differently in the document and presumably did not use a mold but were fashioned based on battens extending fore and aft to the endposts.[830] Slightly later documents on galley construction from Narbonne between 1318-20 also include costs for procuring timber and specific nails to assemble the master mold.[831] The terms *galbe*, *mensura*, and *modulus* (mold) are interpreted as regarding a full-size mold to define the hull of a single decked vessel.[832]

Both the Angevin and Narbonne documents discuss the use of molds for designing longships in the western Mediterranean. Even with the lack of supplemental archaeological information from this area, it suggests that the predesign practices were already standardized throughout the region. Culip VI is the next archaeological example with evidence for the conception of the hull, the surviving floor timbers suggest a geometric progression determined the narrowing and rising (figure 70).[833] A smaller coastal round ship built along the northwestern shoreline around Catalonia or Provence, the ship exhibits design elements reminiscent of those seen on Serçe Limanı approximately three centuries earlier. Culip VI relied on a mold to produce dual master frames with one floor timber placed on the center of the keel and another placed 74 cm forward toward the bow. Every other frame station beyond the master frames was predesigned and narrowed sequentially to the tailframe. An intermediate frame placed one-third of the distance aft of the bow represented the beginning of the rising of consecutive floor timbers toward the stem (figure 71).[834]

[830] Pryor, 'The Galleys of Charles I of Anjou, King of Sicily, ca. 1269-84', 39, 46-7
[831] Sosson, 'Un compte inédit de construction de galères à Narbonne (1318–1320)', 93, 95, 208, 268
[832] Rieth, 'From Words to Technical Practices: moulds and naval architecture in the middle ages', 354.
[833] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 159, 165.
[834] Ibid., 167-9.

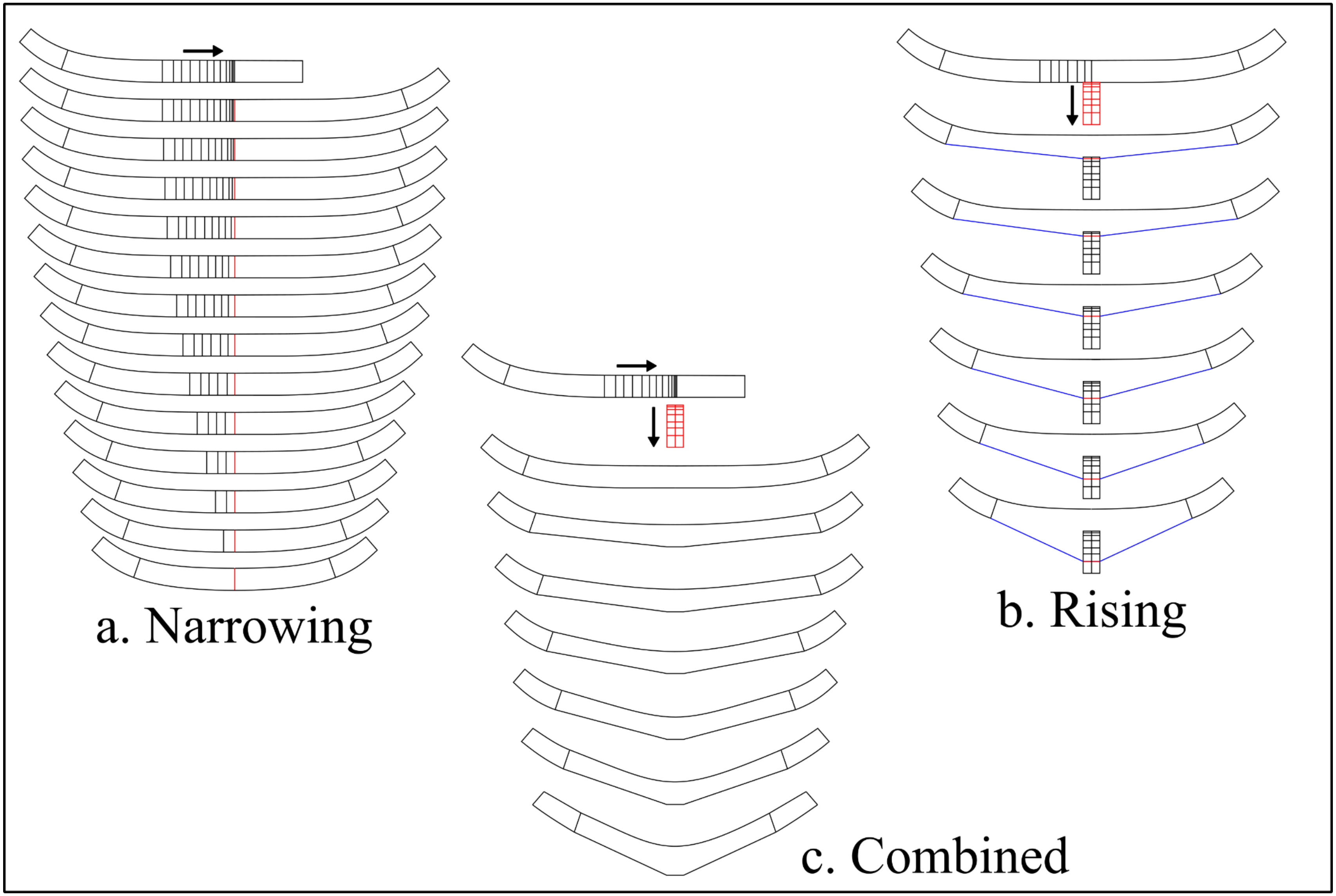

Figure 70 Mold and rising methods applied to the forward frames from Culip VI. (after Rieth, 'L'Arquitectura Naval', 168, fig. 84)

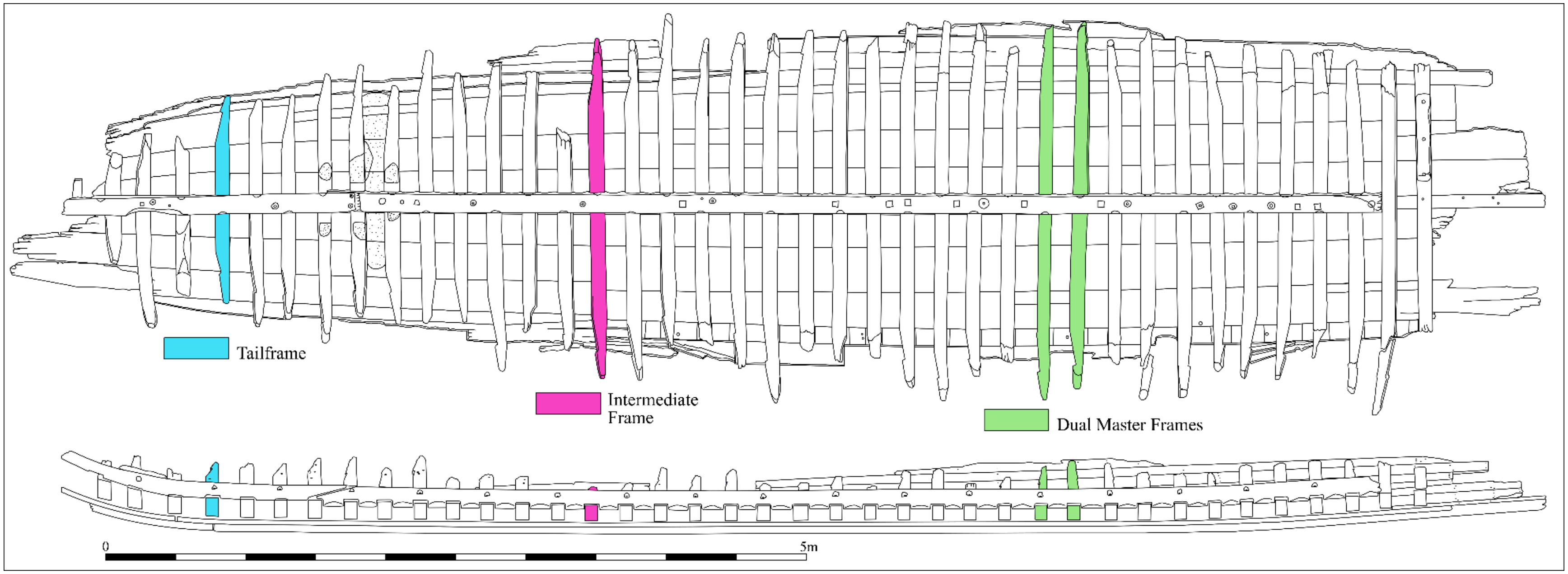

Figure 71   Site plan of Culip VI showing the locations of the key design frames. (after Rieth, 'L'Arquitectura Naval', 140)

Only the forward half of Culip VI survives. Its bow tailframe was identified positioned over the butting of the stem and keel. Many of the floor timbers included a central and turn of the bilge mark, presumably used during the molding process to draw the final shape. Several floor timbers also had incised roman numerals that were likely part of the assembly process, predetermining where each timber fit on the keel when it was being fashioned elsewhere in the shipyard.[835] Culip VI shares elements from Serçe Limanı with its similar predesign system using key frame stations determined with a master mold and rising tablet.

Serçe Limanı's builders connected the L-shaped floor timbers to futtocks at the master frame with scarfs, while Culip VI's shipbuilders used hook-scarfs at every frame station up to the tailframe. The latter system aligned floor timbers with futtocks for fasteners that connected frames together prior to their placement on the keel. Culip VI also shares elements with Marsala A by keeping the square dimensions for each floor timber that allowed predesigned portion to extend nearly to the ends of the hull. The predesigned frames terminate at the point where the stem begins to curve upward.[836] Tailframes on Serçe Limanı are placed further aft on the flat keel, well before the upward curve of the steeper endposts.

Analysis of the floor timbers on Culip VI suggest that two geometric progressions were employed, including the *mezzaluna* (half-circle) and/or the incremental triangle.[837] The mezzaluna involved drawing half a circle with the radius of the exact amount reduced between the master frame and tail frame (figure 72). Depending on the exact number of predesigned frames that were employed, the shipbuilder would divide the circle into an equal number of

[835] Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 287
[836] Rieth and Pujol i Hamelink, 'L'arquitectura naval', 141.
[837] Ibid., 160-1; Rieth, 'First Archaeological Evidence of the Mediterranean Moulding Ship Design Method, The Example of the Culip VI Wreck. Spain, XIIth-XIVth c.', 11.

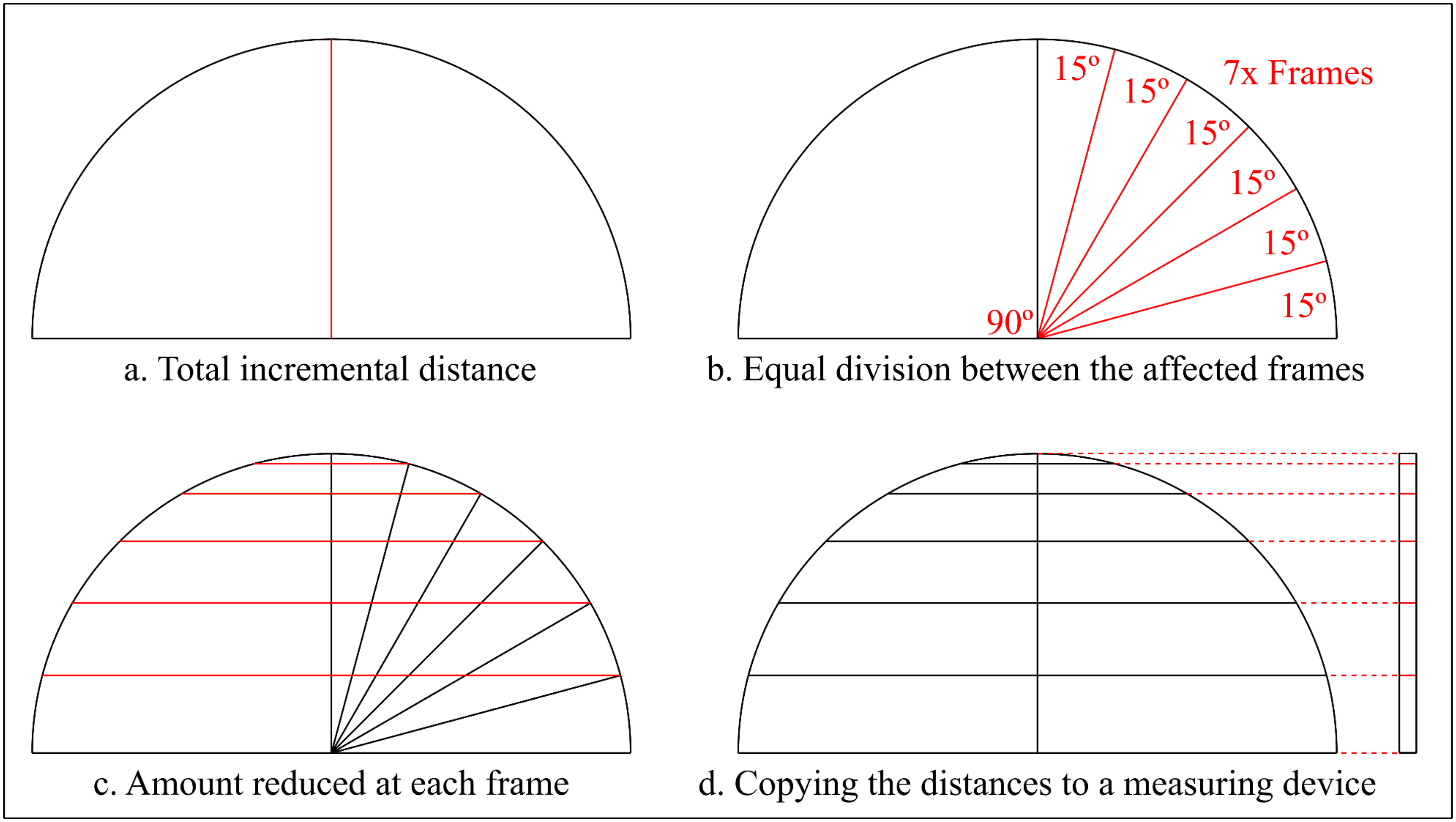

Figure 72 The steps for producing the geometric method called mezzaluna: (a) total distance to be covered, (b) dividing half the circle equally into the number of frames effected, (c) drawing the increments, (d) transcribing the increments to a measuring stick. (Author's drawing)

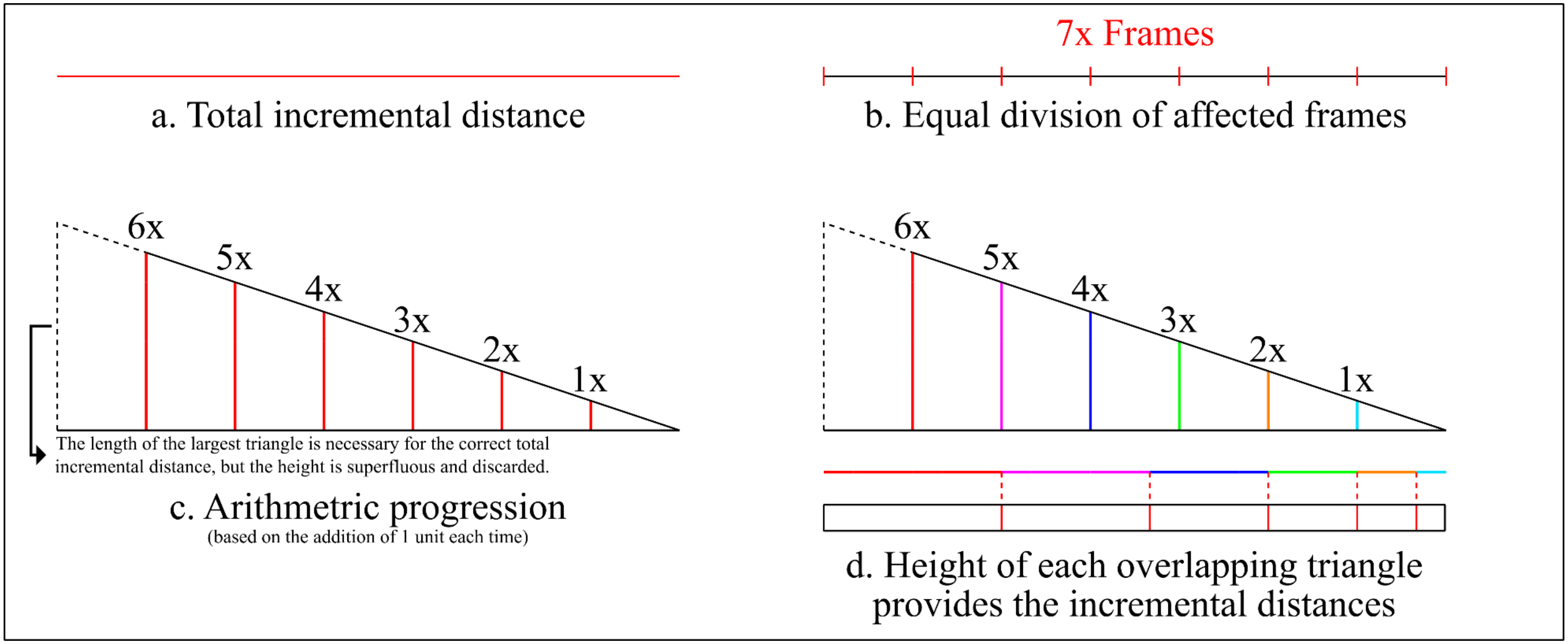

Figure 73 Steps necessary for the geometric method known as the incremental triangle, as described in the fourteenth century: (a) total distance to be covered, (b) equally divide the line into the number of frames effected, (c) use an appropriate arithmetic progression that incrementally increases for all frame stations (in this case one-third of the division between each frame was used as the unit), (d) add the heights from the first six triangles to create the necessary incremental distances. (Author's drawing)

parts. The result would be transferred to a measuring stick employed in the narrowing or rising for each floor timber.

Incremental triangles relied on an arithmetic progression based on the number of predesigned frames required. The length of the reduction was drawn horizontally and divided equally by the number of frames affected. Heights from one end of the line followed an arithmetic progression at each division creating overlapping right triangles. Offsets were collected from the height of each triangle and put on a measuring stick (figure 73).[838] Venetian documents describe their use as early as the first half of the fourteenth century.[839] Geometric progressions was not a new phenomenon, as it originates within the earliest civilizations of Mesopotamia and often cited as applied to column construction in antiquity.[840]

Comparisons of contemporary archaeological hulls with Culip VI is difficult due to limited reporting. Camarina does not include enough information about the amidships area to suggest the sort of master frame(s) involved. It clearly utilized narrowing from the center of the hull and the profile of floor timbers near the bow suggest a reduction in height rather than the rising typically seen on other ships.[841] Less is published about Boccalama B, except that it utilized a single master frame with double futtocks rather than the dual master frames seen on most earlier examples. Boccalama B's master frame was identified 19.6 m forward from the stern, which would place it further forward than the center of the hull's overall length.[842]

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[838] Castro, 'Rising and Narrowing: 16th-Century Geometric Algorithms used to Design the Bottom of Ships in Portugal', 150-2
[839] Bondioli, 'The libro di navigar. A new treatise on Venetian shipbuilding from the 14th century', 219.
[840] Friberg, *A Remarkable Collection of Babylonian Mathmatical Texts: Manuscript in the Schøyen Collection, Cuneiform Texts I*, 152-3; Jones, 'Ancient Greek and Roman Architects' Approach to Curvature - The Corinthian Capital, Entasis and Amphitheaters', 99.
[841] Stefano, 'La galea medievale di Camarina. Notizie preliminari', 89, fig. 4
[842] D'Agostino and Medas, 'Interventi per la difesa delle morfologie sommerse in erosione. Il sito archeologico di San Marco in Boccalama e i relitti medievali', 10

By comparison, the much smaller Les Sorres X follows Culip VI design with dual master frames. One master frame is positioned on the center of the keel, while the other master frame is positioned 62 cm forward of the first.[843] The linear unit between the dual master frames on either vessel is close to the contemporary units of measure used in the areas where each ship was presumed built. The 74 cm between Culip VI's dual master frames is similar to the Genoese *goa* (74.4 cm)[844], while the 62 cm distance used on Les Sorres X is slightly shorter than the Catalan *gúe* (64.79 cm).[845] Floor timbers on Les Sorres X also include central and turn of the bilge markings, suggesting a molding method similar to that for Culip VI.[846]

Michael of Rhodes and the *Zibaldones* (Fifteenth-Century Documents)

Except for Camarina and Boccalama B, most of this discussion on the conception and design of earlier archaeological remains is based on single-decked round ships. There are relatively few documentary sources that refer to the construction of these vessels in comparison to the plethora of sources on longships that increases by the beginning of the fifteenth century. The earliest treatise on this topic is written by Michael of Rhodes, compiled around 1435 as a compilation of miscellaneous texts about the construction, rigging, and other associated elements for three types of longships (with a few remarks on two round ships). Michael was evidently more of a transcriber than a professional: his knowledge of shipbuilding is limited and the supplemental drawings suggest someone unfamiliar with the concepts depicted.[847] The

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[843] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 36; Pujol i Hamelink, 'Medieval shipbuilding in Catalonia, Spain (13th-15th centuries): One principle, different processes', 289-90
[844] Genoese shipbuilding unit of measure included the *palmo* (24.8 cm); 3 *palmi* = 1 *goa* or *gua* (74.4 cm); 10 *palmi* = 1 *canna* (2.48 m); 12 *palmi* = 1 *canella* (2.98 m)
[845] Catalan shipbuilding unit of measure mainly relied on the *palms de gúa* (21.59 cm); 3 *palms de gúa* = 1 *gúes* (64.79 cm)
[846] Pujol i Hamelink, 'Estudi descriptiu i anàlisi del buc', 37.
[847] McGee, 'The Shipbuilding Text of Michael of Rhodes', 223; 230; 240.

information Michael copied was presumably originally compiled by an administrator for the Venetian arsenal. How Michael was given access to this material remains unclear. The cataloging of measurements from existing longships may correlate with the Venetian Senate ordering in 1410-20 the preservation of galleys built by Greek master shipbuilder Theodoro Baxon after his death in 1407.[848]

The measurements listed by Michael follow a method where dimensions based on cord and/or ruler were employed and their description was given in greater lengths than necessary with the subtraction in smaller denominations.[849] For example, rather than tell his reader that the height of the hold for the Flanders galley was 7 *pié* 14 *deda* (2.74 m), Michael wrote that it was 8 *pié* (2.78 m) minus 2 *deda* (4.35 cm).[850] Many of the measures written have no clear relations to each other and seem to follow the earlier notarial style of simply listing individual timbers for documentation separate from the shipbuilder's conception.[851] Many of these measurements are also believed to be from the inside faces of components, such as the widths attributed to the frames. Both the imagery and documentation suggest that Venetian shipbuilding still followed the fundamental predesign methodology mentioned above for earlier ships.

Michael's longships include a master frame, a set of intermediate frames, and tailframes positioned prior to the beginning curvature of the endposts (figures 74 and 75).[852] Differences from previous design methods include the installation of a single master frame with duplicates on either side and the use of battens at specific height intervals from the top of the keel.

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[848] Gertwagen, 'Byzantine Shipbuilding in Fifteenth-century Venetian Crete: War Galleys and the Link to the Arsenal in Venice', 120-1.
[849] Bondioli, 'Early Shipbuilding Records and the Book of Michael of Rhodes', 256.
[850] Venetian units of measure: *dedo* (2.1733 cm); 16 *deda* = 1 *pié* (34.7735 cm); 5 *piedi* = 1 *passo* (173.8675 cm)
[851] McGee, 'The Shipbuilding Text of Michael of Rhodes', 222.
[852] Stahl, ed., *The Book of Michael of Rhodes: A Fifteenth-Century Maritime Manuscript*, 417-18, f.135-6b.

Intermediate frames still mark the beginning of the rising for the floor timbers and the 42 frame stations between amidships and the tailframe on the Flanders galley suggests either every third or sixth frame was predesigned. Either ratio could be applied and accommodate the tailframe position, which Michael mentions explicitly at the 18th frame from amidships. Frame stations beyond the tailframes were designed by the extension of the battens to the endposts and with the assistance of a *simulacrum* or wooden tree. This simulacrum is first mentioned in texts from the beginning of the previous century as a guide piece for positioning the battens, relying on the same progression scale used up to the tailframe and applied beyond it.[853]

Several contemporaneous texts were compiled after Michael's book, including the compilation written by Zorzi di Nicolò, Trombetta da Modon (1444-49), or the anonymous author of 'Ragioni antique spettanti all'arte del mare et fabriche vasselli' (1470s).[854] These subsequent manuscripts were *zibaldones* (unorganized notebooks) that covered various topics and were not necessarily all nautical in nature.[855] Analysis of these texts and the three duplicates from the beginning of the sixteenth century (1520s) variously titled 'Fabrica di galere', 'Arte de far vascelli', and 'Trattato dell'arte di fabbricar navi' either had access to the same Venetian arsenal documents first copied by Michael, slightly different texts, or possibly copied Michael's own faulty book.[856] Many of these sources provide similar descriptions for the same vessels,

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853 Bondioli, 'The Libro di navigar', 222.
854 Anderson, 'Italian Naval Architecture about 1445', 135; Rieth, 'Les illustrations d'un livre de recettes techniques d'architecture navale du millieu du XV^{e} siecle; le libro de Zorzi Trombetta de Modon', 82-3; Merwe, 'Provenance and Technical Description of the Manuscript', XLIV-XLV.
855 Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 3; McGee, 'The Shipbuilding Text of Michael of Rhodes', 233.
856 Anderson, 'Jal's 'Memoire No. 5' and the Manuscript 'Fabrica di Galere'', 160-1; Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 4-5

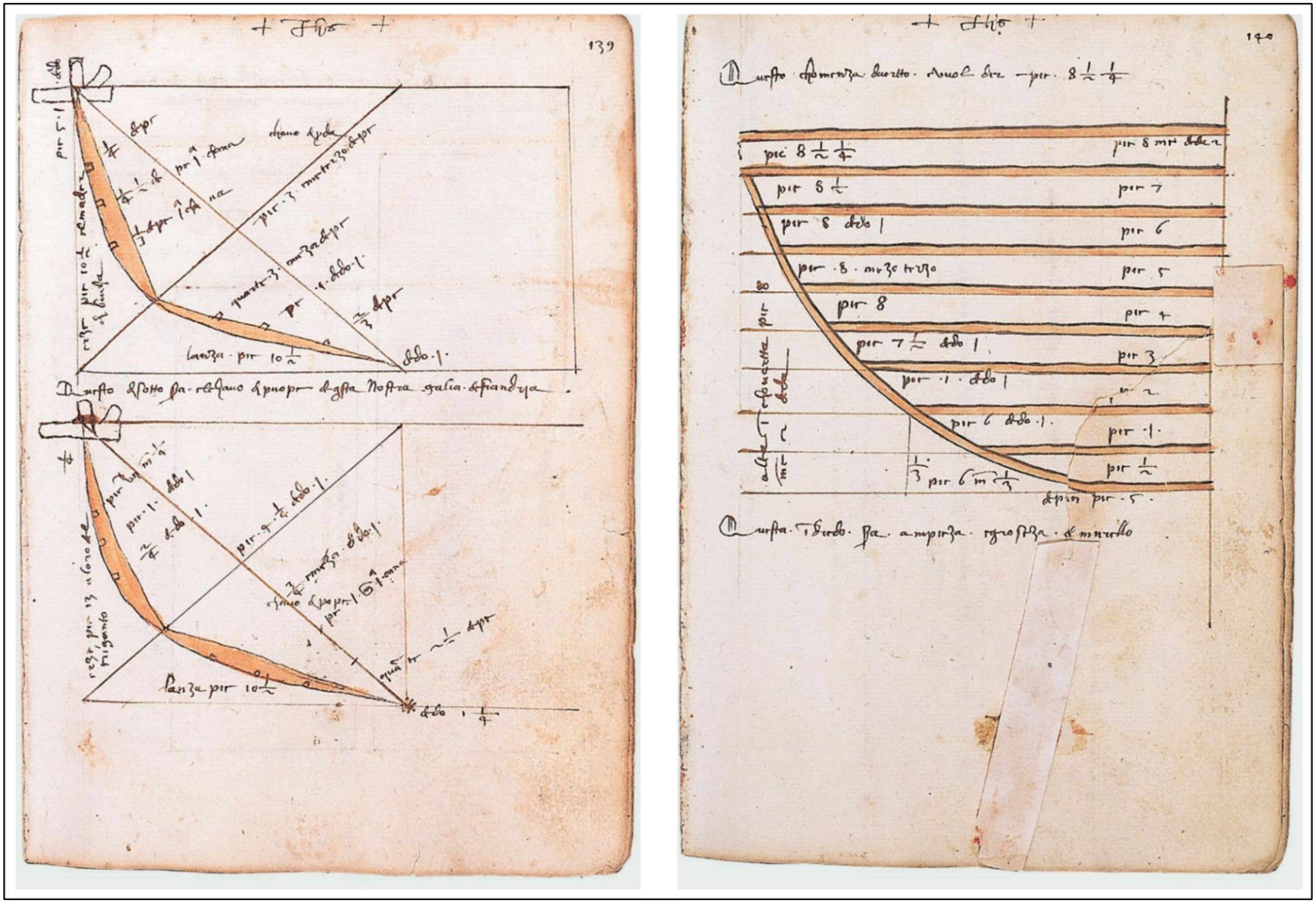

Figure 74 Two pages from Michael of Rhodes' manuscript showing the stem, sternpost, and half-breadth for the Flanders galley (note: the colored sections are a misrepresentation by Michael that the lines represent actual wood). (McGee, ed., The Book of Michael of Rhodes, Vol. 1, 311 and 313, f.139b and f.140b; Reprinted courtsey of The MIT Press)

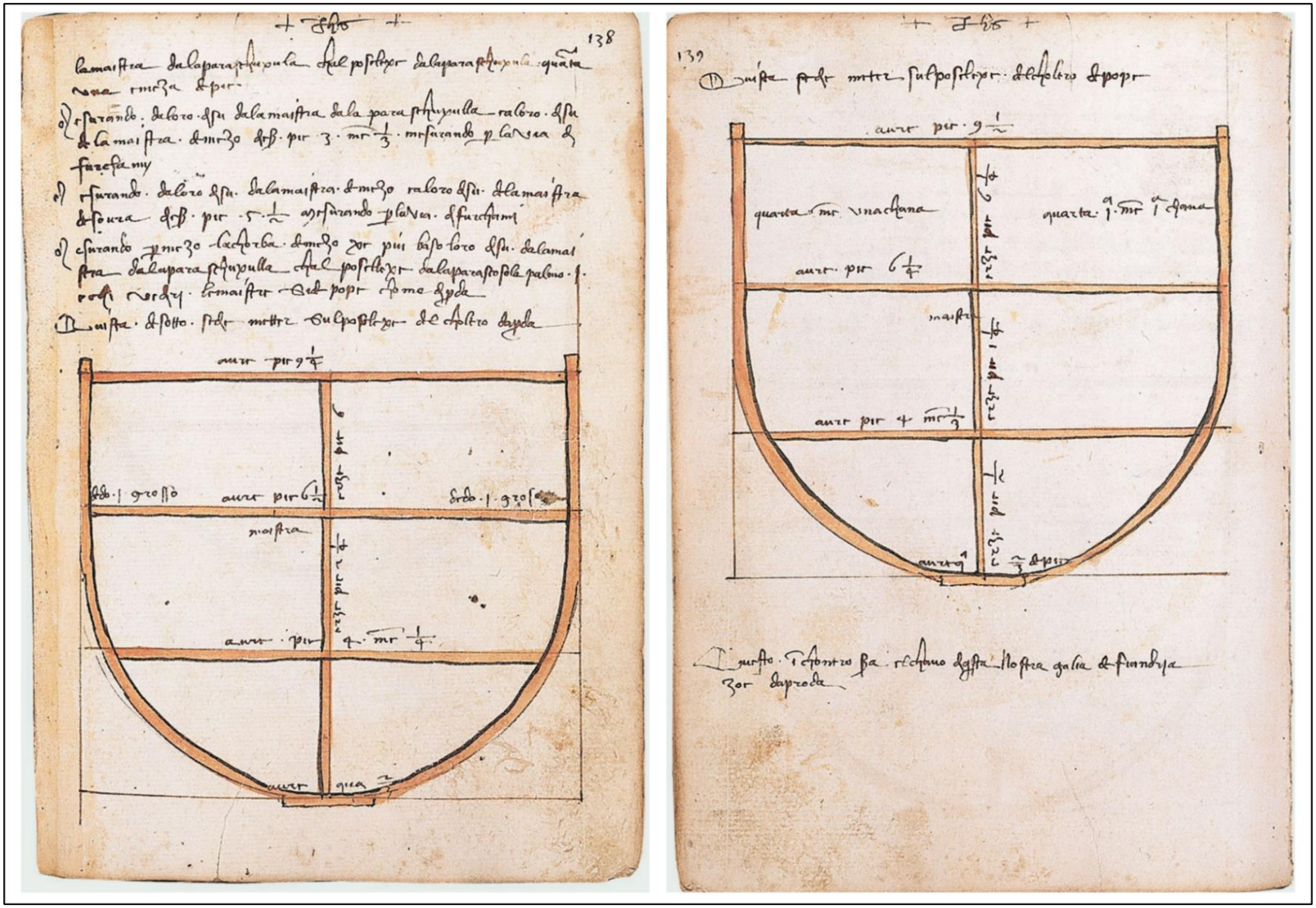

Figure 75   Two pages from Michael of Rhodes' manuscript showing the tailframes and the offsets for placing the ribbands to guide the rest of shipbuilding (note: the colored in sections are a misrepresentation by Michael that the lines represent the actual wood). *(McGee, ed., The Book of Michael of Rhodes, Vol. 1, 309-310, f.138b-f.139a*; Reprinted courtsey of The MIT Press)

Table 12 Longship scantlings from manuscripts in original measurements (AD 1300 – 1550)

Source	*Anjou 1275*[a]	*Michael of Rhodes (ca. 1435)*[b]		*Trombetta (1444-1449)*[c]		*Zulle-Fausto (ca. 1546)*[d]		
Ship	*Red galley*	*Flanders galley*	*Romania galley*	*29-Banks Light galley*	*26-Bank Fusta*	*Quinquereme*	*Light galley*	*Provveditor Great galley*
Measurements Derived by[e]	List	List	List	List	List	List	List	List
Overall Length (on deck)	150 pal	118 ft 8 de	118 ft	112 ft 8 de	95 ft	140 ft 14.5 de	120 ft 12 de	122 ft 2.5 de
Keel	107 pal	98 ft			23 ft			
Stem (Height x Rake)[f]	11 pal 4 dit. x ?	10.5 x 10.5 ft	9 ft x 10 ft 5 de (4.8)	6 ft 4 de x 9 ft 12 de	5 ft x 7 ft 8 de	7 ft 2 de x 9 ft 2 de	6 ft 9 (1/7) de x ?	6 ft 8⅔ de x ?
Keel Fore Scarf Height[g]		1 de				10 de		
Sternpost (Height x Rake)[f]	13 pal 8 dit. x ?	13 x 10.5 ft	12 ft x 10 ft 5 de (4.8)	8 ft 8 de x 9 ft 12 de	7 ft x 8 ft 8 de	10 ft 10 de x 7 ft 4 de	8 ft 10 de x ?	8 ft 13.5 de x ?
Keel Aft Scarf Height[g]		1.25 de	4 de	5 de (4.8)	7 de	10 de		
Floor		10 ft	9 ft 14 de	7 ft 8 de	7 ft	4 ft 8 de		
Deadrise		5 de (4.8)	9 de					
Breadth	17 pal 8 dit.	17.5 ft		13 ft 4 de	11 ft	8 ft 9 de	15 ft 4 de	16 ft
Deck Height	7 pal 8 dit.	7 ft 14 de	7 ft 11 de (10.72)	5 ft 4 de	4 ft 8 de	6 ft 1 de	5 ft 12 de	5 ft 2⅔ de
# Molded Frames	2x 47	2x 42	2x 41	2x 44	2x 39	30 bow, 50 stern	30 bow, 50 stern	30 bow, 50 stern
Amidships Frames	1?	4	5	4	2	5	5	5
Intermediate Frames		18th	18th				15th bow, 25th aft	
Tailframe to fiero/ferir[h] (bow/stern)		6 ft 12 de / 8 ft 12 de	7 ft 8 de / 8 ft 8 de	19 ft 12 de / 22ft 12 de	17 ft / 19 ft 8 de	19 ft 4 de / 33 ft 7 de	16 ft 14 de / 28 ft 11 (6/7) de	17 ft 11 (2/7)(1/2) de / 29 ft 2 (4/7) de
Narrowing (bow/stern)						3 ft / 3 ft 2.5 de	widths provided[i]	widths provided[i]
Rising (bow / stern)							heights provided[i]	heights provided[i]

Measurements for Anjou galley are all in palm measurements (1 dito (2.07 cm); 12 dita = 1 *palmo* (24.8 cm)), while all others are Venetian feet (*dedo* (2.1733 cm); 16 *deda* = 1 *pié* (34.7735 cm)); (a) Pryor, 'The Galleys of Charles I', 38-41; (b) McGee, ed., *The Book of Michael of Rhodes* Vol. 2, 417-433, 443-452; (c) Anderson, 'Italian Naval Architecture about 1445', 138-147; (e) This row is lists whether the measurements are correlated by proportions based off a specific scantling or simply an unrelated list.; (f) Height of the endpost measurements are often based on the location of where the main wale attaches with differences in the additional length of this piece beyond that height.; (g) This is the height from the ground, the keel was raked during this period; (h) This measurement is interpreted differently over time, its usage may be the distance between the final fore/aft tailframe to the last floor-timber set on either endpost.; (i) Only the widths of key frames are provided and not an exact amount, for calculations based on these measurements, see Campana, 'The Immortal Fausto'

Table 13 Longship scantlings from manuscripts in original measurements (AD 1550 - 1700)

Source	*Pre' Teodoro di Niccolò (1576)*[a]			*Drachio (1593)*[b]	*Crescentio (1602)*[c]		*Furttenbach (1629)*[d]	Un Manuel *(1691)*[e]
Ship	*Great galley*	*Great galley*	*Oared Galleon*	*24-Bench Common galley*	*26-Bank galley*	*Galleass*	*Great galley*	*26-bank Senzille galley*
Measurements Derived by[f]	Beam	Beam	Floor	Beam	List	List	List/Overall Deck Length	Overall Deck Length
Overall Length (on deck)	138 ft	138 ft	100 ft	125 ft	174 pal	186 pal	190 pal	144 pied
Keel				100 ft?	123 pal			121 pied 1 pou 1 lig
Stem (Height x Rake)[g]	13 ft x ?	13 ft x 13 ft	9 ft x 10 ft	7 ft 8 de x 12 ft	10 pal. 8 dit x 21 pal	7 pal 8 dit x 22 pal	12 pal. x 26 pal	8 ft 8 pou 4 lig 8 sec x 13 pied 1 pou 1.5 lig
Keel Fore Scarf Height[h]				6 de				
Sternpost (Height x Rake)[g]	17 ft 8 de x ?	17 ft 8 de x 10 ft 8 de	11 ft x 7 ft	11 ft x 11 ft	13 pal. x 21 pal	21 pal 9 dit x 22 pal	18 pal x 26 pal	14 pied 4 pou 9 lig 6 sec x 9 pied 9 pou 9 lig
Keel Aft Scarf Height[h]	8 de			8 de				
Floor	12 ft	11 ft 8 de	7 ft 4 de	7ft 8de	11 pal	15 pal	12 pal 9 dit	8 ft 3 pou
Deadrise								
Trepie	19 ft	18 ft	14 ft 11 de (10.66)	12 ft 3 de				
Siepie	22 ft	21 ft	18 ft 11 de (10.66)	14 ft 1 de				
Bocca/Breadth	23 ft	22 ft 12 de	21 ft (2nd deck 16 ft 8 de)	15 ft	21 pal	30 pal	25 pal. 4 dit	18 pied
Deck Height	9 ft	9 ft	6 ft 8 de (2nd deck 7 ft 8 de)	5 ft	7 pal 3 dit	12 pal	8 pal 4 dit	5 pied 9 pou 7 lig 2 sec
# Molded Frames	40 bow, 45 aft	40 bow, 45 aft	2 x 30	30 bow, 50 aft	2x 45	80 overall	45 bow, 60 stern	2x 44
Amidships Frames	1?	1	5	2	3		2	2
Interim Frames	15th	20th bow, 15th aft	5th	15th bow, 25th aft	10th		25th	23rd
Tailframe to fiero/ferir (bow/stern)[i]	12 ft 8 de / 24 ft 11 de (10.67)	20 ft 8 de / 24 ft	19 ft / 24 ft					

Table 13 Continued

Source	*Pre' Teodoro di Niccolò (1576)*[a]			*Drachio (1593)*[b]	*Crescentio (1602)*[c]		*Furttenbach (1629)*[d]	Un Manuel *(1691)*[e]
Ship	*Great galley*	*Great galley*	*Oared Galleon*	*24-Bench Common galley*	*26-Bank galley*	*Galleass*	*Great galley*	*26-bank Senzille galley*
Narrowing (bow/stern)	? / 3 ft 4 de	2 ft 10 de / 3 ft	2 ft / 2ft	2 ft 8 de / 2ft 8 de	2 pal 9 dit/ 2 pal 9 dit		? x 2 pal	2 pied 3 pou / 2 pied 3 pou
Rising (bow / stern)	8 de / 10 de	10 de / 10 de	1 ft / 2 ft aft	6 de / 7 de	6 dit / 8 dit		1 pal / 1 pal	9 pou
tilting futtocks fore (tilt / haul)		1 ft 8 de / 1 ft 4 de	11 de (10.66)	10 de / 15 de (at main frame)				6 pou / 6 pou
tilting futtocks aft (tilt / haul)		8 de / 1 ft	11 de (10.66)	8 de / 1 ft				6 pou / 6 pou

Pre' Teodoro and Drachio are in Venetian feet (*dedo* (2.1733 cm); 16 *deda* = 1 *pié* (34.7735 cm)), Crescentio and Furttenbach use palms (1 dito (2.07 cm); 12 dita = 1 *palmo* (24.8 cm)), and the French treatise uses their own foot (point (0.188 mm); 12 point = 1 ligne (2.256 mm), 12 ligne = 1 pouce (2.707 cm), 12 pouce = 1 pied du roi (32.484 cm); (a) Lane, 'Venetian Naval Architecture about 1550', 32-39; (b) Drachio, *Visione del Drachio*, 3r-9r; (c) Crescentio, *Nautica Mediterranea*, 10-23, 56-61; (d) Furttenbach, *Architectura Navalis*, 16-20; (e) Fennis, *Un Manuel de Construction des Galères (1691)*, 2-33; (f) This row is lists whether the measurements are correlated by proportions based off a specific scantling or simply an unrelated list.; (g) Height of the endpost measurements are often based on the location of where the main wale attaches with differences in the additional length of this piece beyond that height.; (h) This is the height from the ground, the keel was raked during this period. (i) This measurement is interpreted differently over time, its usage may be the distance between the final fore/aft tailframe to the last floor-timber set on either endpost.

Table 14 Longship scantlings from manuscripts in meters (unless specified) (AD 1300 – 1550)

Source	*Anjou 1275*[a]	*Michael of Rhodes (ca. 1435)*[b]		*Tirombetta (1444-1449)*[c]		*Zulle-Fausto (ca. 1546)*[d]		
Ship	*Red galley*	*Flanders galley*	*Romania galley*	*29-Banks Light galley*	*26-Bank Fusta*	*Quinquereme*	*Light galley*	*Provveditor Great Galley*
Measurements Derived by[e]	List	List	List	List	List	List	List	List
Overall Length (on deck)	39.55	41.21	41.03	39.12	33.04	49	42	42.48
Keel	28.21	34.08			8			
Stem (Height x Rake)[f]	2.99	3.65 x 3.65	3.13 x 3.58	2.17 x 3.39	1.74 x 2.61	2.48 x 3.17	2.29 x ?	2.28
Keel Fore Scarf Height[g]		2.17 cm				21.73 cm		
Sternpost (Height x Rake)[f]	3.6	4.52 x 3.65	4.17 x 3.58	2.956 x 3.39	2.43 x 2.96	3.7 x 2.52	3 x ?	3.08 x ?
Keel Aft Scarf Height[g]		2.72 cm	8.69 cm	10.43 cm	15.21 cm	21.73 cm		
Floor		3.48	3.43	2.61	2.33	1.57		
Deadrise		10.43 cm	19.56 cm					
Breadth	4.61	6.09		4.61	3.83	2.98	5.3	5.56
Deck Height	2.04	2.74	2.67	1.83	1.67	2.11	2	1.8
# Molded Frames	2x 47	2x 42	2x 41	2x 44	2x 39	30 bow, 50 stern	30 bow, 50 stern	30 bow, 50 stern
Amidships Frames	1?	4	5	4	2	5	5	5
Interim Frames		18th	18th				15th bow, 25th aft	
Tailframe to *fiero/ferir* (bow/stern)[h]		2.35 / 3.04	2.61 / 2.96	6.87 / 7.91	5.91 / 6.78	6.69 / 11.63	5.87 / 9.99	6.17 / 10.14
Narrowing (bow/stern)						1.04 / 1.1	widths provided[i]	widths provided[i]
Rising (bow / stern)							heights provided[i]	heights provided[i]

(a) Pryor, 'The Galleys of Charles I', 38-41; (b) McGee, ed., *The Book of Michael of Rhodes* Vol. 2, 417-433, 443-452; (c) Anderson, 'Italian Naval Architecture about 1445', 138-147; (e) This row is lists whether the measurements are correlated by proportions based off a specific scantling or simply an unrelated list.; (f) Height of the endpost measurements are often based on the location of where the main wale attaches with differences in the additional length of this piece beyond that height..; (g) This is the height from the ground, the keel was raked during this period; (h) This measurement is interpreted differently over time, its usage may be the distance between the final fore/aft tailframe to the last floor-timber set on either endpost.; (i) Only the widths of key frames are provided and not an exact amount, for calculations based on these measurements, see Campana, 'The Immortal Fausto'

Table 15 Longship scantlings from manuscripts in meters (unless specified) (AD 1550 – 1700)

Source	*Pre' Teodoro di Niccolò (1576)*[a]			*Drachio (1593)*[b]	*Crescentio (1602)*[c]		*Futtenbach (1629)*[d]	Un Manuel *(1691)*[e]
Ship	*Great galley*	*Great galley*	*Oared Galleon*	*24-Bench Common galley*	*26-Bank galley*	*Galleass*	*Great galley*	*26-bank Senzille galley*
Measurements Derived by[f]	Beam	Beam	Floor	Beam	List	List	List/Overall Deck Length	Overall Deck Length
Overall Length (on deck)	48	48	34.77	43.47	43.15	46.13	47.12	46.78
Keel				34.77?	30.5			39.34
Stem (Height x Rake)[g]	4.52 x ?	4.52 x 4.52	3.13 x 3.48	2.61 x 4.17	2.6 x 5.2	1.86 x 5.46	2.98 x 6.45	2.83 x 4.25
Keel Fore Scarf Height[h]				13.04 cm				
Sternpost (Height x Rake)[g]	6.09 x ?	6.09 x 3.65	3.83 x 2.43	3.83 x 3.83	3.22 x 5.2	5.39 x 5.46	4.46 x 6.45	4.68 x 3.19
Keel Aft Scarf Height[h]	17.39 cm			17.39 cm				
Floor	4.17	4	2.52	2.61	2.73	3.72	3.16	2.68
Trepie	6.61	6.26	5.1	4.24				
Siepie	7.65	7.3	6.49	4.89				
Bocca/Breadth	8	7.91	7.3 (2nd deck 5.74)	5.22	5.2	7.44	6.28	5.85
Deck Height	3.13	3.13	2.26 (2nd deck 2.61)	1.74	1.8	2.98	2.07	1.88
# Molded Frames	40 bow, 45 aft	40 bow, 45 aft	2 x 30	30 bow, 50 aft	2x 45	80 overall	45 bow, 60 stern	2x 44
Amidships Frames	1?	1	5	2	3		2	2
Interim Frames	15th	20th bow, 15th aft	5th	15th bow, 25th aft	10th		25th	23rd
Tailframe to *fiero/ferir* (bow/stern)[i]	4.35 / 8.58	7.13 / 8.35	6.61 / 8.35					
Narrowing (bow/stern)	? / 1.13	91.28 cm / 1.04	70 cm / 70 cm	86.93 cm / 86.93 cm	68.2 cm / 68.2 cm		? / 49.6 cm	73.09 cm / 73.09 cm
Rising (bow / stern)	17.39 cm / 21.73 cm	21.73 cm / 21.73 cm	34.77 cm / 70 cm	13.04 cm / 15.21 cm	12.4 cm / 16.53 cm		24.8 cm / 24.8 cm	24.36 cm
tilting futtocks fore (tilt / haul)		52 cm / 44 cm	23.17 cm	21.73 cm / 32.6 cm (at main frame)				16.24 cm / 16.24 cm
tilting futtocks aft (tilt / haul)		17.39 cm / 34.77 cm	23.17 cm	17.39 cm / 34.77 cm				16.24 cm / 16.24 cm

(a) Lane, 'Venetian Naval Architecture about 1550', 32-39; (b) Drachio, *Visione del Drachio*, 3r-9r; (c) Crescentio, *Nautica Mediterranea*, 10-23, 56-61; (d) Furttenbach, *Architectura Navalis*, 16-20; (e) Fennis, *Un Manuel de Construction des Galères (1691)*, 2-33; (f) This row is lists whether the measurements are correlated by proportions based off a specific scantling or simply an unrelated list.; (g) Height of the endpost measurements are often based on the location of where the main wale attaches with differences in the additional length of this piece beyond that height.; (h) This is the height from the ground, the keel was raked during this period. (i) This measurement is interpreted differently over time, its usage may be the distance between the final fore/aft tailframe to the last floor-timber set on either endpost.

although the level of detail varied and sometimes additional information was included that was not provided by Michael.

Tables 12-15 provide available scantling information for longships recorded in this archival material. The master frame drawn and described by Michael for his Flanders galley indicates the original recorder used offsets at each Venetian foot (34.7735 cm) to document the overall shape, while the tailframes for this vessel only relay the width at two lower locations and the sheer.[857] These locations were important as the positions for the battens, but they did not necessarily represent the points needed to design the overall shape of the hull (figure 76). Representations of the Flanders galley by authors after Zorzi only include the three widths at amidships rather than the systematic offsets first recorded by Michael.

Zorzi and other copyists also chose additional vessels, comprising smaller boats, a longship they directly associated with Theodoro Baxon, a 29-bank galley, and a western ship described as a *balinger*. While these other longships are described with different dimensions, they nonetheless follow a similar frame layout. For instance, the 29-bank galley requires four duplicate frames amidships and 44 additional frame stations fore and aft. Every fourth or fifth frame was predesigned, while the mezzaluna and incremental triangles necessary for the modification at each frame station were first drawn by Zorzi.[858]

Since many of these authors are not shipbuilders by trade, their explanations for the building of these vessels imply narrowing and rising of each frame without explaining how the method was performed.[859] It was only in the sixteenth and seventeenth centuries that actual

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[857] McGee, 'The Shipbuilding Text of Michael of Rhodes', 234-7.
[858] Anderson, 'Italian Naval Architecture about 1445', 138-40; Rieth, 'Les illustrations d'un livre de recettes techniques d'architecture navale du millieu du XV[e] siecle; le libro de Zorzi Trombetta de Modon', 87-8; 97-9
[859] Rieth, 'La Fabrica di Galere', 385; Rieth, 'Mediterranean Ship Design in the Middle Ages', 415.

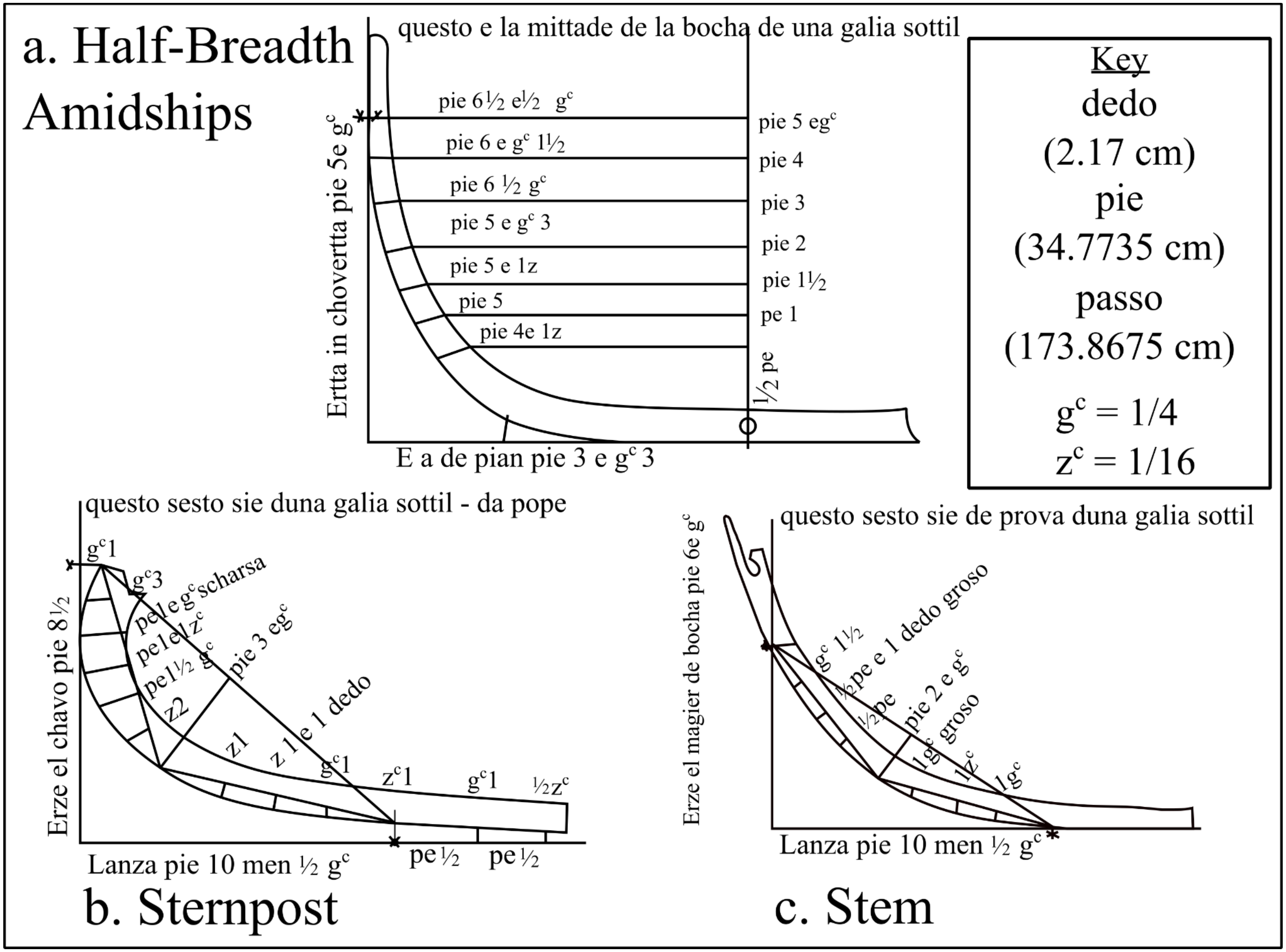

Figure 76 Transcribed images and measurements from the original Trombetta manuscript for a thin galley. (Author's drawing)

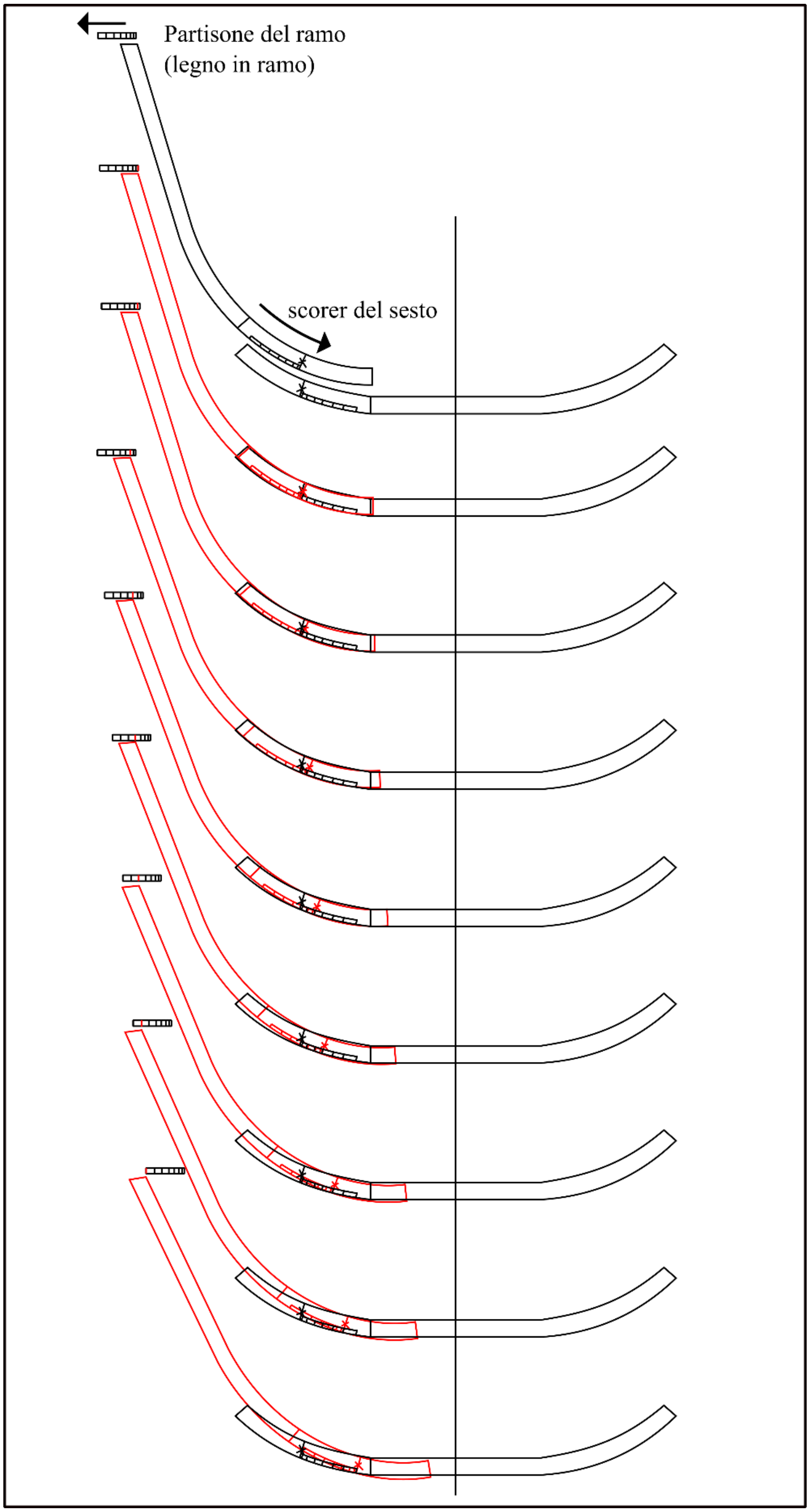

Figure 77   Example showing the tilting outward of the futtock and associated narrowing based on the overlapping turn of the bilge. (Author's drawing)

Table 16 Fifteenth-century round ship scantlings from manuscripts in original measurements

Source	*Michael of Rhodes (ca. 1435)*[a]		*Fabrica de galere (15th c.)*[b]		*Trombetta (1444-1449)*[c]							
Ship Type	*Lateen ship*	*Square-Rigged ship*	*Square-Rigged ship*	*Balinger*	*1000 botte*	*700(a) botte*	*700(b) botte*	*500 botte*	*? botte*	*300 botte*	*250 botte*	*200 botte*
Keel	60 ft	65 ft	65 ft	65 ft	85 ft	72 ft 8 de	70 ft	72 ft 8 de	63 ft	62 ft 8 de	60 ft	60 ft
Stem (Height x Rake)		32 ft 8 de x 22 ft 11 de (10.66)	32 ft 8 de x 32 ft 8 de	21 ft x 20 ft	45 ft 8 de x ?	36 ft x 30 ft	46 ft x ?	34 ft x ?	35 ft x ?	25 ft x ?	27 ft x ?	25 ft x ?
Sternpost (Height x Rake)		21 ft 11 de (10.66) x 5 ft 13 de (13.33)	21 ft 11 de (10.66) x 5 ft 3 de (3.2)	12 ft x 2 ft 8 de	35 ft x ?	21 ft x 4 ft	21 ft x ?	25 ft x ?	19 ft x ?	15 ft 8 de x ?	19 ft x ?	18 ft 8 de x ?
Floor	9 ft	9 ft 12 de		13 ft 8 de	11 ft	10 ft	10 ft	9 ft	10 ft	7 ft	8 ft 8 de	
Trepie	16 ft	17 ft 8 de			13 ft 8 de	19 ft 12 de		18 ft 8 de	17 ft	15 ft	16 ft 4 de	
Siepie					16 ft 8 de	23 ft 12 de	25 ft				18 ft 8 de	
Bocca[d]	24 ft	26 ft 8 de	27 ft	22 ft 8 de	34 ft	28 ft	28 ft	25 ft	25 ft	22 ft 8 de	20 ft 8 de	18 ft 8 de
Depth (Hold)	9ft 8 de	7 ft 8 de	8 ft 8 de - 9 ft	12 ft	12 ft	11 ft		11 ft	10 ft	7 ft 8 de	8 ft 8 de	
1st Deck Length	80 ft	95 ft										
1st Deck Breadth		9 ft 8 de										
1st Deck Height		5 ft 8 de										
Overall Depth		13 ft				22 ft						
Overall Length		96 ft 8 de	102 ft 11 de			106 ft 8 de						

All measurements are in Venetian feet unless specified (*dedo* (2.1733 cm); 16 *deda* = 1 *pié* (34.7735 cm)). (a) McGee, ed., *The Book of Michael of Rhodes* Vol. 2, 473-474, 483-484; (b) Anderson, 'Jal's 'Memoire No. 5' and the Manuscript 'Fabrica di Galere'',163-165; (c) Anderson, 'Italian Naval Architecture about 1445', 150; (d) This measurement may be the true width for earlier roundships, but the breadth begins moving upward into the first deck in later periods.

Table 17 Sixteenth- and seventeenth-century round ship scantlings from manuscripts in original measurements

Source	*Misure di Navilii (1567)*[a]				*Nicolò Sagri (1570)*[b]	*Pre' Teodoro di Niccolò (1576)*[c]		*Crescentio (1602)*[d]	*Futtenbach (1629)*[e]		
Ship Type	Galleon	Naveta	Nave	Nave	Nave	Great galleon	Merchantman	Galleon	Nave	Polaca	Barca
Keel	100 ft	45 ft	70 ft	78 ft		100 ft	50 ft	70 ft	84 pal	59 pal	37 pal 6 dit
Stem (Height x Rake)	33 ft x 29 ft	17 ft x 14 ft	27 ft x 26 ft	30 ft x 24 ft	27 ft 8 de x 27 ft 8 de	33 ft x 24 ft 8 de	20 ft x 15 ft	? x 14 ft	23 pal x 16 pal. 6 dit	34 pal x 21 pal	12 pal x 11 pal
Sternpost (Height x Rake)	32 ft x 14 ft	14 ft 8 de x 8 ft	25 ft x 11 ft	27 ft x 10 ft 8 de		30 ft x 11 ft	18 ft x 6 ft 8 de	? x 7 ft	21 pal x 12 pal. 6 dit	19 pal x 3 pal	6 pal 6 dit x 3 pal
Floor	14 ft	8 ft 8 de	11 ft	12 ft	9 ft	11 ft	7 ft	10-11 ft	26 pal	12 pal	13 pal
Trepie	23 ft 8 de	15 ft	19 ft 8 de	5 ft		22 ft 4 de	13 ft 8 de				
Siepie	30 ft	18 ft	25 ft			29 ft	17 ft 8 de				
Bocca[f]	34 ft 4 de	20 ft	29 ft		27 ft	33 ft	20 ft	27 ft		26 pal	15 pal 6 dit
Depth (Hold)	10 ft	6 ft 8 de	7 ft 8 de	8 ft 12 de	9 ft	11 ft	6 ft 8 de	9 ft	15 pal	14 pal	6 pal 6 dit
1st Deck Length											
1st Deck Breadth	40 ft 8 de	22 ft 8 de	34 ft 8 de	19 ft	30 ft	37 ft 8 de	23 ft	30-32 ft	26 pal	29 pal	
1st Deck Height	6 ft 12 de	4 ft	6 ft 8 de	7 ft 8 de	7 ft 8 de	6 ft	5 ft	6 ft 8 de	6 pal	6 pal	
Upper Deck Breadth	39 ft	16 ft 8 de	24 ft	14 ft		34 ft 8 de	17 ft	25 ft	20 pal		
Upper Deck Height	7 ft		5 ft 8 de	7 ft		7 ft	6 ft	7 ft 12 de			
Overall Depth	23 ft 12 de		19 ft 8 de	23 ft 4 de	22 ft 8 de	24 ft	17 ft 8 de	15 ft 8 de	21 pal	20 pal	
Overall Length	143 ft	67 ft	107 ft	112 ft 8 de	90 ft	135 ft 8 de	71 ft 8 de	90-93 ft	113 pal	85 pal	52 pal

Table 17 Continued

Source	*Misure di Navilii (1567)*[a]				*Nicolò Sagri (1570)*[b]	*Pre' Teodoro di Niccolò (1576)*[c]		*Crescentio (1602)*[d]	*Futtenbach (1629)*[e]
Tailframe to *fiero/ferir* (bow/stern)	33 ft / 14 ft	2 ft / 2 ft	3 ft / 11 ft	6 ft / 16 ft		12 ft 12 de / 26 ft	18 ft / 18 ft		
Narrowing (bow/stern)		2 ft / 2 ft		2 ft 12 de / 2 ft 12 de		3 ft 11 de (10.66) / 4 ft 6 de (6.4)	1 ft 12 de / 1 ft 12 de	3 ft 11 de (10.66) / 3 ft 11 de (10.66)	
Rising (bow / stern)	3 ft 4 de / 5 ft 8 de	1 ft / 1 ft 8 de		1 ft 2 de / 2 ft 4 de		3 ft 11 de (10.66) / 3 ft 11 de (10.66)	2 ft / 2ft	1 pal. 3 dit / 1 pal 6 dit	
Tilting Futtocks Fore (tilt / haul)	5 de / ?	2 de / 4 de		4 de / ?		1 ft / ?			
Tilting Futtocks Aft (tilt / haul)	5 de / ?	2 de / 4 de		4 de / ?		8 de / ?			

All measurements in Venetian feet (*dedo* (2.1733 cm); 16 *deda* = 1 *pié* (34.7735 cm)), except Crescentio and Furttenbach who use palms (1 dito (2.07 cm); 12 dita = 1 *palmo* (24.8 cm)). (a) Nicolardi, 'Misure de navilii. Un nuovo documento di costruzione navale veneziana della seconda metà del XVI secolo',3-5; (b) Dell'Osa, *Il carteggiatore di Nicolò Sagri*, 123-125; (c) Lane, 'Venetian Naval Architecture about 1550', 39-49; (d) Crescentio, *Nautica Mediterranea*, 63-66; (e) Furttenbach, *Architectura Navalis*, 74-78. (f) This measurement may be the true width for earlier roundships, but the breadth begins moving upward into the first deck in later periods.

Table 18 Fifteenth-century round ship scantlings from manuscripts in meters (unless specified)

Source	*Michael of Rhodes (ca. 1435)*[a]		*Fabrica de galere (15th c.)*[b]		*Timbotta (1444-1449)*[c]							
Ship Type	Lateen ship	Square-Rigged ship	Square-Rigged ship	Balinger	1000 botte	700(a) botte	700(b) botte	500 botte	? botte	300 botte	250 botte	200 botte
Keel	20.86	22.6	22.6	22.6	29.56	25.21	24.34	25.21	21.91	21.73	20.86	20.86
Stem (Height x Rake)		11.3 x 7.88	11.3 x 11.3	7.3 x 6.96	15.82 x ?	12.52 x ?	16 x ?	11.82 x ?	12.17 x ?	8.69 x ?	9.39 x ?	8.69 x ?
Sternpost (Height x Rake)		7.53 x 2.03	7.53 x 1.81	4.17 x 87 cm	12.17 x ?	7.3 x ?	7.3 x ?	8.69 x ?	6.61 x ?	5.39 x ?	6.61 x ?	6.43 x ?
Floor	3.13	3.39		4.69	3.83	3.48	3.48	3.13	3.48	2.43	2.96	
Trepie	5.56	6.09			4.69	6.87		6.43	5.91	5.22	5.65	
Siepie					5.74	8.26	8.69				6.43	
Bocca[d]	8.35	9.22	9.39	7.82	11.82	9.74	9.74	8.69	8.69	7.82	7.13	6.43
Depth (Hold)	3.3	2.61	2.96 - 3.13	4.17	4.17	3.83		3.83	3.48	2.61	2.96	
1st Deck Length	27.82	33.04										
1st Deck Breadth		3.3										
1st Deck Height		1.91										
Overall Depth		4.52				7.65						
Overall Length		33.56	35.71			37.03						

(a) McGee, ed., *The Book of Michael of Rhodes* Vol. 2, 473-474, 483-484; (b) Anderson, 'Jal's 'Memoire No. 5' and the Manuscript 'Fabrica di Galere",163-165; (c) Anderson, 'Italian Naval Architecture about 1445', 150; (d) This measurement may be the true width for earlier roundships, but the breadth begins moving upward into the first deck in later periods.

Table 19 Sixteenth- and seventeenth-century round ship scantlings from manuscripts in meters (unless specified)

Source	*Misure di Navilii (1567)*[a]				*Nicolò Sagri (1570)*[b]	*Pre' Teodoro di Niccolò (1576)*[c]		*Crescentio (1602)*[d]	*Futtenbach (1629)*[e]		
Ship Type	Galleon	Naveta	Nave	Nave	Nave	Great galleon	Merchantman	Galleon	Nave	Polaca	Barca
Keel	34.77	15.65	24.34	27.12		34.77	17.39	24.34	20.83	14.63	9.3
Stem (Height x Rake)	11.48 x 10.08	5.91 x 4.87	9.39 x 9.04	10.43 x 8.35	9.56 x 9.56	11.48 x 8.52	6.96 x 5.22	? x 4.87	5.7 x 4.09	8.43 x 5.21	2.98 x 2.73
Sternpost (Height x Rake)	11.13 x 4.87	5.04 x 2.78	8.69 x 3.83	9.39 x 3.65		10.43 x 3.83	6.26 x 2.26	? x 2.43	5.21 x 3.1	4.71 x 74.4 cm	1.61 x 74.4 cm
Floor	4.87	2.96	3.83	4.17	3.13	3.83	2.43	3.48 - 3.83	6.45	2.98	3.22
Trepie	8.17	5.22	6.78	1.74		7.74	4.69				
Siepie	10.43	6.26	8.69			10.08	6.09				
Bocca[f]	11.91	6.96	29 ft		9.39	11.48	6.96	9.39		6.45	3.84
Depth (Hold)	3.48	2.26	10.08	3.04	3.13	3.83	2.26	3.13	3.72	3.47	1.61
1st Deck Length											
1st Deck Breadth	14.08	7.82	12	6.61	10.43	13.04	8	10.43 - 11.13	6.45	7.19	
1st Deck Height	2.35	1.39	2.26	2.61	2.61	2.09	1.74	2.26	1.49	1.49	
Upper Deck Breadth	13.56	5.74	8.35	4.87		12	5.91	8.69	4.96		
Upper Deck Height	2.43		1.91	2.43		2.43	2.09	2.7			
Overall Depth	8.26		6.78	8.09	7.82	8.35	6.09	5.39	5.21	4.96	
Overall Length	49.73	23.3	37.21	39.12	31.3	47.12	24.86	31.3 - 32.34	28.02	21.08	12.9
Tailframe to *fiero/ferir* (bow/stern)	11.48 / 4.87	69.55 cm / 69.55 cm	1.04 / 3.83	2.09 / 5.56		4.43 / 9.04	6.26 / 6.26				
Narrowing (bow/stern)		69.55 cm / 69.55 cm		95.63 cm / 95.63 cm		1.28 / 1.53	60.85 cm / 60.85 cm	1.28 / 1.28			
Rising (bow / stern)	1.13 / 1.91	34.77 cm / 52.16 cm		39.12 cm / 78.24 cm		1.28 / 1.28	69.55 cm / 69.55 cm	31 cm / 37.2 cm			
Tilting Futtocks Fore (tilt / haul)	10.87 cm / ?	4.35 cm / 8.69 cm		8.69 cm / ?		34.77 cm / ?					
Tilting Futtocks Aft (tilt / haul)	10.87 cm / ?	4.35 cm / 8.69 cm		8.69 cm / ?		17.39 cm / ?					

(a) Nicolardi, 'Misure de navilii. Un nuovo documento di costruzione navale veneziana della seconda metà del XVI secolo',3-5; (b) Dell'Osa, *Il carteggiatore di Nicolò Sagri*, 123-125; (c) Lane, 'Venetian Naval Architecture about 1550', 39-49; (d) Crescentio, *Nautica Mediterranea*, 63-66; (e) Furttenbach, *Architectura Navalis*, 74-78. (f) This measurement may be the true width for earlier roundships, but the breadth begins moving upward into the first deck in later periods.

shipbuilders prepared step by step instructions for this procedure. Besides narrowing and rising each floor timber, another system called *partisone de ramo* (futtock adjustment) is first mentioned by the author of 'Fabbrica di galere'.[860] As shown in figure 77, this method required the upper ends of the futtocks to tilt outward while adjusting the bilge curve with a complementary system known as *scorer del sesto* (adjusting the futtock at the turn of the bilge). By adjusting the upper ends of the futtocks, more deck space was preserved beyond amidships while the floor timbers continued their narrowing progression to the endposts.

Compared to the extensive descriptions for longships, Michael's text and the later *zibaldones* provide only simplified lists for round ship hull designs. Michael describes two ships, a single decked round ship with lateen sails and a larger two decked round ship with square sails.[861] Both ships are described in proportions related to their respective keels and amidships profile based on the *fondo* (distance between the turn of the bilge on either side of the keel), three feet above the keel, and the beam. There is an additional measurement for the second deck of the latter ship that only mentions its depth and the overall height from beneath the upper deck to the top of the keel. Michael never mentions a width measurement for the six-foot interval on either round ship, although his depictions of the tailframes for the galleys clearly show this height for the battens. Zorzi includes the main proportions for eight different sizes of round ships, but his detailed imagery shows only the offset measurements for a 700-*botte* round ship. The hull profile for the round ship includes the measurement for the six-foot interval and mentions that the height

[860] Rieth, 'La Fabrica di Galere', 385-6; Rieth, '"To Design" and "to Build" Medieval Ships (Fifth to Fifteenth Centuries) - The Application of Knowledge Held in Common with Civil Architecture, or in Isolation?', 130.
[861] Stahl, ed., *The Book of Michael of Rhodes, vol. 2*, 473-508, f.164-80a.

for the upper two decks combined is equal to the hold.[862] Tables 16-19 present scantlings for these ships as recorded in contemporary archival materials.

Shipbuilding described by various authors throughout the fifteenth and beginning of the sixteenth century appear to represent two types of notarial lists in text and graphic forms. Longship descriptions follow an earlier tradition, which provides lists of timber measurements and occasionally their location within the hull based on the offset distances from other components. Michael's pictorials of these same measurements provided more context to the reader, even if the author himself was unfamiliar with what he was transcribing.[863] Perhaps because the Venetian shipbuilders kept the designing of master frames to themselves, administrators in the arsenal chose to collect as much information as possible by initially recording the entire profile through incremental offsets. Similar offsets might be collected for the tailframes, although the only surviving information we have simply depicts the locations of the battens that becomes the standard recording method for later accounts.

Descriptions for round ships are different, due to their initial measurements providing a closer link to the proportions based on a standard unit emphasized in earlier archaeological evidence. Michael, Zorzi, and the copyists of Fabrica di galere describe measurements for the round ships based on the length of the keel divided into multiples or divisions.[864] Michael's text includes simplified descriptions and only the finished watercolor of a single round ship with square sails.[865] Zorzi's description provides less measurements, but he does include hull profile

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[862] Anderson, 'Italian Naval Architecture about 1445', 150-1; Rieth, 'Les illustrations d'un livre de recettes techniques d'architecture navale du millieu du XV^e siecle; le libro de Zorzi Trombetta de Modon', 100
[863] McGee, 'The Shipbuilding Text of Michael of Rhodes', 234.
[864] McGee, 'The Shipbuilding Text of Michael of Rhodes', 236; Anderson, 'Italian Naval Architecture about 1445', 151-52; Bellabarba, 'Square-Rigged Ship of the Fabrica di Galere Manuscript', 113-6
[865] McGee, ed., *The Book of Michael of Rhodes: A Fifteenth-Century Maritime Manuscript*, 397, f.182b.

drawings of round ships, although their lower halves appear similar to longship profiles.[866] The upper decks for Zorzi's 700-*botte* round ship appears to use the same curve except reversed between the *fondo* and first deck (figure 78). Several scholars suggest that since the focus for the arsenal at the time was to build longships, that it only generated a plethora of state documents on constructing this type.[867] Round ships were often left to private shipyards and those who operated these enterprises did not necessarily collect or share the same level of information.

Fifteenth-Century Archaeology

Compared to the variety of sources focused on longships at this time, there are few archaeological examples to supplement the documents. Lake Garda represents the only contemporaneous longship, which includes a single master frame placed on the center of the keel. Researchers studied the narrowing and rising of the floor timbers and deduced that the incremental triangle for 11.5 cm rise was used.[868] Reconstruction of the ship includes using the *partisone de ramo* to tilt the futtocks outward as they reach the endposts.[869]

Out of the four contemporary round ships with conceptual information, the earliest, Marinières, includes differences from the other three. Marinières' builders relied on dual master frames, positioned exactly one-third of the hull's length aft from the front end of the keel rather than at the center of the hull (figure 79). No evidence for the *partisone de ramo* was used in construction, instead the shipbuilders decided to cant the futtocks outward 5-9º near the endposts

866 Rieth, 'Les illustrations d'un livre de recettes techniques d'architecture navale du millieu du XVᵉ siecle; le libro de Zorzi Trombetta de Modon', 101, fig. 4
867 Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 131-2; McGee, 'The Shipbuilding Text of Michael of Rhodes', 237; Bondioli, 'Early Shipbuilding Records and the Book of Michael of Rhodes', 276.
868 Bondioli and Capulli, 'Il relitto cinquecentesco della fusta veneziana di Lazise: Analisi strutturale e studio sul metodo di configurazione dell'innalzamento verticale dei madieri (stellatura) mediante l'uso dei sesti', 84-6.
869 Capulli, *Le navi della Serenissima. La «galea» di Lazise*, 120.

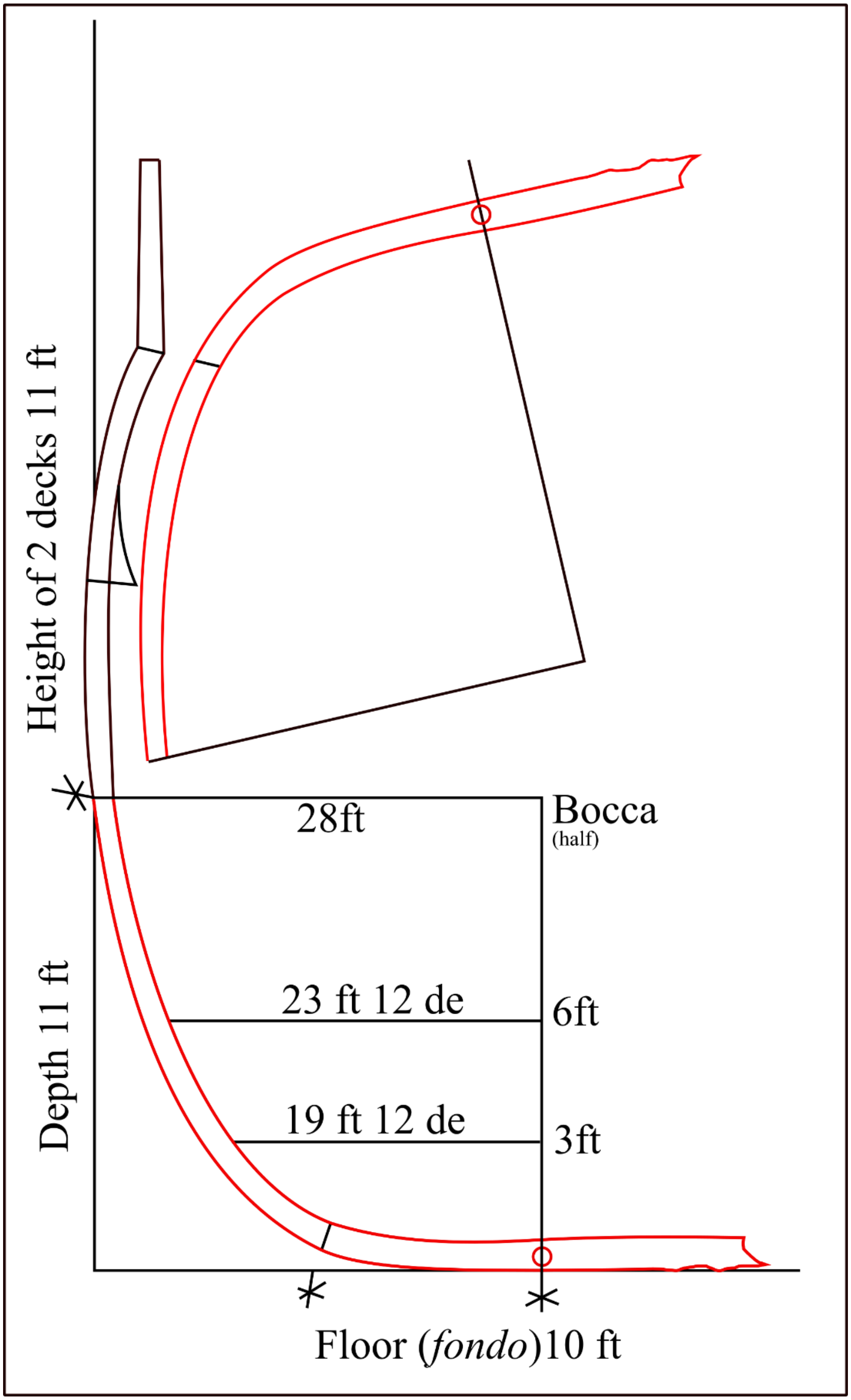

Figure 78   Transcribed Zorzi's 700-botte round ship profile, showing the flipping of the lower hull master curve to create the upper decks. (Author's drawing)

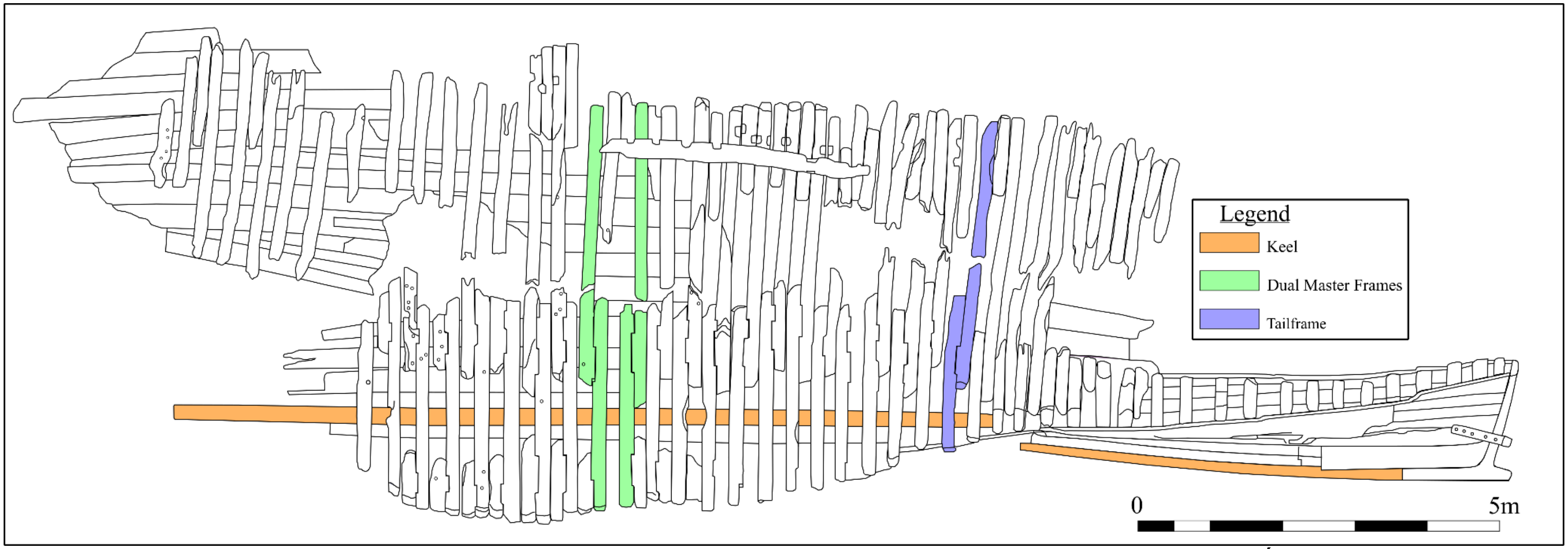

Figure 79 Site plan of Marinières shipwreck showing the location of key design frames. (after Daeffler, 'L'Épave des Marinières, 39)

to increase the width of the upper decks.[870] The investigators of this wreck assume that the canting was a roughshod answer to the decrease in deck space, possibly due to the lack of teaching *partisone de ramo* to Atlantic-Iberian shipbuilders.[871]

Most of this claim is based on the application of canting frames throughout the hull of the sixteenth-century Red Bay 24M, although the archaeologists studying this vessel also claim the use of tangent arcs making it technologically ahead of Mediterranean contemporaries.[872] Not enough information is available about Mediterranean-Iberian shipbuilding to know whether the process of canting frames was an exclusive Atlantic technique.

Data from Contarina I and Mariposa B contrast by the former using a single master frame, while the latter continues the earlier practice of dual master frames. Contarina I's single master frame is positioned 21.5 cm forward from the center of the keel (exactly one frame station). There is a clear mold to narrow the floor timbers towards the endposts, but there does not seem to be an application of a rising tablet to create a foot on the floor timbers for the entry and runs.[873] The conceptualization of this ship harks back to the process employed on Marsala A with a single mold tilted inward for a minor deadrise. There is an outward flair at Contarina I's futtocks, possibly in conjunction with *partisone de ramo*. Less is published about Mariposa B, except that the dual master frames appear positioned roughly at the center of the keel. The reconstruction of its shape suggests its profile includes an initial deadrise with a gradual increase in the angles of the floor timbers toward the stern.[874]

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[870] Daeffler, 'L'épave des Marinières', 24.
[871] Ibid., 28.
[872] Loewen, 'The Frames: Atlantic Design and Principles and Basque Fabrication Methods', 91-5.
[873] Beltrame, 'A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy', 413
[874] Gavini and Silvetti, 'Alghero-La Mariposa: Relitto "B". Nuovi elementi costruttivi sui resti di una nave della fine del XV secolo', 156, fig. 2

Sixteenth-Century Written Sources

Misure di vascelli etc. di … proto nell'Arsenale di Venetia (1546)

The most extensive documentary sources available for the sixteenth century Mediterranean were composed by shipyard workers associated with the Venetian arsenal. Some of these authors wrote self-promotional reports seeking rewards and praise from the ruling elite. Dynamics within the arsenal changed during this period, especially with the invitation by the Venetian Senate in 1526 to humanist Vettor Fausto to construct ships for the State. Fausto read many of the surviving texts by Greek and Roman scholars and claimed to have learned the processes for constructing ideal ship shapes from this research. He convinced the Senate to allow him to build a quinquereme with five oars per bank that was successful in winning a race against a traditional galley with three oars per bank.[875] Conservative shipbuilders in the arsenal were jealous of the outsider and his success. Fausto received his own ship shed that was covered and locked to outsiders.[876] He was also given trusted workers and apparently at least one pupil who learned some of their shipbuilding skills from Fausto. Fausto died in 1546 without any heirs and his knowledge was presumably not written down or shared amongst the arsenal administrators.[877]

In 1570, Giovanni di Maria di Zanetto (also known as Zulle) became master shipbuilder for the Venetian arsenal.[878] Originally one of Fausto's apprentices, he claimed to have learned how to design ships from his master; the manuscript 'Misure di vascelli etc. di … proto

[875] Campana, 'The Defence of the Venetian *Dominio da Mar* in the Sixteenth Century: Ship Design, Naval Architecture, and the Naval Career of Vettor Fausto's *Quinquereme*', 59-60.
[876] Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 19
[877] Campana, 'The Immortal Fausto: The Life, Works, and Ships of the Venetian Humanist and Naval Architect Vettor Fausto (1490-1546)', 164-5.
[878] Lane, *Venetian Ships and Shipbuilders of the Renaissance*, 71.

nell'Arsenale di Venetia' (1546) is believed to be written by Zulle.[879] The document discusses the construction of several different longship and round ship types (including Fausto's quinquereme) and provides recipe lists for measurements in the typical style seen in earlier notebooks. It is mainly concerned with the general measurements, including the overall length of ships, the number of predesigned frames with their dimensions at specific stations, and the shape of entries and runs.

All longships described in Misure di vascelli share a common number of 85 predesigned frames with the same positioning on the keel. One master frame is accompanied by 5-6 duplicates (often the master is placed second from the bow) with 30 predesigned frames forward and 50 aft.[880] Misure di vascelli is also a different recipe list than those in the fifteenth century by concerning itself mainly with distances between key frame stations and the major dimensions of those same frames but not the exact curvatures. Several descriptive lines are included about the master mold for the quinquereme, but it is limited in character without any further details about how the shape was created.[881] Exactly what methods Fausto used that separated his work from that of the rest of the arsenal shipbuilders is a matter of debate. Fausto applied the same criteria to his ships on the placement of frames, but his supposed ingenuity is the application of algebraic and geometric formulas that were not necessarily in common practice.

Many of the measurements provided in Misure di vascelli are proportional to each other or reflect the application of the mathematical gauss formula, which was already used in

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[879] Campana, 'Vettor Fausto (1490-1546), Professor of Greek and a Naval Architect: A New Light on the 16th-Century Manuscript *Misure di Vascelli etc. di....proto Dell'Arsenale di Venetia*', 187; Campana, 'The Immortal Fausto', 168.
[880] Campana, 'The Immortal Fausto', 130-1; 182; 248.
[881] Campana, 'Vettor Fausto (1490-1546), Professor of Greek and a Naval Architect', 165-75.

contemporary shipbuilding by means of the incremental triangle.[882] There is also a later sixteenth-century document from the Venetian State Archives with concentric circles of two different sizes, their respective circumferences reflecting the overall length versus the beam for Fausto's quinquereme. The concentric circles were also applied to the earlier Contarina I, suggesting a similar application in design.[883] The bilge curve presumably relied on a smaller circular arc from the midship flat to the six-foot offset above the keel and a diameter matching half the beam (plus one-eighth more). Not enough information about the use of circles is included to know if the remainder of the master mold followed a larger circle based off the hull or was simply adjusted to give a gentle curve up to the gunwale.

Misure de navilii (1567)

The first document specifically focusing on round ships is 'Misure de navilii', dated to 1567 and assumed to be the work of either a caulker or another individual from the Venetian arsenal.[884] It is a typical notebook from the period with several folios devoted to different topics and a smaller section with lists of construction measurements for different round ship types, including a galleon, *naves*, and *navetas*.[885] The lists follow a similar format noted for the fifteenth century sources, mainly that the beginning measurements follow the outline of the lower hull listing the same measurements for the *fondo*, three feet, six feet, and maximum beam marks. There is no attempt by the author to demonstrate an understanding of proportions in relation to the keel, they are simply lists with measurements that were presumably collected in the shipyard.

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[882] Campana, 'The Immortal Fausto', 12-13.
[883] Bondioli, 'The Libro di navigar', 216-7.
[884] Nicolardi, 'Misure de navilii. Un nuovo documento di costruzione navale veneziana della seconda metà del XVI secolo', 240.
[885] Ibid., 239.

Compared to the earlier works of Michael and his copyists, the codification seen in Navilii's measurements takes a step forward by including the widths of the decks above the hold. Another innovation is the detailed recording of the dimensions for the master frame and tail frames, and the compiling of the narrowing, rising, and the amount of outward flair applied to the futtocks near the endposts. Intermediate frames where the rising normally begins is absent in this text, as the author states it begins amidships at the first frame station on either side of the master frame.[886] The master frame is positioned forward of the center of the keel based on a 1.5 *passo* (2.61 m) unit rather than a proportion. Misure de Navilii provides much more information for reconstruction of each ship and includes the progressions not normally shared by shipbuilders.

Pre' Teodoro di Niccolò's Notebook (1576)

Venetian arsenal documents dating to the end of the sixteenth century allow modern scholars greater insight into building of both longships and round ships. The notebook by Pre' Teodoro di Niccolò, dated to 1576, provides not only the traditional recipe lists of measurements, but also further imagery for profiles. Pre' Teodoro was a monk entrusted with his own construction projects within the Arsenal by 1544. He was initially an apprentice to Francesco Bressan, the shipbuilding foreman for the shipyard between 1540 and 1570.[887]

Teodoro's notebook provides clues about shipbuilding that are not emphasized in earlier documents. His discussion of longships specifically states that the base measurement for the design is the beam rather than the keel. No measurement for the keel is mentioned, instead Teodoro only gives the overall length of each ship and then proceeds with the beam.[888] Half-

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[886] Ibid., 41-3.
[887] Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 6
[888] Lane, 'Venetian Naval Architecture about 1550', 33, 36-8, 43

widths for the *fondo*, three-foot, and six-foot marks are all written in reverse order from the beam down to the keel. Teodoro also tells the reader about"drawing the square", a reference to the half-breadth profile seen on most representations (beginning with Zorzi's notebook) where the width is half the beam and height the depth of the hold for each vessel (figures 80 and 81). This square is easy enough to accomplish for single-decked vessels (such as longships), but it is more clunky in application when Teodoro applies it to his round ship profiles. The "square" for the round ship profiles has become rectangular and the addition of two upper decks are added that combine to make a more ideal box-shape. Nonetheless, the drawing of the master frame only fits within the traditional first "square" and extends beyond this box in the upper portion. Reconstruction of the offsets written down by Theodoro for his great galleon presents a sharp curve from the floor to the upper deck, while there is gentler curve for the merchantman.[889] Both drawings clearly reference the square to obtain the bottom curvature from the centerline to the bocca, although this is no longer the greatest width for either ship. Often somewhere close to half the height of the first deck above the hold becomes the greatest width. Close examination of Theodoro's profiles suggests that he relied on flipping the master frame's curve to complete drawing the ship above the hold. For the great galleon, the tumblehome seen at the upper deck was created by relying on the curvature of the tailframe, which included the additional tilt outward added to the frames at this juncture (figures 82 and 83).[890]

Teodoro describes his round ships in the manner typical of earlier recipe books with the distance of the keel stated and the offset measurements generally in incremental order. The keel and beam are described first for the great galleon, followed by the three-foot and six-

[889] Ibid., 44, 47; fig. 5, 7.
[890] Ibid., 43, n. 3.

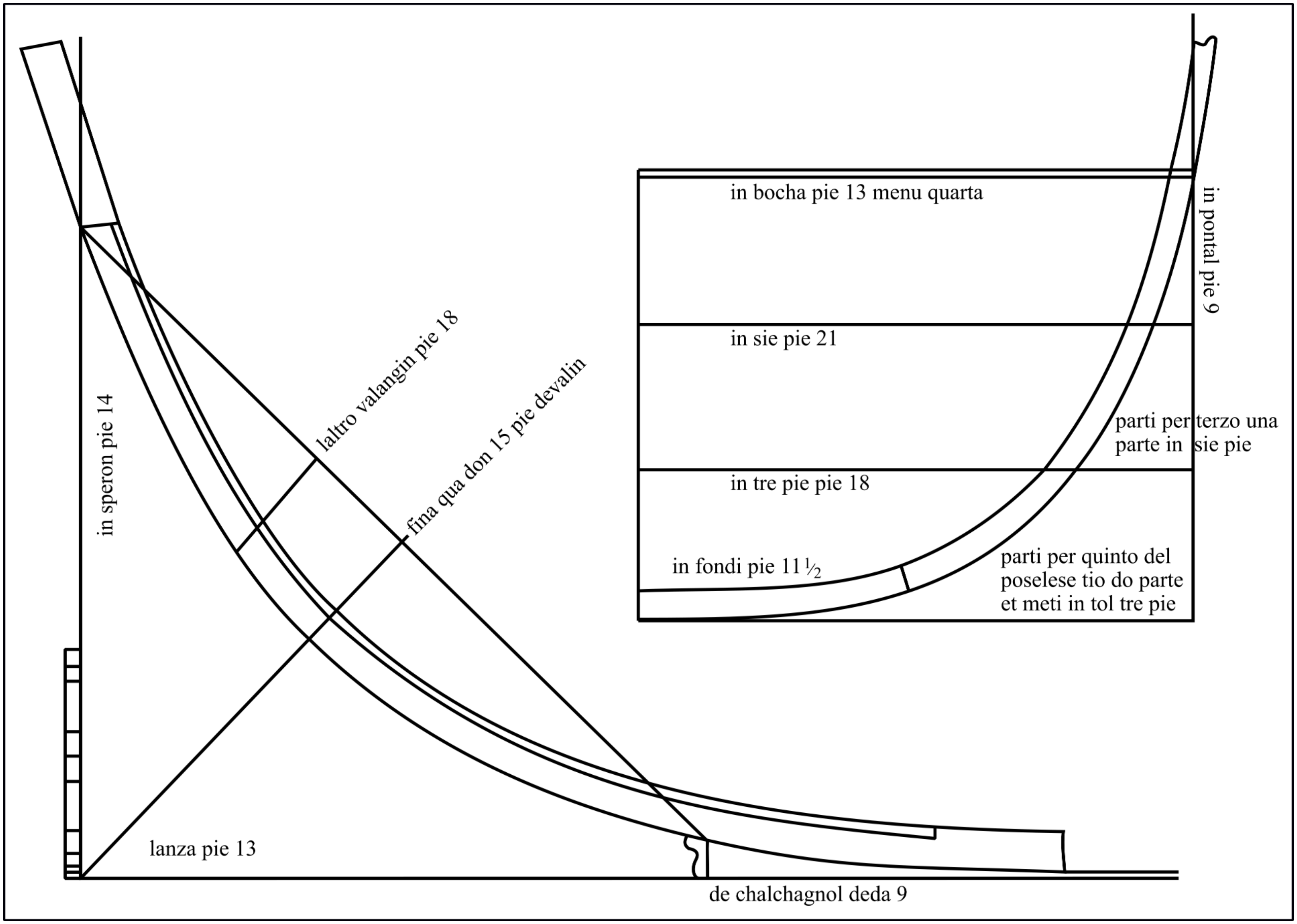

Figure 80 Transcribed drawing of the great galley from Pre' Teodoro's notebook. (Author's drawing)

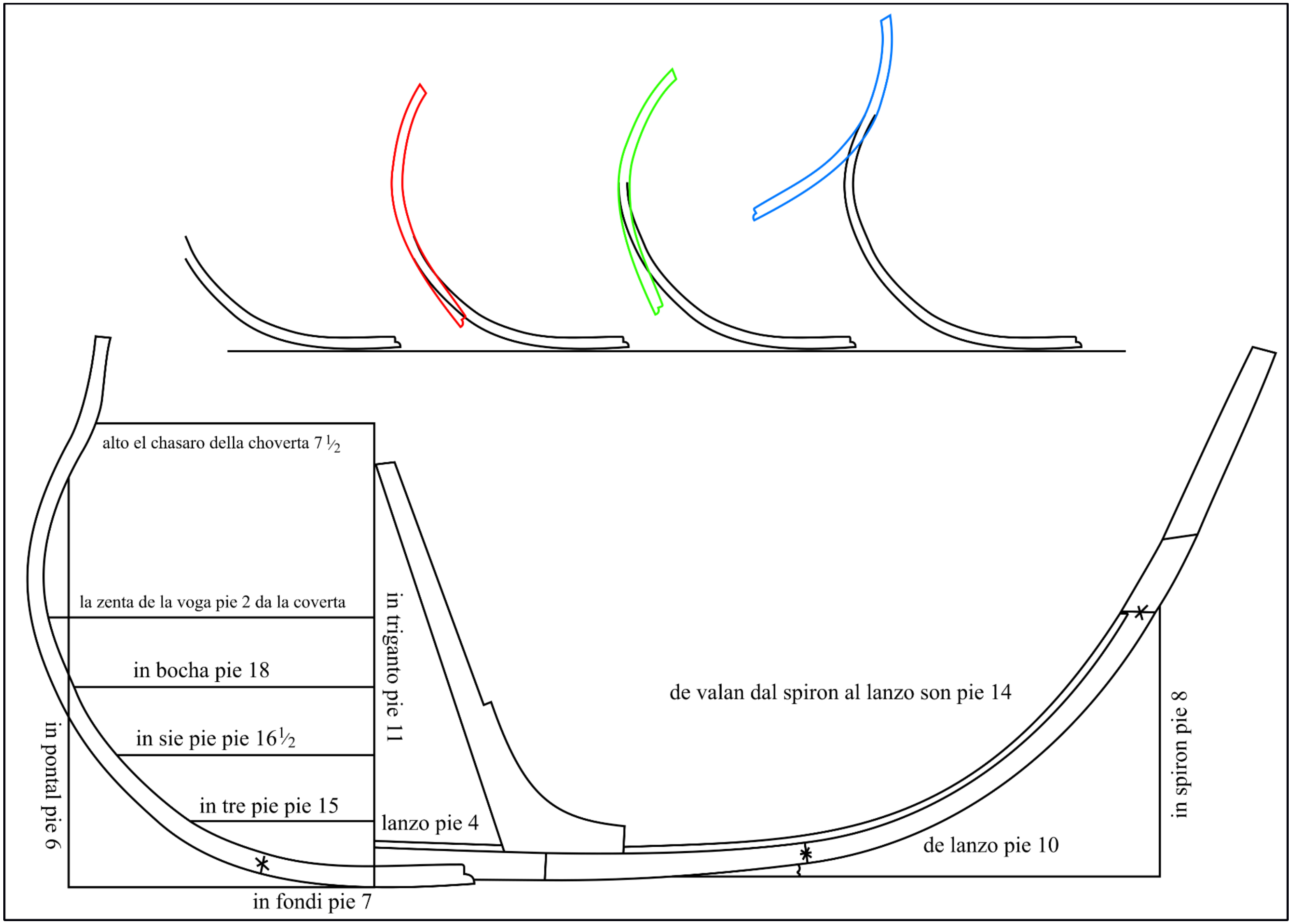

Figure 81 Transcribed drawing of Pre' Teodoro's oared galleon, the top shows the use of the master frame mold to create the rest of the hull. (Author's drawing)

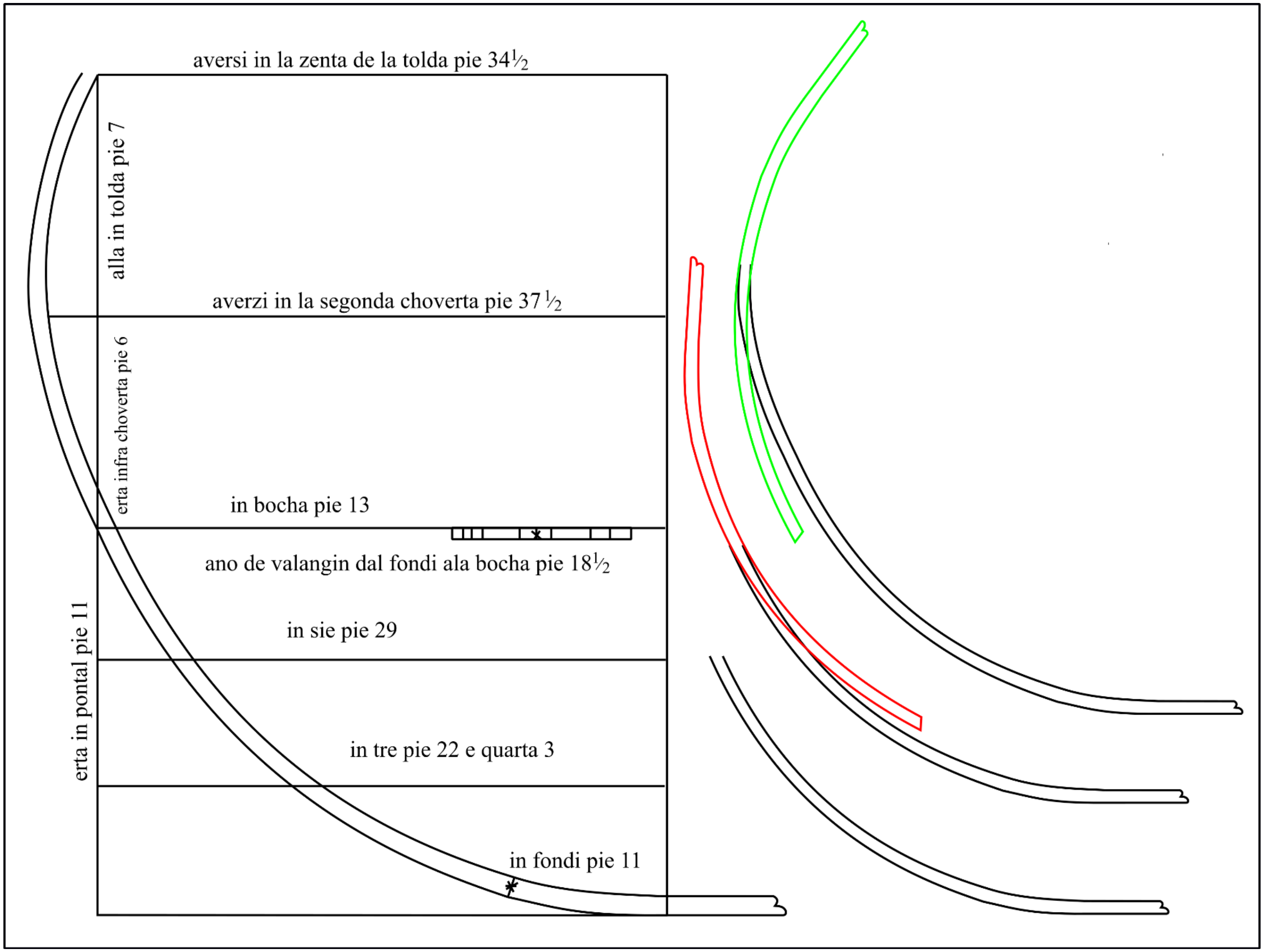

Figure 82 Transcribed drawing of Pre' Teodoro's great galleon, the right shows the use of the master frame mold to create the rest of the hull. (Author's drawing)

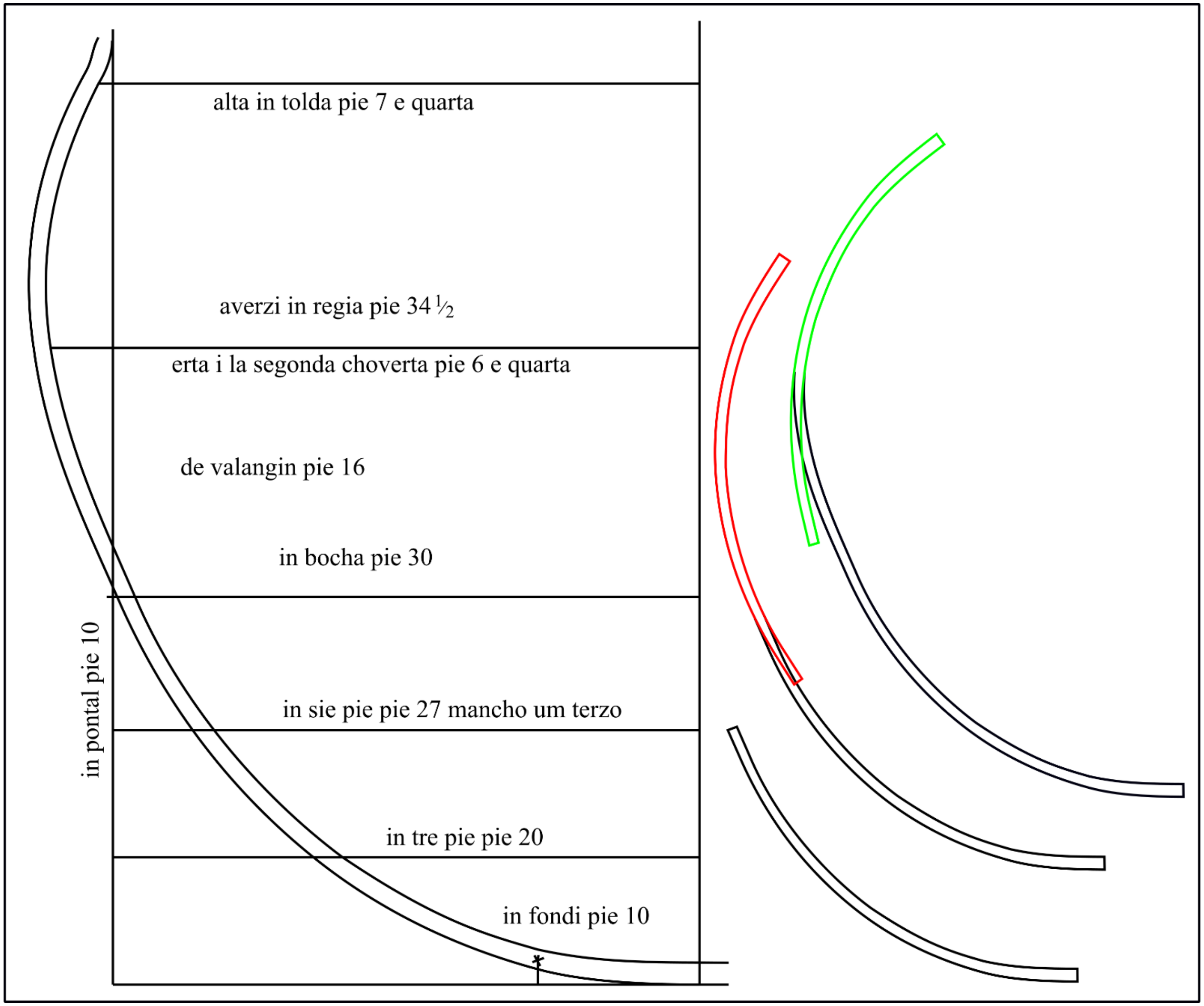

Figure 83 Transcribed drawing of Pre' Teodoro's merchantman, the right shows the use of the master frame mold to create the rest of the hull. (Author's drawing)

foot interval without mention of the *fondo*, although this is written down on the profile drawing.[891] For the merchantman, the keel and beam are again described, followed by the three-foot and six-foot interval with the *fondo* listed last.[892] Compared to the anonymous author for Misure de Navilii, there is evidence of Theodoro's familiarity with the ships. When Theodoro is describing the great galley or galleon, he emphasizes how certain dimensions were obtained by proportions of the beam, floor, or depth of hold. The descriptions for the other great galley, oared galleon, or certain parts of the merchantman are straightforward, providing the measurements without much attention to their proportional relationships.

Theodoro's notebook also provides insight into the development of shipbuilding within the Venetian arsenal by suggesting a gradual evolution in recording procedures. Previous personnel were concerned with preserving the general dimensions from important hulls either during their construction or dismantling. Most of this focus was on longships as the typical warship utilized by the Venetian Republic during this period. Offset measurements were first recorded at specific intervals to reconstruct the transverse profile more accurately, but there is a transition to only measuring for the locations of key battens along the frames. These construction lists and drawings must have become standardized for arsenal administrators and perhaps influential for apprentices or outsiders entering the shipbuilding trade.

Over this time it is evident that shipbuilding was increasingly perceived as a worthwhile intellectual pursuit. This likely accounts for the appearance of non-traditional craftsmen in the shipyard such as Fausto who was clearly despised as an outsider by many in the shipbuilding community. Teodoro, although noted as a religious man, may have received less ire because he

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891 Ibid., 43.
892 Ibid., 48.

completed a typical apprenticeship with a notable master builder. His notes follow the contemporary trend where shipbuilders began forming their own "recipe" lists of ideal ship dimensions and sketches of the key axial timbers and master frame. What is interesting about this approach is the adoption by Teodoro of the drawing system originally implemented by arsenal administrators to record round ships in the same manner as longships. Not enough information is provided to know whether Teodoro was an outlier in this regard, whether he saw or was familiar with administration recording procedures that he then mimicked, or if this system was an original practice or subsequent adoption by the traditional shipbuilders in the yard.

Visione del Drachio (1593)

Many of the manuscripts from this period only provide dimensions, so we are fortunate that chastened shipbuilder Baldissera Quinto Drachio decided to put pen to paper in 1593. Drachio originally started working in the Venetian arsenal in 1546 under Francesco Bressan. After several decades, Drachio suggested cost-saving reforms that angered his compatriots who pushed calumnies to see him fired.[893] His *Visione del Drachio* (1593) is apologetic and informative letter seeking reinstation by his previous employer, while also appealing to his fellow shipbuilders for their own humility.

Drachio's instructions for building a typical thin galley differ from most other sources by providing specific details on the design techniques for key elements. His work was based on a series of cords, specific lengths tied to posts positioned at either end of the hull that indicated the rake of the endposts, the curvature of the keel, the rising curve for the framing, and the sheer for the overall hull.[894] Measuring sticks were produced to mark the rising interval between the flat

[893] Hocker and McManamon, 'Medieval Shipbuilding in the Mediterranean and Written Culture at Venice', 20-1
[894] Drachio, *Visione del Drachio*, 4r-5r.

part of the keel to the curvature of the endposts, which replicated this height for designing the stem and sternpost. This system of cords may have also been used to draw the endpost curves by positioning stakes in the ground to act as one end of a compass and the other as the apex of each arc.[895] Every fifth frame was predesigned before its installation on the keel and the remainder of the floor timbers and futtocks were fashioned based on battens installed at key points along the hull.

The thin galley is described in a manner similar to several ships in Teodoro's notebook, where the overall length is included rather than just that of the keel. The reason for this discrepancy in Drachio's letter suggests the use of multiples based off the beam as a proportion of the overall length rather than the keel. Since the rockered keel is created based on the shape of a slack cord tied at different heights between two posts, our only knowledge of its intended length is that these posts are 20 paces apart and another 5 paces added as the total rake for both endposts.[896] Both the length of the keel and the added rakes provide easy proportional divisions into fourths or fifths. The overall length is also divided into eighths and this becomes the beam for the ship, which is further divided by half for the *fondo* or thirds to find the depth of hold.

Drachio also emulates earlier recipes by discussing the offset widths for the three-foot and six-foot line in reverse order, as if beginning from the beam rather than the floor. Devising the mold for the ship relies on creating the "square" from the beam by depth of hold, along with the usual offsets. Drachio includes the curvature of the hull by describing how the curve was obtained using a bendable thin slat (*cantinella*) with the standard offsets used as key points for it to cross. Each point is further offset by the thickness of the floor timbers, which in this case are 3

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[895] Bondioli, 'The Art of Designing and Building Venetian Galleys from the 15th to the 16th Century', 224-6, fig.33.4.
[896] Drachio, *Visione del Drachio*, 4r-v.

½ *dedas* (7.61 cm) molded. The master frame is placed two-fifths of the distance aft of the bow based on the overall length of the vessel. The galley has 30 control frames forward and 50 aft with only the two master frames mentioned compared to the four to six described in other manuscripts.[897]

Narrowing of each floor timber is based on the sixth of the beam, while the rising is a seventh of the same number. Drachio also explicitly states that the application of the *partisone del ramo* and *scorer del sesto* as conceived based on fourth of the narrowing, while the angle is 1.5 times greater.[898] Narrowing for the after end of the hull is the same measure, but the *ramo* (futtock tilt) is now based on a fifth of this length rather than the fourth noted above. Rising aft is based on the sixth of the narrowing rather than the seventh noted for the bow. Compared to the narrowing, *ramo*, and *scorer del sesto*, which affect all control frames except the master frame, the rising begins halfway between tail frames in either section. Drachio recommends using the incremental triangle for figuring out the gradual increase of these measurements at each frame station.[899] The remainder of *Visione del Drachio* continues with the construction of the outrigger, placement of 24 benches and corresponding thole pins, position of the mast, and the armament for the vessel. Drachio ends his letter by acknowledging the brilliance of outsiders like Fausto as academics but also condemns their ships, especially the quinquereme, as a prison for its crew. He hopes that what was written would answer his critics and allow him to be reinstated at the arsenal.

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[897] Ibid., 6r-v.
[898] Ibid., 7r-8r.
[899] Ibid., 8r.

Sixteenth-Century Archaeology

Compared to earlier periods, the sixteenth century provides more examples of design factors from several ships. For instance, the original constructors for Villefranche relied on a single master frame positioned roughly five-eighths of the distance forward from the after end of the keel.[900] This position is a little over a third from the front end of the keel or slightly forward of amidships when based on the overall length of the ship. The aft tail frame was located 11 frame stations behind the master. It was identified by the presence of horizontal fastenings between the floor timber and first futtocks. Surrounding frames suggest the other floor timbers were mounted and the futtocks attached with fasteners driven at an angle from above.[901] All futtocks were attached on the floor timber face closest to the master frame, which is opposite to the common method usually seen on most vessels. The wineglass shape required that the master frame included a 32 cm deadrise that increases on the subsequent frames fore or aft.[902]

Not all frame stations uncovered were recorded by the archaeologists, but the profiles that were collected suggest two different rising amounts to create the entry and run for the ship. Due to the relatively few floor timbers that survive behind the aft tail frame, it is unclear how the shipbuilders created the Y-frames or whether these only relied on battens attached to the lower end of the hull. The profiles of each surviving frame suggests that the carpenters relied on a single arc with a 7 m radius and that the sweep for the deadrise was drawn by reversing the upper curve. Past the second deck, a smaller associated tangent arc was utilized to straighten the frames as they progressed up to the sheer strake (figure 84).[903]

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[900] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 39; Guérout and Rieth, 'The wreck of the *Lomellina* at Villefranche sur Mer', 41.
[901] Guérout et al., 'Le navire Génois de Villefranche, un naufrage de 1516?', 42-4, fig. 17
[902] Ibid., 40.
[903] Cazenave de la Roche, *The Mortella III Wreck*, 128, fig. 71.

Mortella III and Calvi 1 also provide further insights into the design process for ships built along the Ligurian coastline. Mortella III's remains include a single master frame that also relied on a 5.8 m radius arc, as the surviving floor timber and futtocks follow this curvature closely (figure 85).[904] The master floor timber includes a 33 cm deadrise and the absence of a foot to create a wineglass profile is supplemented by the robust double keel. Uncovering multiple sections across the hull also allowed an accurate determination of keel length (25 m), while the missing flat section of the lower stem added an additional meter.[905] Based on this information, the master frame was positioned directly on the center of the keel with the mainmast positioned slightly forward of this point.

Most of the surviving frame stations between the center of the hull and the sternpost were uncovered during the excavation. Except for the master frame, none of the other frames were removed for further recording that might help identify the aft tailframe. Based on the theoretical descriptions in contemporary Iberian treatises, the tailframes are positioned 12 m distant from the central master frame.[906] None of the after frames provide any direct evidence separating them from the other frame stations. Most of the forward section of the hull remains unexcavated and the stem is missing. Surviving elements of the V-frames suggest these were installed straight onto the keel, while their associated first futtocks canted outward.[907]

Since the remains from Calvi 1 are mainly the stern section of the hull, there is unfortunately less predesign evidence in its construction compared to the other ships. Most of the stern is comprised of Y-frames and these are assumed by most reconstructions as empirically

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[904] Ibid., 125-7, fig. 72.
[905] Ibid., 71-3.
[906] Ibid., 43-5.
[907] Ibid., 56, fig. 4.

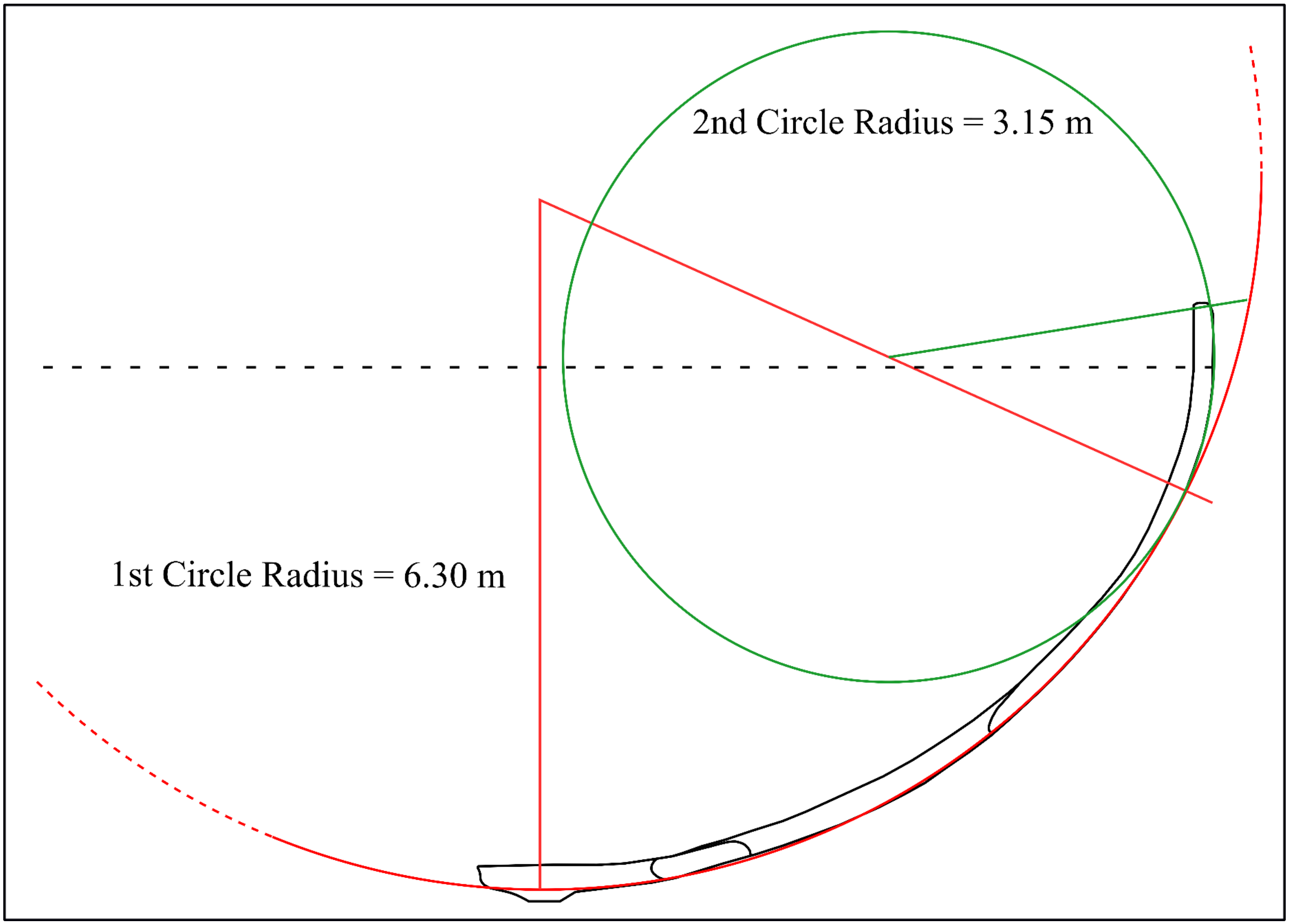

Figure 84   Outline of floor timber W54 from Villefranche shipwreck showing the single arc below the waterline and a smaller arc used near the transition to the upper hull. (after Arnaud, 'The Mortella III Wreck', 128, fig. 171)

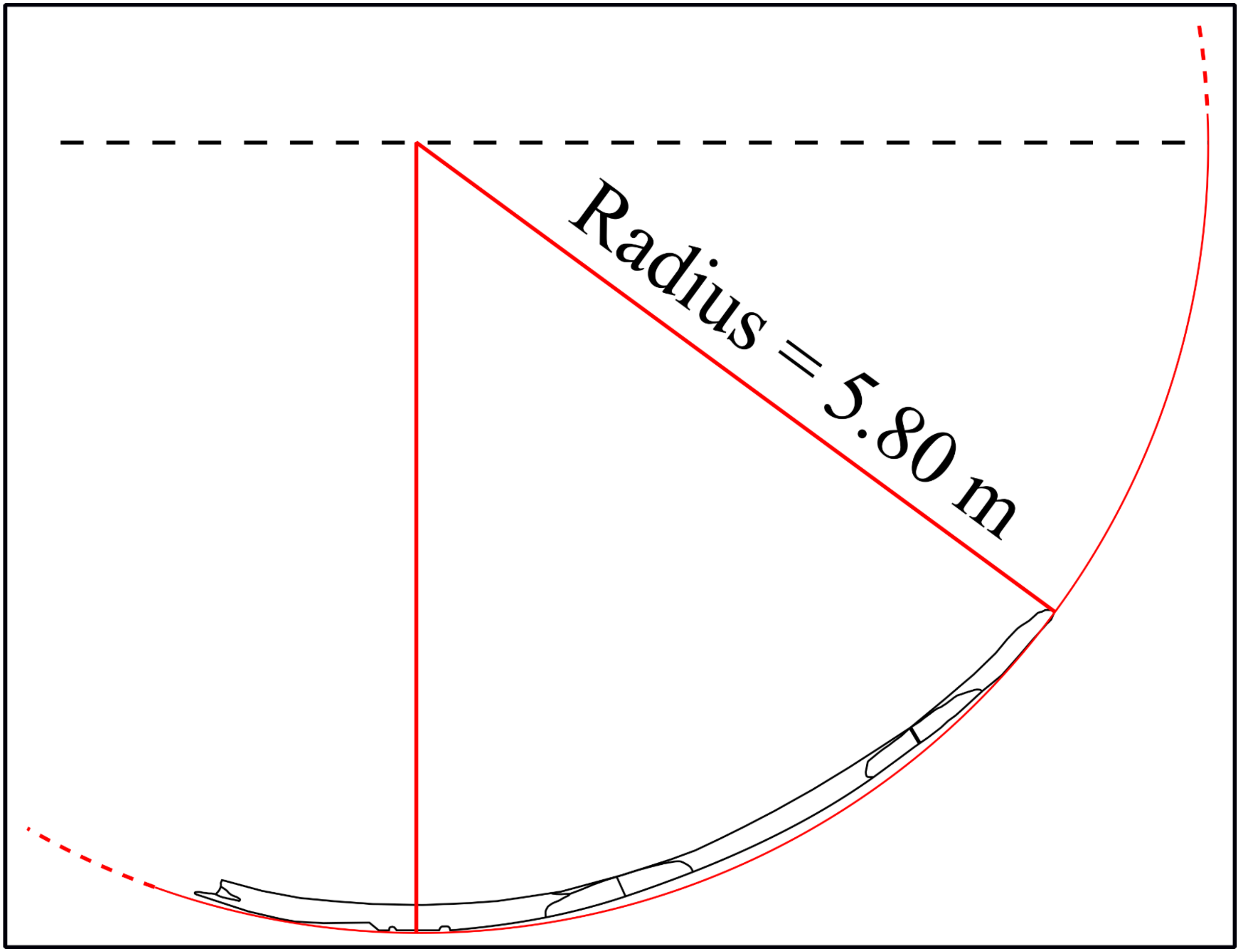

Figure 85 Outline of the master frame from Mortella III shipwreck showing the single arc below the waterline. (after Arnaud, 'The Mortella III Wreck', 128, fig. 171)

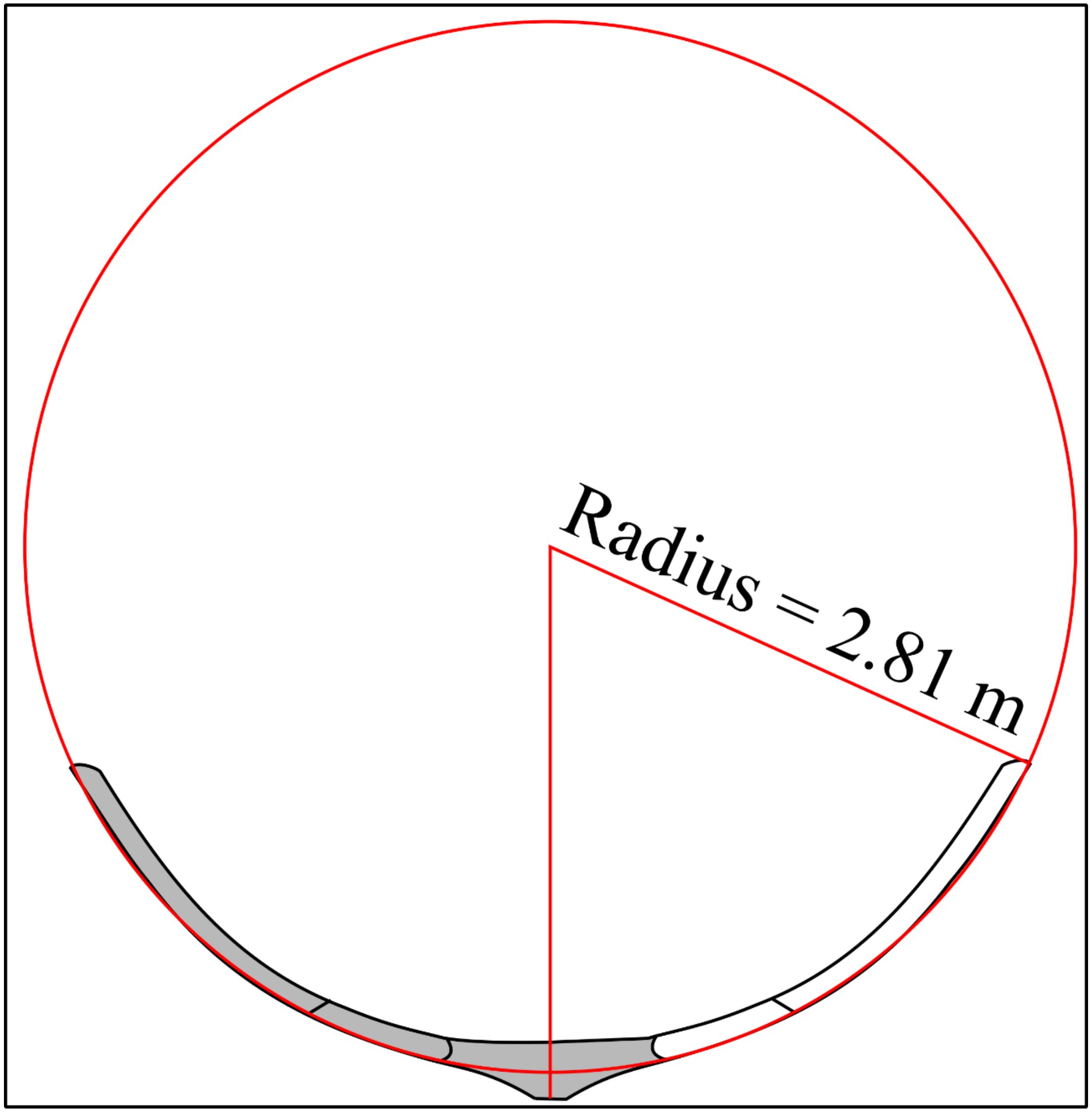

Figure 86   Outline of floor-timber 20 from Calvi 1 with the surviving portion in gray. (after Arnaud, 'The Mortella III Wreck', 127, fig. 168)

devised through a mixture of battens attached at specific points along the frames and relying on the reverse curve of the master frames' futtocks.[908] The earliest reconstruction by Pierre Villié examined the treatises by Teodoro de Nicolo, the Portuguese priest, Fernando de Oliveira, and Joseph Furttenbach. Villié decided that Teodoro's *nave* description was an exact match with Calvi 1's remains.[909] The master frame was positioned on the center of the keel and most of the other measurements for the hull were proportions based off this length.

Michel Daeffler attempted a second reconstruction of the missing forward section by relying on a larger sample of contemporary documents. He argued that the master frame was also placed on the center of the keel with the maximum beam being 7.68 m (Villié's reconstructed beam was slightly larger: 7.8 m).[910] Daeffler also argued that other elements of the hull were in proportion to the keel's length. The after tailframe was positioned three-tenths forward on the keel from the sternpost. Daeffler's master profile relied on applying several different concepts by contemporary authors, including tangent arcs inside and outside the "square", and he suggests that several master templates were used to create the floor timbers and futtocks. He emphasized the use of the molds by showing how the surviving Y-timbers were fashioned with the central futtock template.[911] Based on surviving frame stations further forward on the hull, Arnaud Cazenave de la Roche argues instead that the frames were devised in a similar manner to Mortella III with a single arc below the waterline. Calvi 1 also shares elements with

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[908] Daeffler, 'Deux exemples de conception des navires de commerce de la seconde moitié du XVI^{e} siécle', 152, fig. 11
[909] Villié, 'L'épave Calvi 1 (1991)', 99
[910] Daeffler, 'Deux exemples de conception des navires de commerce de la seconde moitié du XVI^{e} siécle', 146
[911] Ibid., 152, fig. 11.

Villefranche, such as a 39 cm deadrise created at the bottom creating the wineglass shape and a secondary tangent arc used to shape the upper futtocks (figure 86).[912]

The remainder of the ships listed on Table 1 provide limited information about the intended designs of smaller vessels. Most of these examples predominantly rely on a dual master frame pattern. Cap Lardier 1 is an exception, where a single master frame was possible depending on how the stains left behind from its missing timbers and fasteners are interpreted. Several of the ships suggest that dual master frames were positioned based on the keel length alone. Most of the keel from Sardinaux is missing, except for the forward end and a small section at the stern.[913] While most of the frame stations are represented, only the forward end of the planking survives. Reconstruction of the missing frame stations at the bow (from the staining on the surviving planks), along with the remainder of the framing, suggests that dual master frames were positioned near the center of the keel. Sardinaux is also one of few smaller vessels published with several floor timber profiles. The narrowing applied from amidships to the endposts suggest at least an 8 cm decrease, while there does not appear to be any rising applied to the surviving frame stations.[914]

Remains from the West Turtle Shoal wreck also suggest that the dual master frames were positioned forward of the center of the keel. This interpretation is tentative because the missing heel timber precludes having an accurate keel length. West Turtle Shoals provides one of the few examples of an aft tail frame positioned nine frame stations from the aft master frame (figure

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[912] Cazenave de la Roche, *The Mortella III Wreck*, 126-7, fig. 68.
[913] Joncheray, 'Un navire de commerce de la fin du XVII[e] siecle, l'épave des Sardinaux. Première partie: Le navire et son mode de chargement', 44
[914] Ibid., 47-51, fig. 26.

87). Compared to the surrounding frames, the tailframe is the only example with a futtock butted on its forward face and another hook scarfed on the after face.

Most of the center sections of the floor timbers from Yassıada 3 are missing, but the scarf joints at the arms identified the position of the master frames. Based on the estimated overall length for the ship, the dual master frames are positioned 71.5 cm forward (or 59.5 cm between endposts rabbets) by two frame stations from the center.[915] Agropoli is unique with the dual master frames butted together without space between them. The original keel length for the ship is unknown, but the master frames are positioned 10.35 m from the bow.[916] Current estimates place the overall length of the original ship at 23 m, which suggests the dual master frames were placed forward of center. While research on *Kadırga* identified the dual master frames, further work is still required to differentiate between the original design and repairs. Cap Lardier 1 is the only example where the dual master frames appear to be centered based on the overall estimated length for the ship rather than the keel.

Seventeenth-Century Treatises

Nautica mediterranea (1602)

Conceptual information about Mediterranean shipbuilding from the late medieval and renaissance eras is largely derived from surviving documents associated with the Venetian arsenal. Several seventeenth century sources originate from different shipbuilding enclaves in the western Mediterranean. In 1602, papal engineer Bartolomeo Crescentio published his work *Nautica mediterranea*, which discusses topics such as navigation, propulsion, and shipbuilding.

[915] These measurements were obtained from Labbe, 'A Preliminary Reconstruction of the Yassıada Sixteenth-Century Ottoman Wreck', 154, fig. A.4. with the origin point for the dual master frames centered between the floor-timbers.

[916] Bondioli, Capulli, and Pellegrini, 'Note storico-archeologiche sul relitto di Agropoli', 72.

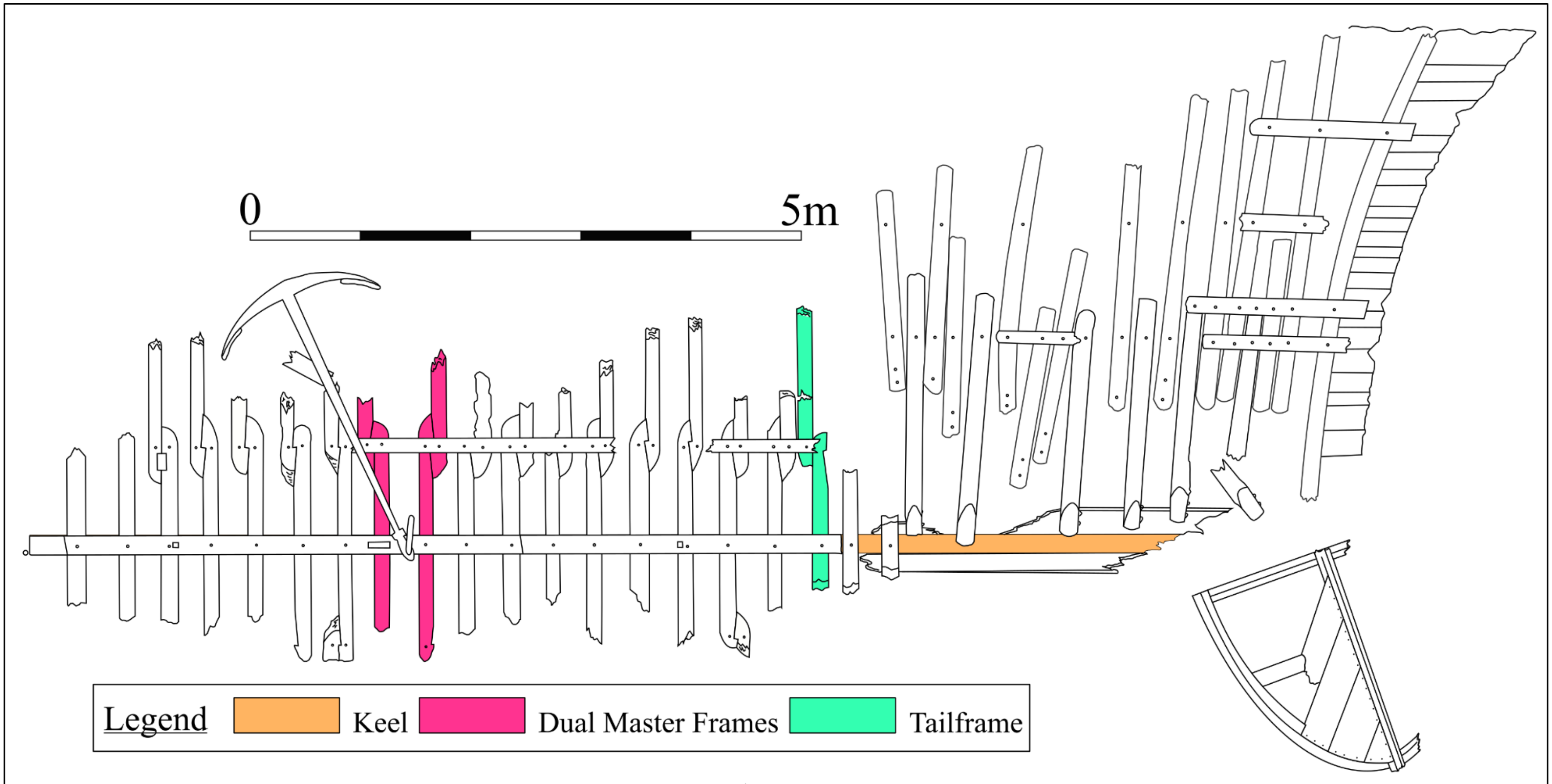

Figure 87 Site plan of the West Turtle Shoals shipwreck with the key design frames highlighted. (after Russo, West Turtle Shoals Wreck (8MO142), 7)

Several chapters within Crescentio's work include instructions for building a galley, galleass, and a galleon. His instructions for the galley are the most complete and assumes that the reader will apply this information when reconstructing the other two vessel types. From the limited information provided by Crescentio at the beginning of his book, we know that he served on galleys for the pontiff and spoke with shipbuilders from Naples.[917] The narrative for the galley suggests he was familiar with the concepts presented but not necessarily proficient in the theory and methodology.

For instance, Crescentio begins his construction narrative by explaining how to design the sternpost by first creating a circle using a compass. Cutting the circle into a fourth creates the "square" providing the rake and height of the sternpost. Crescentio explains that the true rake of the sternpost is much longer than the square created by the circle and that this line needs to be extended beyond for the true length.[918] In the following figure, we are provided with a completed sternpost drawn within the square (figure 88). Key features include a line drawn near the center of the rake and another providing the radius of a circle from the corner of the square. Drachio's description that battens were used to curve and match specific points seems to apply to Crescentio's sternpost (although the latter author argued for a compass). This curve extends upward to meet the edge of the square representing the height of the sternpost where the main wale ends. The sternpost extends outside the square, which shows a similarity with several earlier Venetian examples.

Crescentio's stem and master frame drawings also include this feature where the upper end of the stem or futtock continued beyond the line representing the height of the hull (figures

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[917] Crescentio, *Nautica mediterranea*, 21.
[918] Ibid., 9-13.

89 and 90). On both examples, the point where the timber extends beyond this line is where the main wale should be positioned. Most contemporary treatises record the height of the master frame or endpost as the position for the main wale, although these components often extend further beyond this point based on the preference of the author (or shipbuilder). While the three figures by Crescentio are not identical, all three timbers are created using the same methodology with the curve differentiation based on the two intermediate points provided.

Crescentio explains that shipbuilders created guide sticks called *brusca* that relied on the mezzaluna or infinite stick methods.[919] The galley includes a single master frame with identical copies fore and aft. Beyond these center frames, there were an additional 45 other frames all narrowed using the mezzaluna. All frames fore and aft of the 10th frame from the central section included a rising adjustment to each floor timber. While the mezzaluna could be used to adjust the narrowing and rising, Crescentio mentions that Neapolitan shipbuilders preferred the infinite stick method to adjust the latter.[920] Narrowing of the ship was equal on both ends, but the rising adjustment differed depending on whether it was for the bow or stern. Beyond the tailframes, the floor timbers were adjusted empirically by the shipbuilder's own judgement.[921]

Other components Crescentio includes appear in a figure showing the central profile for the cambered deck, central-walkway, and the base extension for the outrigger. Only after including this construction information does Crescentio mention the heights for the wale between amidships and endposts, although the measurements he cites do not match those included on the figures. He claims that adding additional palms above the wale provides the camber for the deck.

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[919] This method is similar to the incremental triangle by relying on an arithmetic progression in a linear format that followed the total length the builder was going to reduce or increase frames on the ship.
[920] Crescentio, *Nautica mediterranea*, 16-18.
[921] Ibid., 19-22.

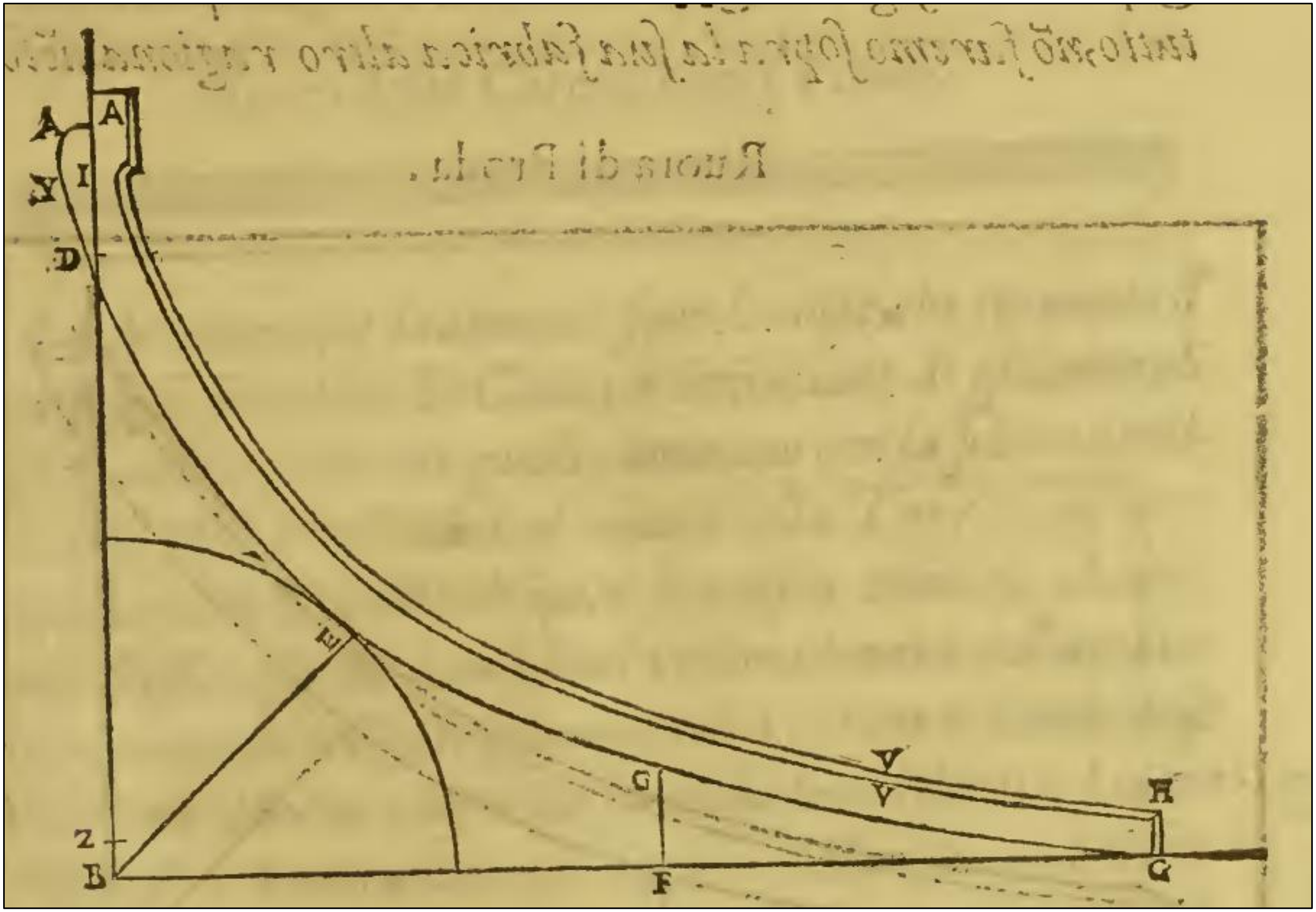

Figure 88 Crescentio's drawing for the galley's sternpost. (Crescentio, Nautica mediterranea*, 11)*

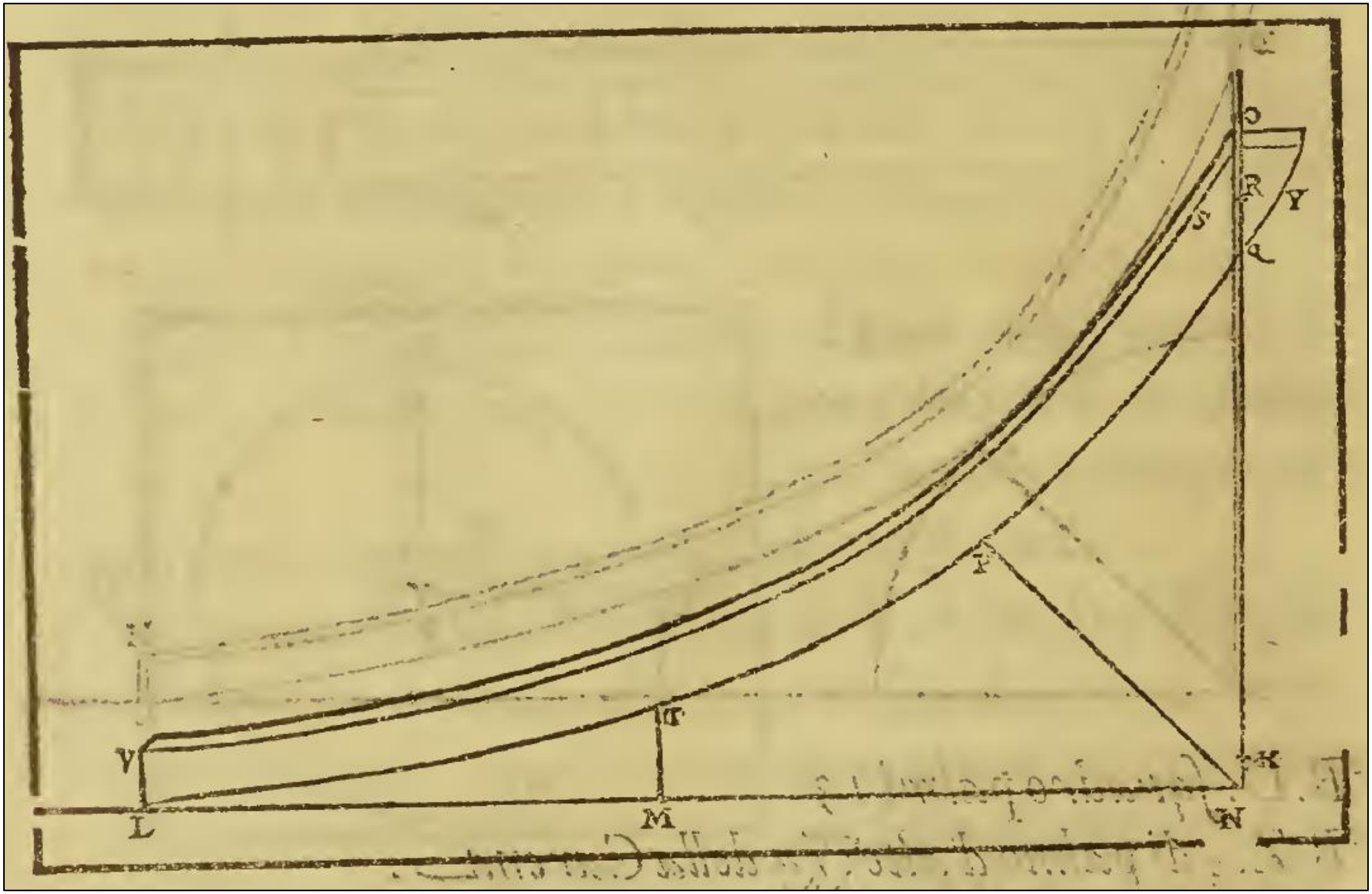

Figure 89 Stem for Crescentio's galley. (Crescentio, Nautica mediterranea, *12)*

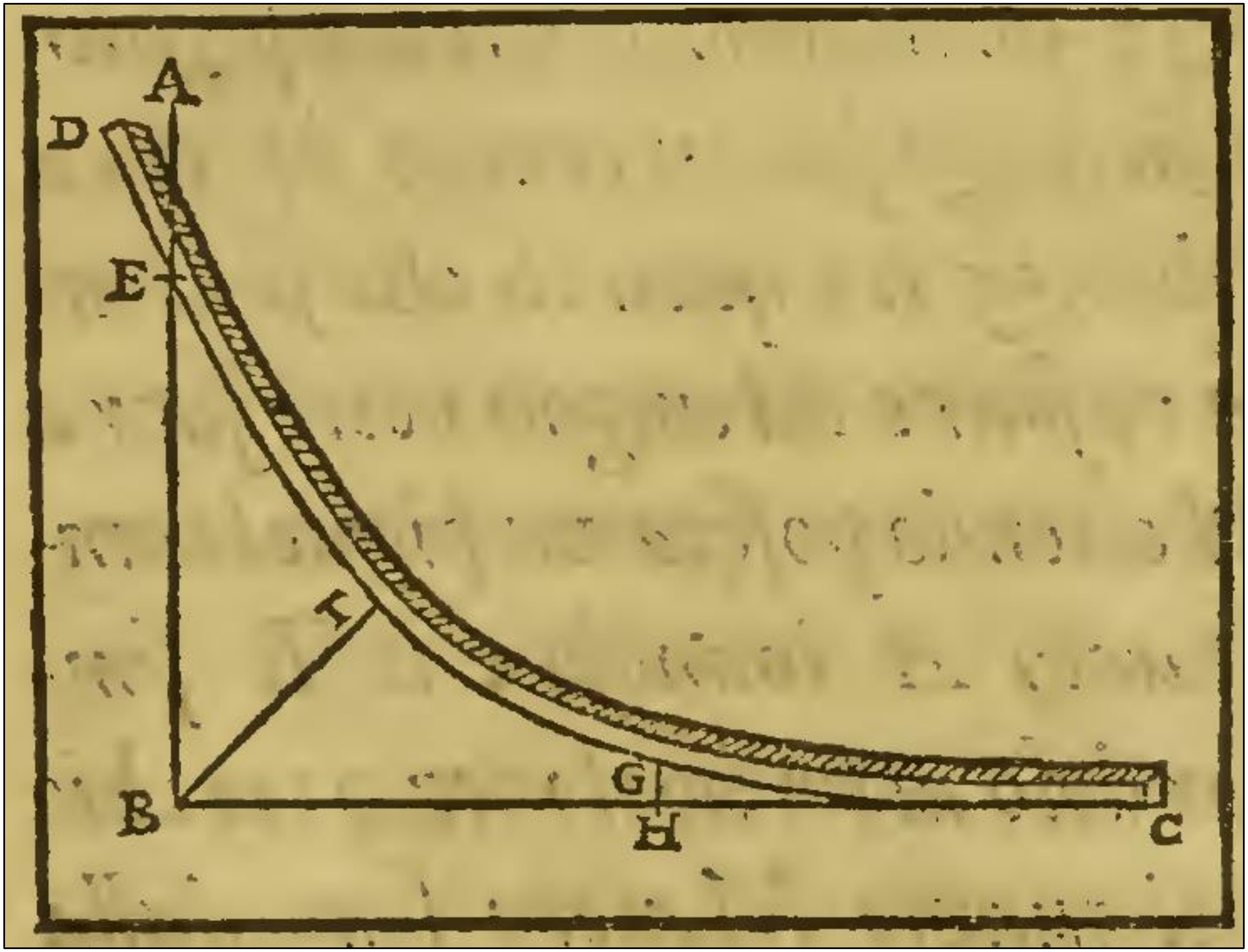

Figure 90 Half-breadth profile for Crescentio's galley. (Crescentio, Nautica mediterranea, *15)*

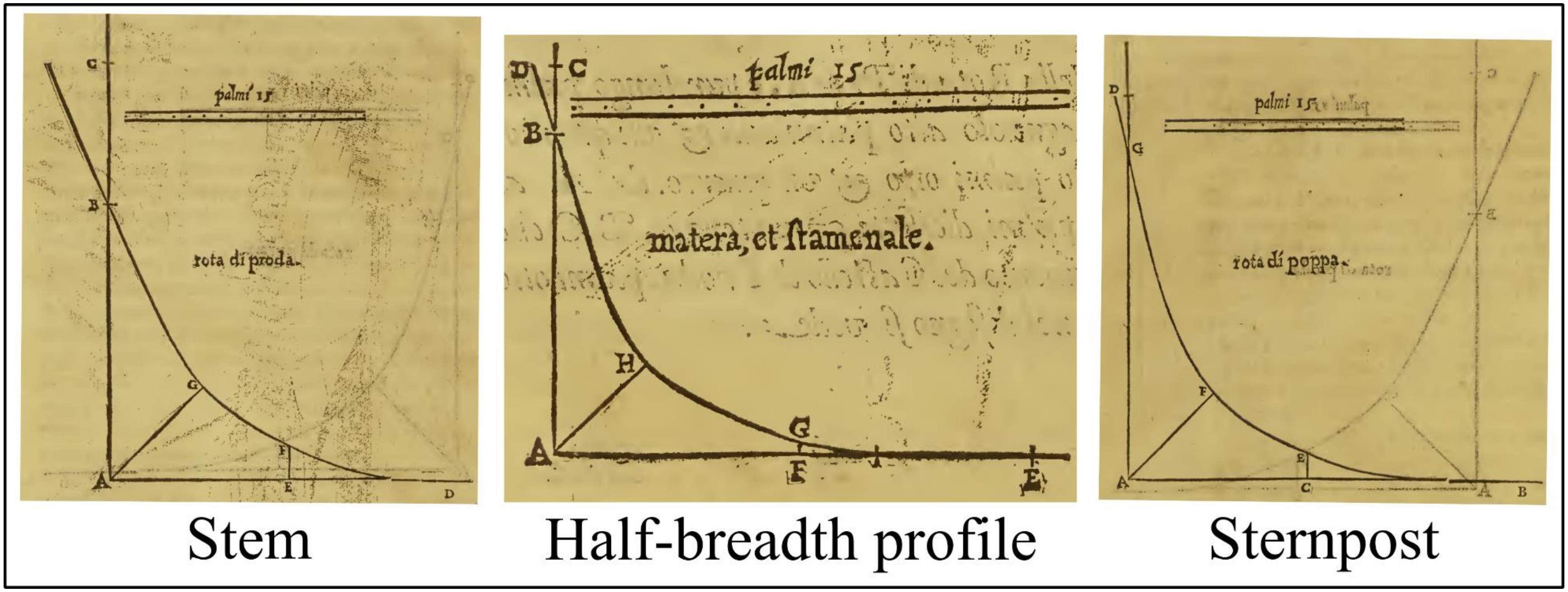

Figure 91 Crescentio's drawings for the stem, half-breadth profile, and sternpost of the galleass. (Crescentio, Nautica mediterranea, *59-60)*

After this description Crescentio mentions the overall length of the ship and further divides it between the endposts, keel, and then between specific cabin or cargo areas.[922] The remainder of the chapter discusses the positioning of the mainmast step, dimensions of the masts, rudder, and the accoutrements of the outrigger system.

In the following chapters, Crescentio discusses how the outrigger elements were assembled and how to manufacture sails before delving into a more theoretical discussion on machines to permit rowing with fewer crewmembers. The discussion of the other two ships is brief. Crescentio writes that all components used in the galley are also utilized for the galleass with only the difference in size as the major factor.[923] His galleass figures are less fleshed out with only lines showing the curves for the endposts and master frames (figure 91).

Crescentio's description for the galleon (or general round ship) includes extra information about finding the proportions for the vessel. He explains that the hull is based on the "*interzo*" rule: the endposts and keel together equal three times what the beam should be.[924] Narrowing of the frames is by a third of the floor, but the rising is dependent on the shipbuilder. Crescentio's own rising amount shows a very subtle difference between the fore and aft floor timbers from the master frame. He continues with a description of the height of three different decks that are related to each other by ratios and that they altogether comprise almost a third of the overall length for the ship. After providing this information, Crescentio then states the length of the keel, along with the rakes for both endposts. There are no figures for this section, so Crescentio includes descriptions with the gradual entry and run for the ship. The first wale is

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922 Ibid., 23.
923 Ibid., 57-8.
924 Ibid., 63.

described as positioned at the load waterline, which is approximately half the height of the ship.[925]

The remainder of this chapter contains a variety of details, including a description of the ship's castles and their equivalent terrestrial defensive structures. Crescentio also suggests including a false stem elongating the bow to cut better through the water, the use of dovetail scarfs to keep wales recessed over the futtocks after iron nails rust away, and the recommendation for using bronze fasteners to extend the overall life of the vessel.[926] The chapter concludes with the mention of a treatise by Ragusan naval officer Nicolo Sagri with measurements for a galleon similar in proportions to the ship described by Crescentio. A single figure copied from Sagri's treatise shows a circle with a quarter representing the curvature for the stem.[927] Several points marked along the radius of the circle from the keel to the center represent different deck levels based on divisions of the overall length of the ship.[928] Finally, there is a tonnage calculation by Sagri based on Venetian feet that determines how many *salmas* (270.7 dry liters or 139 kg) of wheat from Sicily the ship could carry. The five chapters after the construction section describe the masts and sails for the galleon, the hardware, and how to launch the three types of ships after their hulls are sealed.

Crescentio's book overlaps with the treatises and *zibaldones* that came before it. Compared to the lists of scantlings with limited imagery provided by Michael of Rhodes, Crescentio is more aligned with the details provided by Zorzi. He put scales on his drawings and included better descriptions for the design of key hull timbers. Crescentio encounters the same

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[925] Ibid., 64-5.
[926] Ibid., 66.
[927] Dell'Osa, *Il carteggiatore di Nicolò Sagri*, 124-5, fig. 1.
[928] Crescentio, *Nautica Mediterranea*, 68-69.

issues that arise from Venetian manuscripts not prepared by shipbuilders. These texts provide the overall design without explaining the proportions that led to the use of specific measurements. For the galley and galleass, Crescentio is satisfied with his figures, measurements, and explaining the methods for narrowing and rising. He only briefly references the overall measurements without ever explicitly stating the keel length, except when measuring out the distances between cabins or areas within the hold. The elements for the outrigger and propulsion system are less detailed in imagery but have their own chapter on the assembly.

When Crescentio shifts to the galleon or *nave*, he appears to be borrowing much more from other sources (such as Sagri) to make up for his own inexperience with these vessels. The galleon is laid out in proportions beginning with the keel that dictate the rest of the measurements for the overall vessel. His elongated bow, recessed wales, and other modifications suggest someone attempting to apply construction elements from the traditional longship assembly upon round ship design. The absence of any design figures for the galleon compared to the longships also supports the argument that Crescentio did not have the access to or understanding of this class of vessel. The different linear units between Crescentio's longships and round ships provide additional evidence that he was borrowing from other sources. Almost all the units used to discuss the galley and galleass are either in palms or cubits, while the round ships are discussed in feet (presumably either Venetian or Ragusan). If the round ships described by Crescentio were mainly derived from Adriatic texts, then it remains unclear whether the mention of the Neapolitan shipbuilders was his only source for the longship assembly.

Neapolitan preference for the infinite stick when applying the rising on floor timbers to create better curves seems limited when compared to the same effect using the mezzaluna.[929]

Architectura navalis (1629)

In 1629, Joseph Furttenbach published his shipbuilding treatise *Architectura navalis* at Ulm, Germany. Furttenbach was the twentieth son of an affluent family sent to Italy at a young age to learn mercantilism around 1607.[930] For the next decade, Furttenbach traveled between the major northern Italian cities learning about the local culture and developing commercial ties for his family back in Ulm. Furttenbach published several treatises after returning home based on engineering, architecture, and his personal experiences while visiting places like Milan, Florence, or Genoa. While Furttenbach's original shipbuilding treatise was published in German, much of the key terminology and measurements was in Italian.

Horst Nowacki's summary of Furttenbach surmises that the author visited the Venetian shipyards to obtain his information regarding Italian shipbuilding.[931] Massimo Corradi and Claudia Tacchella argued that Furttenbach learned most of his shipbuilding information from the Genoese arsenal.[932] Examining the text itself seems to agree with the latter hypothesis, especially since Furttenbach relies on palms rather than feet for the measurements of each ship. He also cites Genoa within his text when discussing his departures from this city to visit the Ligurian coastline or to travel in larger vessels to Syria on trade missions.[933]

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[929] For a comparison of the curves between the infinite stick versus mezzaluna, see Castro, 'Rising and Narrowing: 16th-Century Geometric Algorithms used to Design the Bottom of Ships in Portugal', 153, fig. 9

[930] Corradi and Tacchella, 'At the Origins of Shipbuilding Treatises: Joseph Furttenbach and the *Architectura Navalis*', 2.

[931] Nowacki, 'Shape Creation Knowledge in Civil and Naval Architecture', 28.

[932] Corradi and Tacchella, 'At the Origins of Shipbuilding Treatises: Joseph Furttenbach and the *Architectura Navalis*', 3.

[933] Furttenbach, *Architectura navalis*, 71, 78.

Nowacki also believed that Furttenbach's writings were an original creation that were not copied from similar publications around the same time such as João Baptista Lavanha's *Livro primeiro da architectura naval*.[934] Although it might be true that Furttenbach was unaware of Lavanha's writings (and his similar application of the term "naval architect"), there is some overlap between Crescentio and Furttenbach. Crescentio's own writings compares his galley to a fish, specifically a dolphin, where the head is wide and blunt before becoming thinner toward the stern. The rudder acts as the tail of the fish and maneuvers the entire vessel in the water.[935] Furttenbach makes the same statement about his own galley, describing the ship as dolphin-like.[936] This overlap suggests that Furttenbach either obtained or had access to Crescentio's book during his travels through Italy (or perhaps the dolphin was a well-known analogy). Beyond this similar statement, it appears that Furttenbach's own work is unique and discusses measurements not found in Crescentio's treatise, even if the design process is the same in both works. The fish analogy is also used elsewhere, since English royal shipbuilder Matthew Baker depicted in a watercolor the image of a galleon and a superimposed fish.[937]

Compared to Crescentio's treatise, *Architectura navalis* is a relatively straightforward text that describes the design and assembly of major hull components for various ship types. The most detailed description is reserved for a great galley with discussions of officers, crew, rations, positions of the guns, and information on its construction. The remainder of the document summarizes other ship types such as the galleass, *galeotta* (longship), brigantine, felucca, *fregata* (longship frigate), *leudo* (lateen sailboat), *barchetta* (little boat), *piatta* (canal boat), *nave* (ship),

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[934] Nowacki, 'Shape Creation Knowledge in Civil and Naval Architecture', 28-9.
[935] Crescentio, *Nautica mediterranea*, 13-14.
[936] Furttenbach, *Architectura navalis*, 16.
[937] Blatcher, 'Chatham Dockyard and a little-known shipwright, Matthew Baker (1530-1613)', 160-2

polacre (ship similar to a xebec), *tartan* (sailboat), barge, *caramuzzala* (Turkish vessel), *barca* (small longship), and sailboat. The *piatta*, *fregata*, *nave*, *polaca*, and *barca* include additional information about their designs, construction, and provide an associated drawing. While Furttenbach's writing suggests he had first-hand knowledge about the construction of his great galley, it lacks the same level of direct observation for other vessels mentioned in the treatise. In fact, he noted at the beginning of his discussion for the *nave* that it took him longer to finally write about an existing ship that he claimed was better-shaped than others and that some of the work contains speculation.[938] Furttenbach's description of the *barca* appears to convey a similar message, as he claims the associated plan is for a ship he was aboard as a passenger while traveling from Genoa to San Remo.[939]

Compared to the earlier sources, it seems ironic that a treatise about Mediterranean shipbuilding written by a German includes some of the best descriptions and associated imagery about longship construction. Furttenbach's great galley is designed in the manner mentioned by most authors since Michael of Rhodes' manuscript. The ship includes a keel, sternpost, and stem flat scarfed to each other with a counter timber (stern and stem knees) that covers the scarfs on the inside of the hull (figure 92).[940] The beak of the galley is composed of a large hanging knee attached to the front face of the stem. There is a modification of the sternpost with the addition of two wedges: one to hold the lower gudgeon and another to act as a skeg on a curved post. Overall, the hull is composed of 162 frames with two dual master frame positioned slightly forward from the center of the overall length of the hull. The remainder of the framing is divided into six sections, the first two on either side of the master frames reduce in width only, the next

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938 Furttenbach, *Architectura navalis*, 71.
939 Ibid., 87.
940 Ibid., 16-17, 21-4.

two continue to reduce and have a foot added from a rising tablet, while the final aft and fore sections increase the rising between each frame station on the sternpost and stem respectively.[941] Like Crescentio and other contemporary shipbuilding treatise authors, Furttenbach argues for predesigning the ship's key components on paper using a compass that was subsequently applied to timbers in the shipyard. Both endposts shown by Furttenbach are designed by providing the square with an arc extended from the point where the rake and height for either post meet (figure 93).[942] Once the square is set up, two arcs are drawn with a compass that both meet toward the middle of either post. The master frame for the great galley follows a similar pattern, except a flat floor separates either side (figure 94). Each consecutive frame is reduced by using a mezzaluna that can also be used to create the rising scale for floor timbers further away from the center of the hull.

The last section of Y-timbers is designed by first collecting offsets from a drooping cord connected between the last stern frame to the 34th station.[943] Both arms of each Y-timber are designed based off the master frames' futtocks that overlap on their upper sections and are flipped over to continue this curve to the foot.[944] The upper width for each Y-timber is reduced based on a consecutive scale also provided by Furttenbach. This scale is drawn with the same length over the hull where the frames are installed. At the bottom is the width of the 34th frame, while the top line is the width of the last Y-timber. Between these lines are 32 equal parts that create a long trapezoid providing the widths for the top of each consecutive Y-frame.

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[941] Ibid., 26-8.
[942] Ibid., 21-4.
[943] Furttenbach claims to use the cord in the shipyard to collect offsets for the rising foot of the stern frames but also informs the reader to collect these measurements using a compass from the image in his book.
[944] Furttenbach, *Architectura navalis*, 33-5.

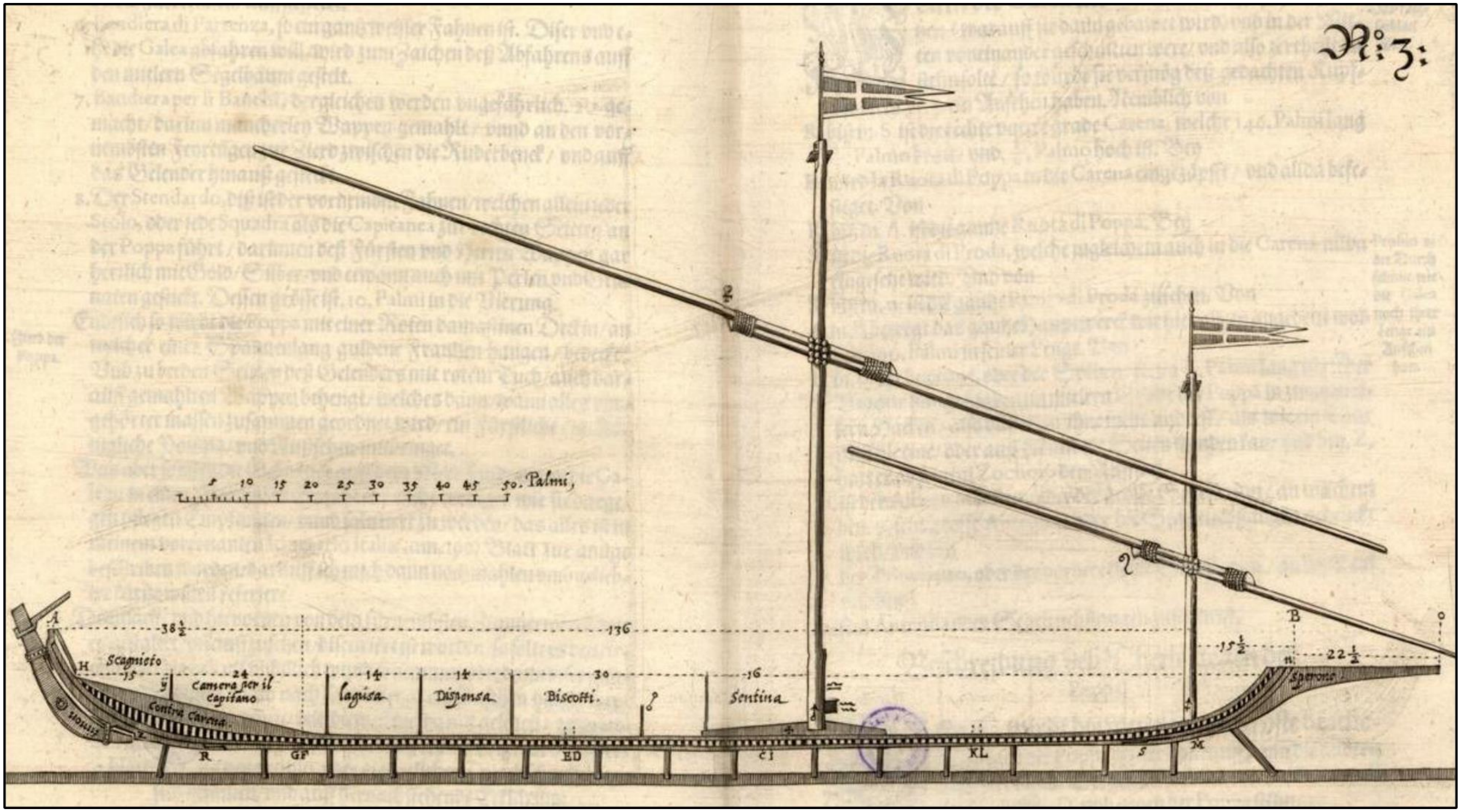

Figure 92 Side profile of Furttenbach's great galley. (Furttenbach, Architectura navalis*, engr. 3)*

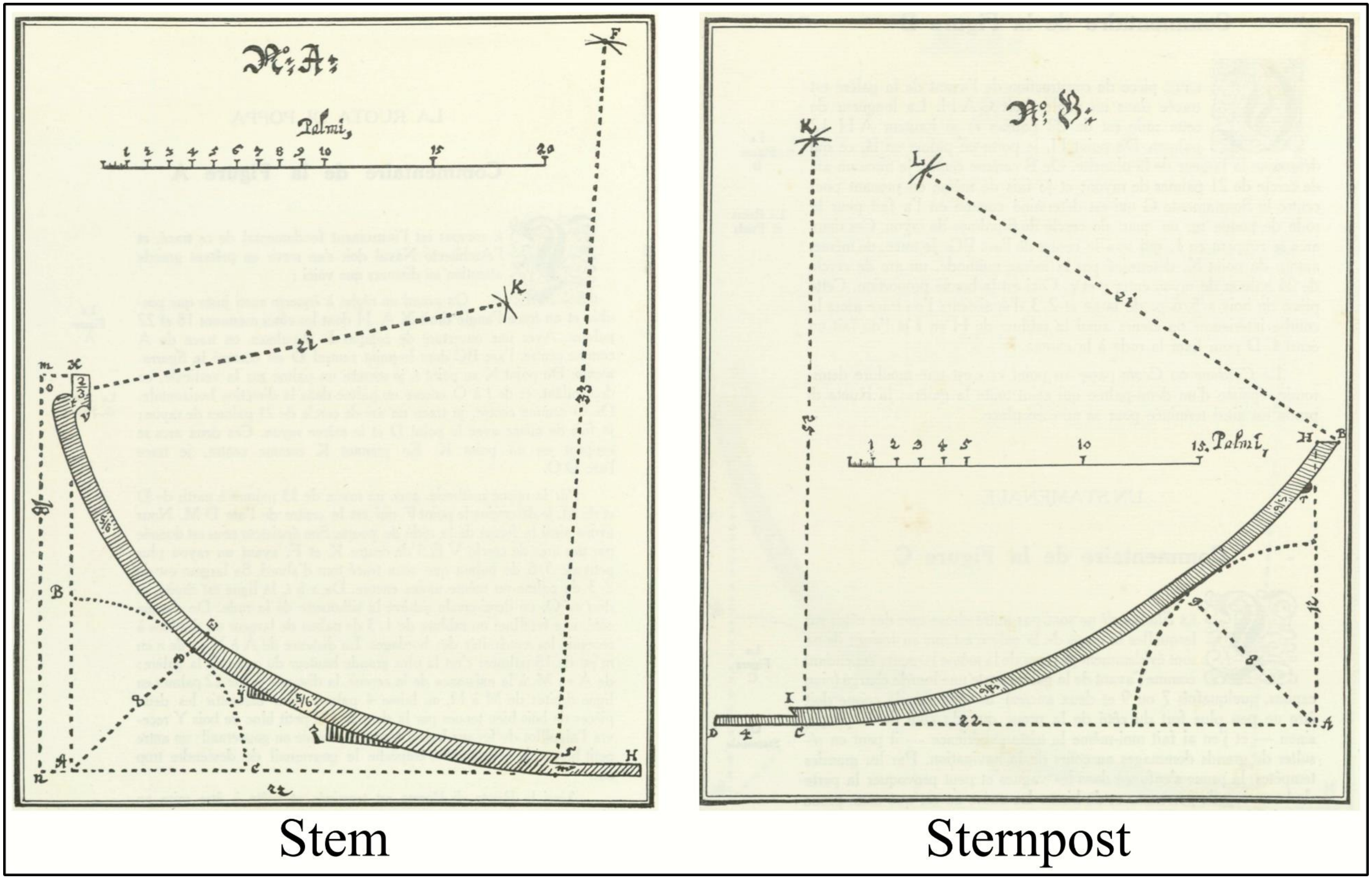

Figure 93 Side profile of Furttenbach's great galley. (Furttenbach, Architectura navalis, *fig. A and B)*

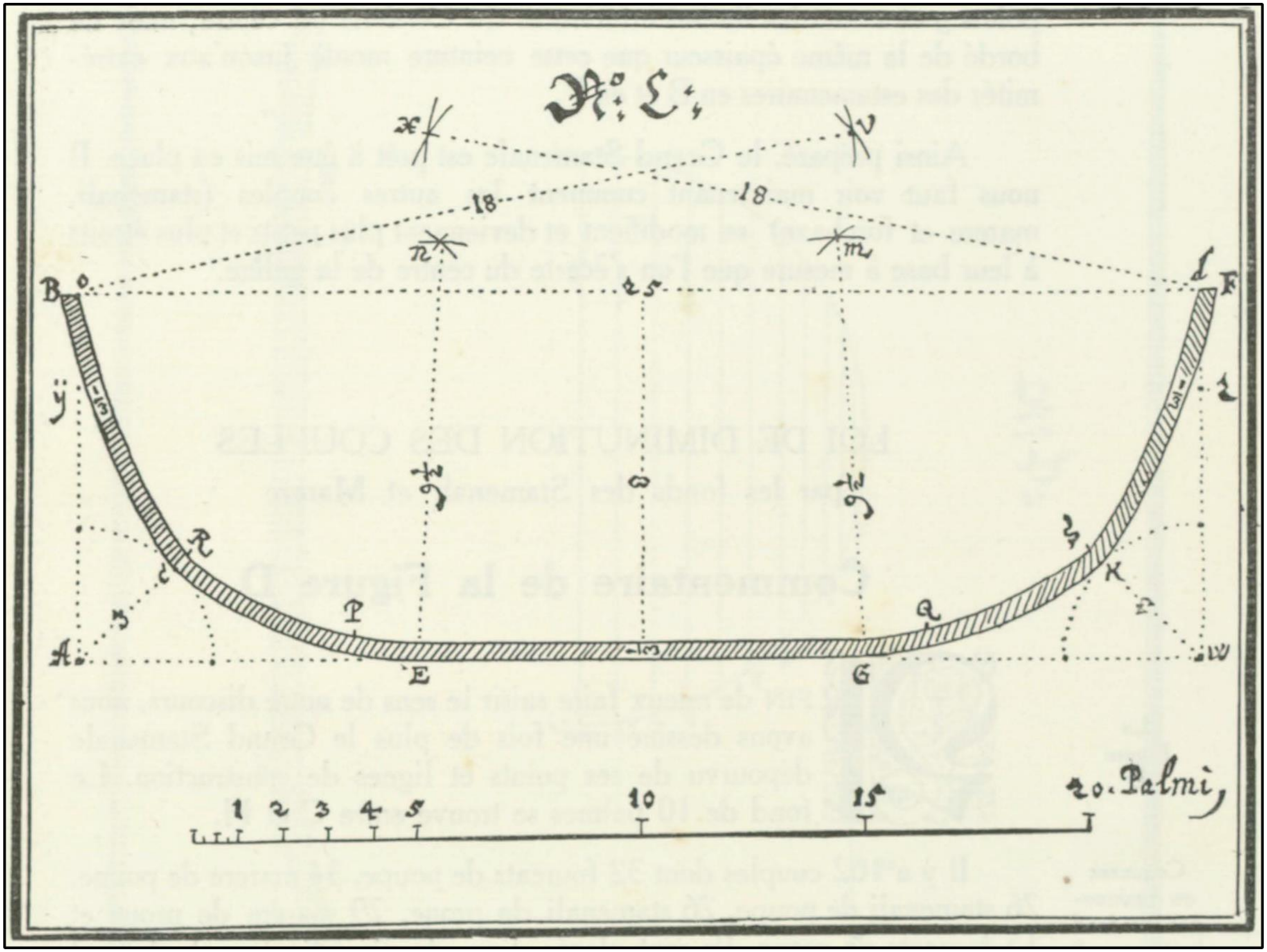

Figure 94 Amidships profile for Furttenbach's great galley. (Furttenbach, Architectura navalis*, fig. C)*

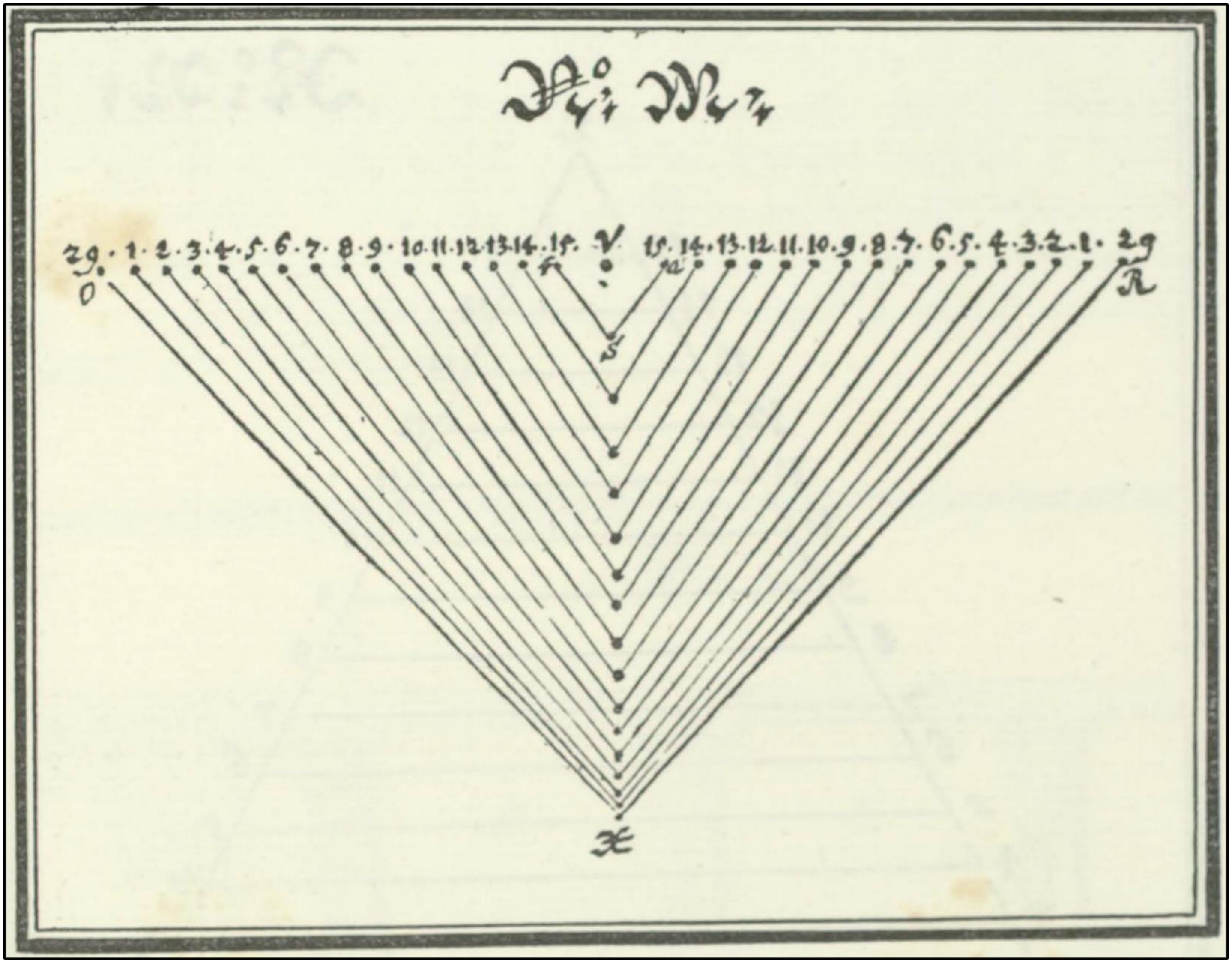

Figure 95 Method for predesigning the bow frames. Furttenbach instructs the reader to use the futtocks of the master frames to adjust them accordingly on this figure to find their correct shape at each frame station. (Furttenbach, Architectura navalis, *fig. M)*

The V-frames at the bow are devised based on a slightly different system (figure 95). None of the V-frames include the foot seen on the Y-frames, their height is provided by a figure composed by Furttenbach showing that that each frame becomes shorter as they get closer to the bow. The shape for each V-frame is drawn as a corresponding V-shaped scale by Furttenbach, informing the reader to again use the futtock shape of the master frame to fit on the scale as appropriate.[945] Another figure providing a triangle divided into equal parts for the width of each consecutive V-frame provides further context. After the framing is installed, Furttenbach describes that the ceiling was mounted within the hull and that a thicker piece of wood was used to fit into the crook of the aft Y-timbers.[946] The remainder of this section includes details about the mast step, masts, deck, outrigger construction, central gangway, stern and bow structures, along with the anchors, flags, and other elements deemed important to outfit the ship.

Furttenbach's images for his great galley and all other ships in his treatise show an obvious misalignment of the tangent curves between sections. This misalignment is due to the different arcs applied to the frames providing a "boxy" shape, while earlier imagery, such as Crescentio's publication, provide faired profiles. This difference seems to suggest the different design methodologies, perhaps between different shipbuilding communities. Crescentio appears to follow the earlier methods described by Venetian manuscripts that specific points must be met in one fluid curve using a compass (or batten in the shipyard), while Furttenbach is arguing for more complex shape with tangent arcs implemented within the shape of the hull. Another possible explanation is that Furttenbach is providing the basic arcs with the assumption that a

[945] Ibid., 36-9.
[946] Ibid., 32.

craftsman using his work would know to fair the misalignment between these arcs when applied to the timber.

The round ship that Furttenbach describes as a *nave* is suggested by Corradi and Tacchella to be a contemporary Dutch *fluyt* (ship).[947] From the description provided by Furttenbach, it seems the author indeed found an ideal Dutch candidate for his drawing. Contemporary Dutch shipbuilding relied on a technique where most of the bottom planking was temporarily fastened before the installation of any framing. Multiple master frames were possible, but for the most part these ships relied on a single master frame.[948] Adoption of frame-based shipbuilding in the Low Countries only became widespread by the end of the seventeenth century.

What Furttenbach describes for his *nave* is a combination of recording the outline from a Northern round ship while applying his knowledge of Mediterranean shipbuilding to fill in the details. Furttenbach's *nave* includes two images with associated text informing us that the ship relied on dual master frames positioned in the center based on the overall length (figure 96 and 97).[949] As mentioned earlier, Furttenbach acknowledges some speculation about this vessel's construction because it was already built rather than sitting on the stocks in a shipyard. This speculation is evident in the profile of the master frame and last Y-timber that Furttenbach presents in his figures for the ship.

Furttenbach indicates that a compass can find a wide arc to represent most of the side of the ship, while a much shorter arc cuts toward a flat floor across the middle of the hull. The last

[947] Corradi and Tacchella, 'At the Origins of Shipbuilding Treatises: Joseph Furttenbach and the *Architectura Navalis*', 7.
[948] Van Duivenvoorde, *Dutch East India Company Shipbuilding: The archaeological study of Batavia and other seventeenth-century VOC ships*, 24.
[949] Furttenbach, *Architectura navalis*, 74-5.

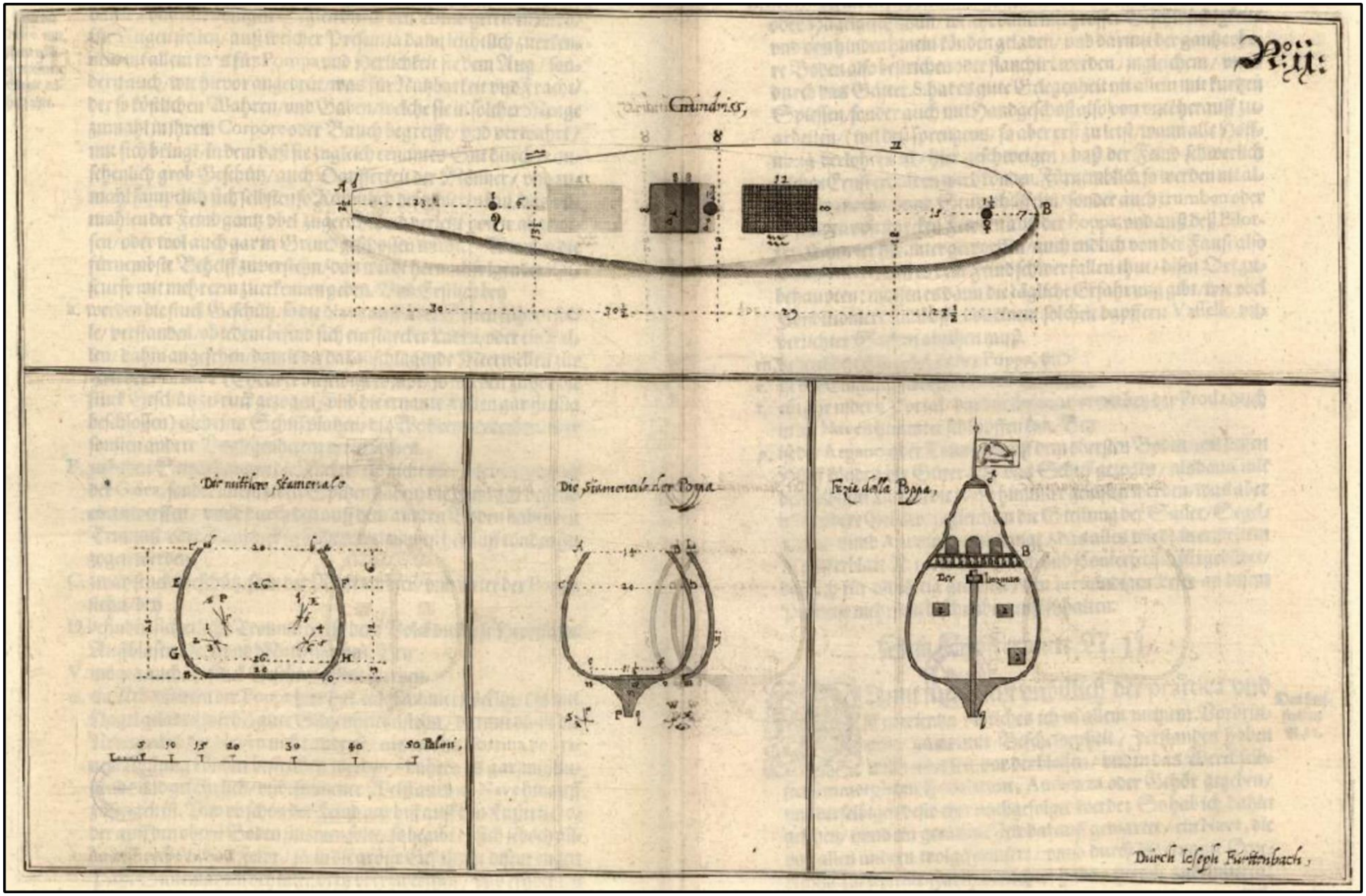

Figure 96 Furttenbach's nave showing the top view (above), amidships profile that appears similar to a Dutch fluyt (bottom left), last stern frame (bottom center), and shape of the stern with superstructure (bottom right). (Furttenbach, Architectura navalis, *engr. 11)*

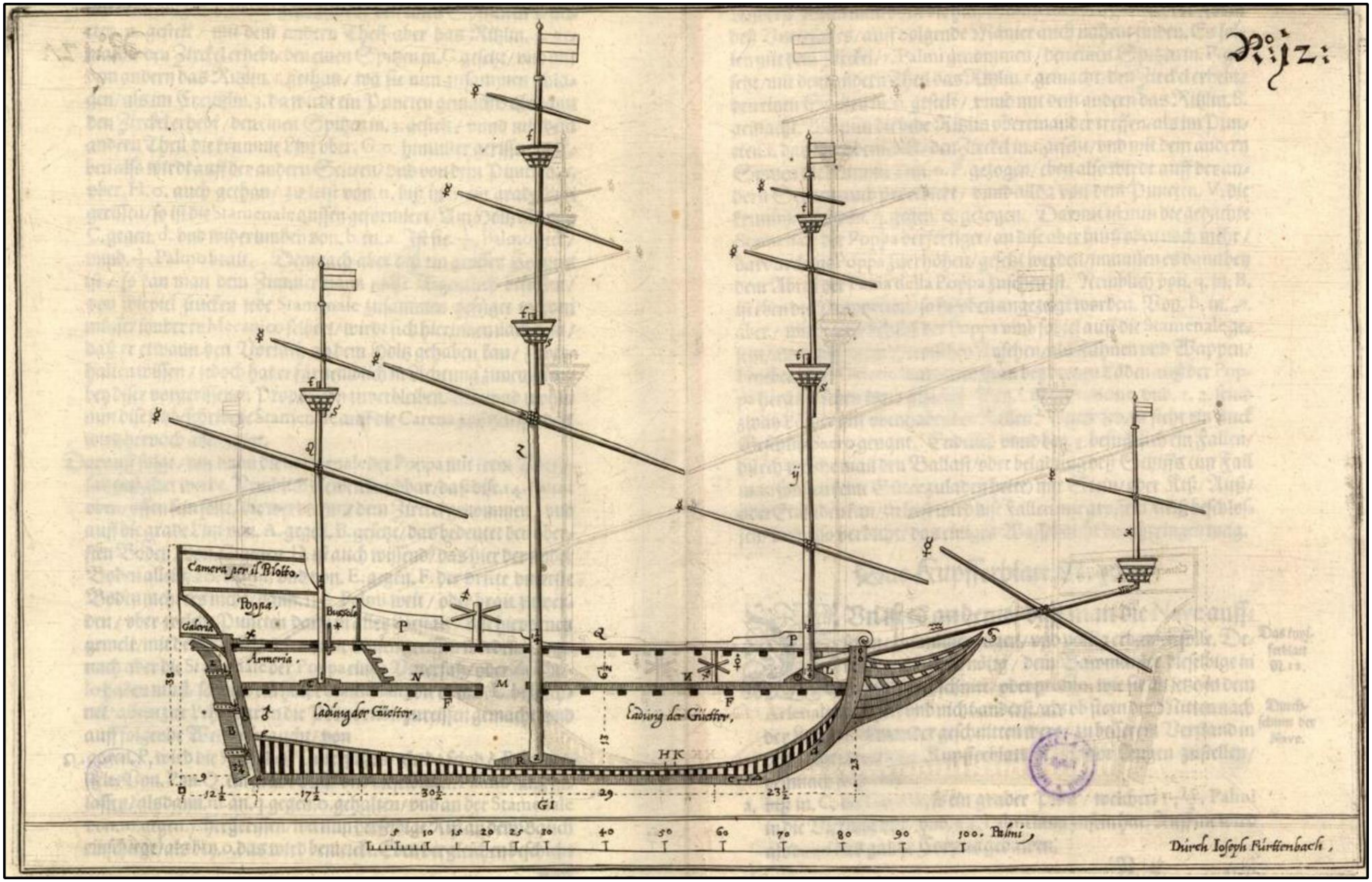

Figure 97   Side profile of Furttenbach's nave. (Furttenbach, Architectura navalis, *engr. 12)*

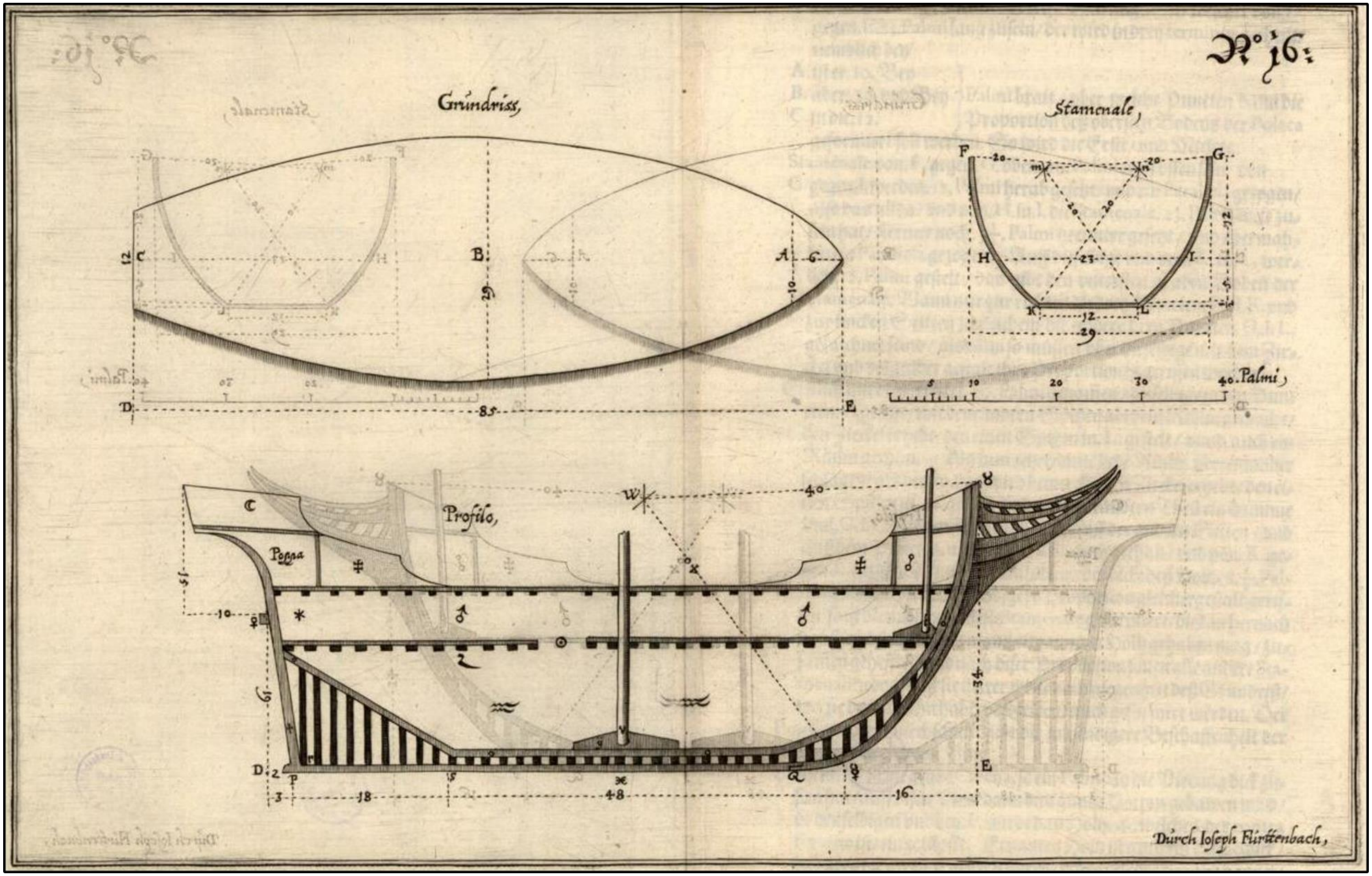

Figure 98 Top view, amidships profile, and side profile of Furttenbach's polaca. (Furttenbach, Architectura navalis, *engr. 16)*

Y-timber drawn by Furttenbach shows a similar profile, except narrower and with the addition of a foot based on the reverse futtock arc from the master profile. None of the earlier Mediterranean profiles from treatises or archaeological material convey the same shape provided by Furttenbach for the lower hull, while the general shape of contemporary Dutch ships is similar. This outline seems to be the Northern contribution mentioned by Furttenbach at the beginning of his description.

The second image of the *nave* includes a side profile of the entire hull where Furttenbach shows the dual master frames positioned roughly in the center of the hull. He then explains that 6 frames aft and 12 frames forward from the center all gradually narrow without adding a foot. The remaining 24 aft frames all rise gradually to reach 6 palms at the last Y-frame, while the 18 frame stations at the bow also include a foot without Furttenbach explaining how much the rising should increase.[950] Similar to the great galley, the remainder of this section includes a summary of different letters or astrology signs used to designate different parts of the ship. The frames are covered with ceiling and a mast step is positioned to receive the mainmast foot just aft of the master frames. Furttenbach's *nave* includes two decks and its 84-palm (20.83 m) overall length to 20 palm (4.96 m) width indicates the 4:1 ratio of a slender round ship.

The other round ship that Furttenbach mentions, known as a *polaca*, is described as 85 palms (21.08 m) overall by 29 palms (7.19 m) width, close to the 3:1 ratio.[951] The master frame for this ship includes a flat floor and the sides are comprised of a single arc (figure 98). Furthermore, the smaller vessel is described as including only a single master frame with 9 flat frame stations aft and 8 forward from the center. The remainder of the 9 stern frames and 10 bow

[950] Ibid., 75.
[951] Ibid., 79.

frames all include heels that are greater than those seen on the *nave*. The *polaca* also includes two decks with a reduce sterncastle and a more prominent forecastle attached to a higher stem than what is shown on the *nave*.

Remainder of Furttenbach's smaller watercraft follow a similar system with an amidships profile, top view, and side profile providing the basic measurements. Anything beyond these measurements must be assumed by the reader or borrowed from the detailed description of the great galley. The main differences between these vessels are the measurements included, number of frames utilized, and the arcs used to generate the master frame. There is also a difference in the number of master frames utilized by ship type, and this seems to be based on the overall length to width ratio. For example, the thin single-decked *barca* is reported as 52 palms overall length to 15.5 palms beam (or 3.35:1) and includes dual master frames in its construction.[952] Most of the smaller vessels only mention or signify on the plans a single master frame and these vessels seem to hover closer to the 3:1 ratio like the *polaca* (which also has the single master frame).

Architectura navalis clearly represents another manuscript where the author either had access to contemporary sources of shipbuilding information or interacted with a Mediterranean shipyard. From comments by Furttenbach within his work, most of the ships he describes were either built or operated along the Ligurian coastline. The similar reliance on master frames and the division of the frame stations to provide the narrowing and/or rising reflects a manner that was equally utilized and mentioned by earlier Venetian treatises. Where Furttenbach differs from other authors is his claim that, Mediterranean shipbuilders could predesign almost every frame

[952] Ibid., 87-8.

for a hull. The rising and narrowing of Y- and V-frames were preconceived, while their shape was based on the futtock arcs from the master frames. Nothing described by Furttenbach prevents the application of battens and their use by shipbuilders to simply shape timbers that fit these frame stations, it nonetheless still provides another avenue for the conception in these sections of the hull.

Another difference in Furttenbach's treatise is the application of multiple arcs to create the sides of each hull that were not faired (except for the *nave*'s profile). Furttenbach is still relying on the square utilized over the last several centuries to create his master profiles, while also emphasizing the use of arcs rather than the older method of a single mold or the system described by Drachio of bending a batten to provide the correct shape. Furttenbach's treatise was designed for an intellectual audience interested in shipbuilding who do not necessarily have a construction background. He also follows in the footsteps of earlier authors who have a much greater knowledge of longship construction and lack the same understanding of round ship assemblies.

Un manuel de construction des galères (1691)

The last primary document is an anonymous manuscript titled, *Un manuel de construction des galères*, transcribed and published by Jan Fennis, which discusses the construction of a French *senzille*[953] galley during the reign of Louis XIV (1643-1715). Fennis believes this unknown individual was a galley officer or captain who was present in Marseille when a Council of Construction met in late 1691 to discuss standardizing shipbuilding across the

[953] This term refers to the rowing system traditionally known as *alla sensile*, which incorporates three oarsmen per bench each pulling their own oar, a system used extensively on the light galleys of late medieval and early modern period.

fleet.[954] The author was presumably someone who normally operated with the northern galley fleet along the English Channel, as Fennis notes several places in the manuscript where there is some bias against Mediterranean-based merchants who supplied equipment or victuals to the fleet.[955] *Un manuel de construction des galères* is divided into two sections: the first explains the design process while the second half includes a description of each separate part in the assembly of the vessel, rigging, masts, overall expenses, crew, and victualing for similar ships.

Fennis believes the anonymous author had access to several prepared documents that were originally written for the Council of Construction, which were copied verbatim or altered for the manuscript.[956] Several places within *Un manuel de construction des galères* include errors or references to figures that were not present in the final manuscript. Fennis also concluded that the manuscript was prepared by the anonymous author with the assistance of a copyist and a separate illustrator. Many of the earlier figures in *Un manuel de construction des galères* were either provided to the author ahead of writing the manuscript or at least conceptualized with rudimentary drawings prior to the completion of the wreck. Fennis notes errors later in the manuscript where figures are missing from the text or omitted but cited elsewhere. These errors suggest that later sections of the manuscript were written before the illustrations became available.[957] The anonymous author's main source for information was the master shipbuilder Hubac, who is cited in the manuscript as the constructor of another galley in the Mediterranean fleet.[958]

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954 Fennis, *Un manuel de construction des galères (1691)*, xxxix.
955 Ibid., xxxv.
956 Ibid., xxix-xxx.
957 Ibid., xxxvii-xxxix.
958 Ibid., xxxv.

Whereas Crescentio and Furttenbach were less concerned about the related proportions between elements of hull construction, *Un manuel de construction des galères* clearly states that many of the galley measurements were related to each other. The overall length for the ship is cited as 144 *pieds* (46.78 m)[959], a number that could easily be divided (or square rooted) when necessary. The first part of the design chapters discusses dividing the overall length into five sections, with the longest part including the center of the hull (over 100 *pieds* / 32.48 m) to comprise the 26 benches for the rowers. The remaining sections are for the stern and bow canopies that either house the passengers or the forward cannons. After explaining this division, the manuscript begins constructing the hull by first finding the rake of the endposts and length of the keel.[960] The stem is noted as one-eleventh of the overall length, while the sternpost is three-fourths of the stem. Anything that remains from the overall length of the hull is used for the total length of the keel. The instructions also state that the keel timber must have a slight natural curve so that it becomes straight due to the weight of the endposts. The height of the sternpost is cited as one-tenth of the overall length and the stem is half this height with the addition of 1.5 *pieds* (48.73 cm).[961]

Once the rakes of the endposts are measured out to create the square for each, then the curves are created using a compass. The directions are clear that a single arc is necessary for either endpost, but it does not state the radius of the circle that is used (figure 99). There is a built-in skeg for the rudder on the sternpost, while the stem includes a heel for supporting the long beakhead. After completing the directions for preparing the axial timbers, the manuscript

[959] Post 1668 French linear conversions: *point* (0.188 mm); 12 *point* = 1 *ligne* (2.256 mm); 12 *ligne* = 1 *pouce* (2.707 cm); 12 *pouce* = 1 *pied du roi* (32.484 cm); 2.5 *pieds* = 1 *pas ordinaire* (81.210 cm)
[960] Fennis, *Un manuel de construction des galères (1691)*, 3.
[961] Ibid., 4-5.

describes how to place the dual master frames, intermediate frames (23rd frame stations), and tailframes (44th frame stations). The overall length of the hull is divided by four to find the tailframe and dual master frame positions. Intermediate frames require dividing the hull by six and placing them roughly equidistant between the dual master frames and tailframes.[962]

The master profile is based on proportions of the overall length and each side is composed of two arcs, along with the flat of the floor (figure 100). According to the manuscript, every frame station from the dual master frames to the 44th floor timbers is gradually reduced on an equally divided progression scale.[963] Between the 23rd and 44th frame stations, the floor timbers rise based on the mezzaluna scale described in earlier treatises. Futtocks attached to floor timbers in this frame section are slowly tilted outward (known as *trébuchment* in French) and hauled down to maintain the same height across the hull.[964] This system allows the deck to maintain the same width for a greater distance, even though the hull reduces toward the endposts. Tools for modifying the frames include a floor timber template, rising tablet, and an additional futtock template for *trébuchment*.[965] Compared to earlier instructions for designing longships, this manuscript does not explicitly state a difference between the amount of rising and narrowing utilized on either side of the dual master frames.

Only the Y- and V-frames are comprised of much different shapes than those described toward amidships. The 30-33 frames abaft of the 44th frame station are divided into three

[962] Ibid., 6-7.
[963] Ibid., 9-10.
[964] Ibid., 11-13.
[965] When shipbuilders started using a separate futtock template is unclear. The first mention of tilting the futtock in Fabrica di galere suggests fifteenth century, but we assume it was used much earlier. Its application for adjusting the angle of the futtocks can easily be scribed onto a single frame mold, so it might be a user preference or could originate from the beginning of this practice. No doubt it would be easier to transport or store two template pieces rather than a single profile.

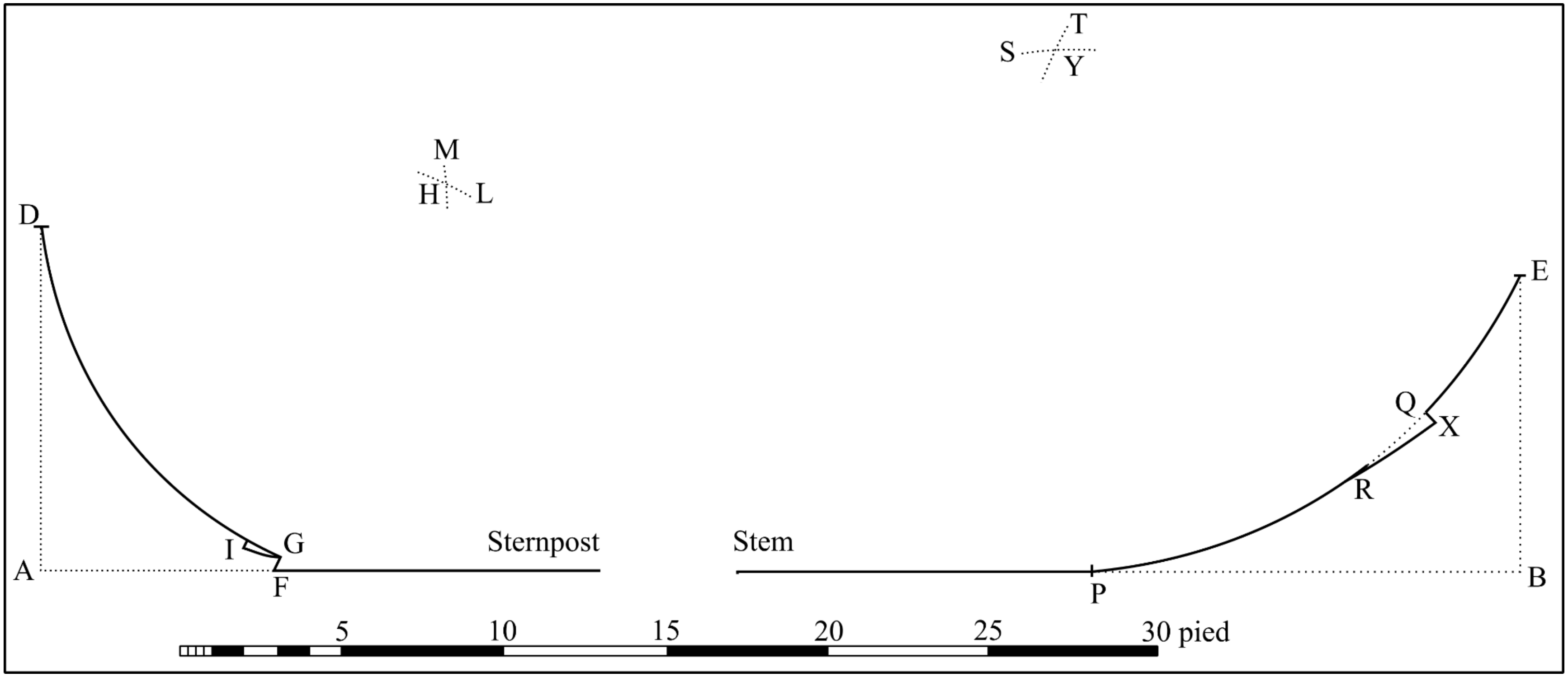

Figure 99 Transcribed drawings of the endposts for the galley in Un manuel de construction des galères. *(after Fennis, Un manuel, 300, figs. 5 and 6)*

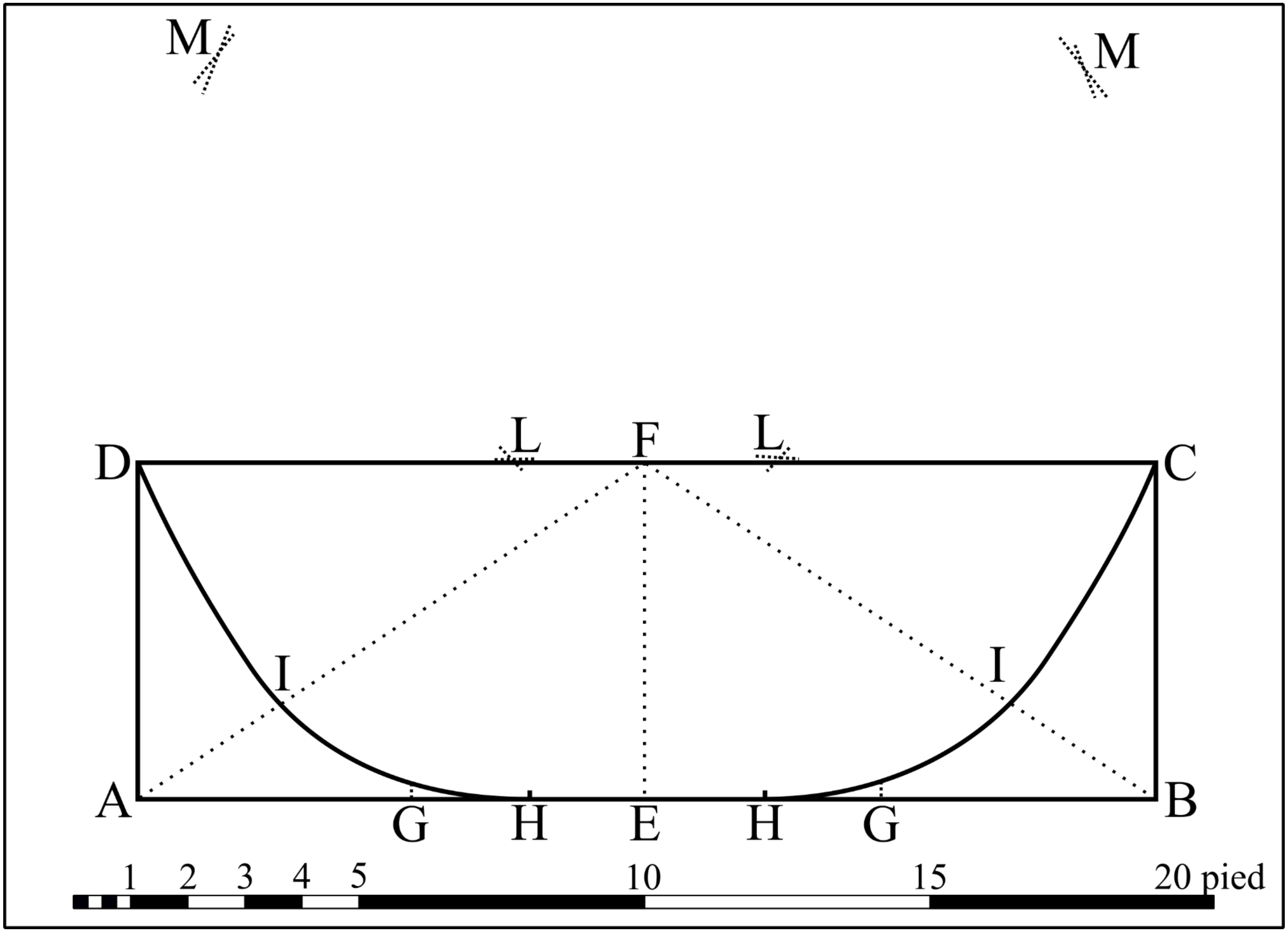

Figure 100 Master profile for the galley described in Un manuel de construction des galères. *(after Fennis,* Un manuel*, 301, figs. 8)*

categories (*singlons*, *mautroves*, and *fourcats*) that follow the same shape before having a much taller foot and acute angled arms.[966] There are 15 V-frames (described also as *singlons* or *fourcats*) at the bow with every third frame predesigned. Both the Y- and V-frames are described as empirically fashioned in the shipyard by the shipbuilders relying on battens to create a mold.

The anonymous author also provides theoretical instructions on how to find the correct shape for stern and bow frames in a more complex manner than described by Furttenbach.[967] These instructions appear to draw the half-breadth plans for either end of the ship with the waterlines (representing the placement of battens) as key positions on either side of each frame. The last section of the design process discusses finding the correct arc for the camber of the deck and relying on the same progression method used to find the rising and narrowing of the framing.[968]

The remainder of the manuscript has a synopsis of the individual timbers that comprise the rest of the galley and discussions of its metal hardware, rigging, mast designs, and sail plans. The section on the hull components describes each timber and includes a figure showing what the part should look like prior to its installation. The illustrations show the scarfs that connect the pieces together and the recesses cut in components such as stringers, mast step partners, or wales. None of the earlier treatises include this level of detail, due to the previous authors assuming that the reader would be familiar enough with ship construction to assemble the smaller components (or perhaps the authors were unfamiliar with these details).

The primary sources on Mediterranean ship construction from the seventeenth century have similarities and differences in how they convey information for building longships and

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[966] Fennis, *Un manuel de construction des galères (1691)*, 19-20.
[967] Ibid., 24, 28-9.
[968] Ibid., 33-4.

other vessels. Crescentio's work is a western Mediterranean *zibaldone* with its mixture of ship design, nautical information, and engineering inventions. His knowledge about how the endposts were designed for the longship reflects the earlier practice of bending a batten to create the necessary curve, although he argues for the application of the compass on paper. Crescentio provides less information about round ships and relies on other contemporary treatises for supplemental material. Furttenbach comes from a merchant background and appears focused on all aspects of the Ligurian longship with supplemental information on various sizes of round ships. Like Crescentio, his knowledge of constructing other ships appears limited. This is partly due to the fact that several of the ships Furttenbach includes were vessels already completed rather than available for inspection in a shipyard. The author of *Un manuel de construction des galères* remains unknown but must have had a naval career like Crescentio. The work of this French officer reflects ongoing efforts by government councils to standardize the galley fleets.

Crescentio's work appears to be for middle-class individuals interested in nautical matters but not familiar with them. Furttenbach's treatise suggests a similar readership, albeit with much more details read and copied by those designing ships in Northern European shipyards.[969] The author of *Un manuel de construction des galères* writes for a more specific audience, French naval personnel involved in the galley fleets. The writing of *Un manuel de construction des galères* was part of the attempts by Louis XIV and his councilors to modernize France.

French efforts included developing a naval architect discipline from traditional shipbuilders who could eventually design hulls and predict their sailing capabilities before the

[969] Hoving, *Nicolaes Witsen and Shipbuilding in the Dutch Golden Age*, 3.

keel was ever laid in the shipyard.[970] This initiative might explain why the author of *Un manuel de construction des galères* emphasized drawing the shapes of key thin galley components on paper before sketching them out on a loft floor. The author also attempts to predesign the Y- and V-frames but acknowledges that these are still empirically fashioned based on molds from battens attached to the central frames and endposts. Even with the changes taking place in France, *Un manuel de construction des galères* remains firmly in the style of earlier treatises by explaining the construction of Mediterranean longships instead of reflecting contemporary or later works that focus on the ideal shapes for Atlantic warships that dominated European navies by the end of the seventeenth century.

Summary

Archaeological and documentary sources on ship construction from antiquity until the early modern period suggest different stakeholders influenced the discipline. Shipbuilders in antiquity created ships based on a longitudinal vision, where the strakes provided primary hull integrity and dictated form. Framing acted as a reinforcement to keep the preferred shape intact in a dynamic environment. This method of construction had means for predetermining form, as several archaeological examples attest to the use of general proportions relying on a standard linear unit and creating "master" strakes that checked the profile of the ship for uniformity. State sanctioned projects contributed to this trend by demanding standardization between naval vessels.

In these situations, shipbuilders were left to develop their own methodologies for creating vessels of similar size and shape in a short amount of time. Examples in the Mediterranean and

[970] Pritchard, 'From Shipwright to Naval Constructor: The Professionalization of 18th-Century French Naval Shipbuilders', 13-15

Northwestern Europe indicate this level of naval construction necessitated temporary molds or the preassembly of several strakes before they were mounted upon the existing lower hull structure. The final products served state enterprises by ensuring that adequately sized vessels were prepared for naval actions, that these vessels could be stored in standard naval sheds, and that novel personnel could operate them without concern for differences in shape or draft when in shallow areas. Not all ships from antiquity provided this same level of predetermination. Private shipbuilding was much more random in vessel shapes and sizes. Nonetheless, we can be certain that ship owners still wished to know the general proportions of their vessel before an agreement was made with the shipbuilder.

By the time Serçe Limanı was constructed in the eleventh century, shipbuilding had already transitioned from a predominantly shell-based to a frame-based methodology. The evidence from Serçe Limanı and many earlier vessels emphasizes that proportions based on a contemporary linear unit continued as part of the construction process. Serçe Limanı was different from previous ships because shipbuilders realized by this point that the frame-based approach reduced the necessity for planking to be guided by simplified edge joinery (i.e. coaks) to create the final shape. The contemporary process remained the same by relying on the keel as the basis for positioning key frames to dictate the overall profile. In this case, dual master frames provided the shipbuilder with the starting point for projecting the rest of the framing system toward the endposts. Intermediate frames provided the point where the narrowing from the center of the ship shifts to include increasing the foot of consecutive floor timbers for the entry and run. Tailframes are the limit of this predesign before the shipbuilder falls back to earlier methods where the planking defines the hull. In these situations, temporary battens were attached to frames to allow longitudinal predetermination for the fit of the planking and to allow molds to be created for endpost framing.

Only the key frames on Serçe Limanı include scarfs, while the remainder of the floor timber and first futtocks simply overlap without being fastened together. These signatures are why this period in ship construction is considered “frame-based” rather than explicitly “frame-first”, because the installation of frame elements and/or planking was piecemeal as the assembly progressed. Evidence from Marsala A suggests the same, albeit with less information available to confirm the same system attributed to Serçe Limanı. The lack of rising included in reconstructions of Marsala A and the duplication of the shape for each frame suggest the builder could predesign beyond the tailframes. Slightly later ships, such as Rhodes 4, had larger scantlings requiring scarfs for every frame to ensure ease of assembly in the shipyard. Bottom-based shipbuilding followed a different process where the lower planking was laid out before frames were installed. The evidence from this shipbuilding method suggests a narrowing progression without the use of a rising tablet.

Most of the shipbuilding documents that survive from the late medieval period are focused on state construction of longships. These estimates discuss costs for each hull component and provide clues that identify the use of a master frame to dictate hull form. The other major considerations are overall vessel length and measurements taken of the specific position of the wale that supports the deck beams and outrigger assembly. This period offers few archaeological remains of longships, and the limited disassembly of Boccalama B provides few details. One practice that can be pointed out is the preference by northern Adriatic shipbuilders for a single master frame rather than the dual frames seen on earlier ships.

Contemporary round ships such as Culip VI and Les Sorres X reveal a conceptual system similar to Serçe Limanı. Dual master frames rely on the length of the keel for their positioning, intermediate frames indicate the beginning of the rising applied to floor timbers, and tailframes indicate the limit of this predesign before ribbands dictate the form at the endposts. Differences from Serçe Limanı include the application of center and bilge markings as surviving elements from the creation of each frame and the concern for scarfing every frame station. These scarfs do not impart much lateral strength to the ship, instead they enabled workers to connect pieces together as part of the shipyard assembly process. Roman numerals incised in timbers suggest a more organized shipyard with a large roster of workers acting in concert to build the hull.

Fifteenth-century documents and later sources provide a combination of information that their authors found pertinent to their own purposes. Most of the first group of sources are copyists of records associated with the Venetian arsenal. This information simply lists various measurements that often have no proportional relation. Scholars believe that arsenal officials (not necessarily shipbuilders themselves) went into the shipyard or storage area with cord and ruler to measure internal offsets.

Information recorded by Michael of Rhodes and his copyists provides evidence of the cognitive process of the builders. The overall length of every longship is the first measurement recorded for any document, evincing a concern by medieval and early modern states for the standardization of naval vessels. Each longship also includes evidence for the same key frame stations. Differences between descriptions include the additional amidship frames that were identical in shape to the single master frame. The number of frames between tailframes is repeatedly mentioned as an important consideration and their division also implies that not every frame was first devised on an incremental scale. Select frames were narrowed, raised, and/or their futtocks tilted outward and adjusted near the floor timber to provide additional deck space. Many of these adjustments relied on a master mold and rising tablet based off a square drawn from the hull measurements to create the endposts and master frame profile. Evidence suggests that certain shipbuilders, used an incremental scale and wooden tree beyond the tailframes to predesign floor timbers positioned on the endposts.

Round ships receive less attention in fifteenth-century texts, presumably these were often commercial vessels which remained in the realm of private industry and their construction was managed by private shipyards. Michael of Rhodes and the others describe the round ship construction process as reliant on proportions beginning with the length of the keel. These same authors were the first to combine measurements with supplemental imagery. Modern scholars do not equate these drawings with plans created by later naval architects, but the drawings do showcase creating the square by relying on the main measurements to dictate the endposts or master frame. Comparison of drawings between longships and round ships indicates that the lower halves were very similar. The round ship drawings are taken a step further by duplicating the lower half and reversing to generate the upper two decks, with a resulting very narrow and tall ship.

Little archaeological evidence is available for longships from this period besides the Lake Garda hull, which shows evidence for the use of the incremental devices described in texts for determining narrowing and rising between floor timbers. Archaeological examples of round ships are either single-decked (like Contarina I) or from the western Mediterranean. Contarina I suggests a later vessel built in the manner seen in Marsala A, an axial-based ship that includes a narrowing progression without rising applied and no scarfs necessary between frame elements.

Marinières includes positioning of the dual master frames based on the keel, while the absence of evidence for tilting the futtocks near the endposts was replaced by canting the futtocks outward.

Sixteenth-century documents reflect ongoing efforts to convey the same information first provided by Michael of Rhodes and the copyists. Fausto was viewed as a disruptive outsider in the Venetian arsenal and his lasting influence on shipbuilding is not clear. He supposedly left no writings to pass down, although he taught some version of design to apprentices like Zulle, who was able to utilize this knowledge to gain promotion within the arsenal. If Zulle wrote Misure di vascelli… he still followed earlier patterns by emphasizing the overall length of his longships. This measurement is supplemented by stating the room and space between each frame across the hull as the means to devise the overall frame pattern. Less detail is provided about the incremental changes and instead the widths at key frame stations are included. No profiles for master frames are described and a later document from the Venetian Senate suggests that Fausto relied on the compass and concentric circles for his hull designs.

The anonymous author of Misure de Navalii simply lists three round ships without providing any mention of relationship between the proportions. Measurements begin with the keel and continue with the three traditional offsets within the hold before considering the upper decks. The main difference from earlier documents is the inclusion of the actual measures for narrowing, rising, and modifying the futtocks. Intermediate frames described in earlier round ship construction are omitted here, as the author states the rising is applied directly after the master frame.

Teodoro and Drachio provide the most detailed accounts of construction applied in the shipyard beyond the simple abstraction written about by fifteenth-century copyists. Both men were well-versed in construction and applied their own knowledge in the texts they wrote.

Teodoro was more concerned with showing both ship types by providing measurement lists. His longships are first listed by their overall length and he is one of the few authors to emphasize that there are related proportions based on the beam. The round ships are initially described by their keels and follow similar listings for the remainder of the measurements. Teodoro's descriptions also show the reader when he is more familiar with a specific ship by including how and why certain measurements are related, otherwise he simply lists the rest like previous authors. His drawings follow a similar method seen in the fifteenth century, with the square drawn where the lower half of the hull fits inside and leaves this confine as it extends beyond the square for the upper decks.

Since longships are often single-decked vessels, the maximum beam fits at the edge of the square, but the shape of Teodoro's round ships move this measure beyond the normal limits. Part of the reason is because the master frame is flipped to trace this profile or the shape of a tailframe is included to create the hollow. Drachio only describes a single longship but conveys the application of techniques in the shipyard omitted by previous writers. His mention of the use of cords, string, and bendable slats to create the axial timbers and midship curve suggest an absence of strict proportional relationships. Linear measurements stem from the beam and are divided into fractions to dictate how the rest of the hull is formed. Proportions also remain a concern in the placement of the key frame stations and incremental changes to them.

The limited archaeological material available from the sixteenth-century Mediterranean provides few Adriatic vessels to directly compare with the documents. Mariposa B, Villefranche, Mortella III, and Calvi 1 present a collection of western shipwrecks from a different shipbuilding community. Recent reconstructions suggest a theme between the latter three ships, as the hull was formed with a single circular arc below the waterline. Villefranche and Calvi 1 with wineglass shapes also infer that some elements of shell-based shipbuilding remain for the assembly of the keel and garboards dictating the bottom foot of the floor timbers. Many of the smaller ships recorded from this period are predominantly western ships as well. Yassıada 3 is the sole example of an eastern round ship. The smaller examples support earlier findings of round ships being devised by proportions related to the keel and by the placement of dual master frames slightly forward.

Available manuscripts from the seventeenth century are not Venetian and often were not compiled by shipbuilders. These works share a background similar to the fifteenth-century authors who were men associated with the sea or who obtained their information by conversing with local shipbuilders. Crescentio, Furttenbach, and the anonymous author of *Un manuel de construction des galères* each emphasize the use of compass arcs for producing the endposts and the master frames. The overall length for each longship remains an important consideration for the authors when describing their individual examples. Crescentio and Furttenbach are more comfortable describing their longships in the traditional list form without reference to related divisions. The anonymous author of *Un manuel de construction des galères* does the opposite by emphasizing that most key frame stations are reliant on divisions of the overall length.

Tilting of futtocks is only described by the French author and is absent in the other two discussions. Furttenbach implies tilting of futtocks by including the width of the tailframes without providing the direct amount seen in the later treatise. Differences between these authors includes Furttenbach's explanation for predesigning the frames on the endposts that the other two authors claim is left to the traditional method of installing temporary battens. Crescentio and Furttenbach also include round ships in their compilations, but their discussions reveal the same unfamiliarity with round ship construction shown by earlier authors. Crescentio appears to borrow from other sources, acknowledging Sagri as a reference, and the linear unit is different from that applied in his longships. Furttenbach obtains profiles of Northern ships and applied the knowledge he obtained for how longships were built to round ship design.

Reviewing the corpus of late medieval and early modern evidence from archaeological finds and archival records suggest there is a consistent underlying design method by builders from various communities relying on a master frame and rising tablet. These tools allowed the construction of both longships and round ships. The differences between these typologies were relayed through the documents based on naval or mercantile interests. Longships remained the principal naval vessel for most Mediterranean maritime states until the modern period. These ships required some level of standardization, and the documents convey similar types of measurements. Overall length and beam were important measures, with the division of one of these providing the remaining essential scantlings for the ship. Frame proportions were also important for laying out key frame stations. Round ships remained in the hands of private industry and suggest proportions based on a linear unit from the keel or beam. Earlier round ships seem to share many of the key frames in longships, such as the intermediate frame that extended the amidships profile for greater hull capacity. Later vessels remove this and begin the rising after the master frame, possibly due to the addition of the straight sternpost and rudder for better handling.

Several archaeological examples convey differences from the above documents, including the absence of a rising tablet in the construction of the floor timbers or the adoption of tilting the futtocks outwards near the endposts. Most of the documentary record is from the Venetian arsenal, while the archaeological material predominantly stems from elsewhere in the Mediterranean. This outside, non-Adriatic group is heavily reliant on dual master frames to project different narrowing or risings outward to the endposts, while Adriatic construction adopts a single master frame for the same purpose. Other differences include the shape of large western round ships that continued to rely on designs from the shell-based construction period (wineglass) and/or single arcs for the profile of the ship. The circular arc is not discussed in Venetian shipbuilding outside Fausto and no document collections include detailed explanations for this archaeological finding.

Geometric progressions for the incremental changes between frames are developed with some success in reapplying these examples to archaeological remains. Predesigning frames beyond the endposts (besides the application of battens) is suggested by several documents, while it has not been identified so far in archaeological remains. Our conception of the cognitive decisions by Mediterranean shipbuilders remains hamstrung by the concentration of documents on a single state-shipyard enterprise and limited associated remains. Although the tools for conceiving the hull remain the same, the preferences by shipbuilders shows variance in the Mediterranean communities throughout this period.

CHAPTER VI

CONCLUSION

Natural forces over millions of years created a unique environment that today is known as the Mediterranean. Pressure between tectonic plates created a series of mountains that built a permeable barrier between this region and the rest of Europe. Wind patterns at this latitude and global climate changes created a desert border along the southern shore separating the hospitable North African coast from the southern interior of this continent. River networks provide alluvial fields and help maintain the sea, but inflow from the Atlantic Ocean via the Straits of Gibraltar is the main contributing source.

Surface currents pass along the southern coast until this water becomes denser and eventually leaves the circuit altogether. These conditions produce variable winds and storm conditions that greatly affect how people navigate this maritime landscape. The earliest Near Eastern civilizations only perceived the Mediterranean as an expansive sea. Cultures with greater reliance on this sea for access to resources and trade often applied possessive connotations of ownership. Exploration by early coastal dwellers and the subsequent expansion of early maritime empires acknowledged the Mediterranean as an inland sea surrounded by a much greater ocean.

Whether coastal communities that lived and thrived around the Mediterranean over the last two millennia saw themselves as a shared maritime society separate from other groups is unclear. Early Islamic writers often referred to the sea as owned by the Byzantines and viewed it as a barrier between themselves and Europeans. Their counterparts in Constantinople always referred to the regional seas that surrounded their territories rather than ascribing a name for the entire environment. Improvements in cartography during the late medieval period may have given the Mediterranean a more realistic form and cognizance for those that occupied this space. The assembling of many territories under single rulers by the sixteenth century contributed toward shared political identities, but the shift in economic and global interactions to the Atlantic and beyond stagnated this development.

Early scientific voyages to the far-flung corners of the Mediterranean began to systematically catalog similar finds along the distant shorelines. The shared climate and similar biota led early geographers to define the Mediterranean as an entity distinct from other landscapes. The rise of environmental determinism in positivistic science led researchers in different disciplines to describe human adaptation as influenced by the local terrain. Historians adopted this paradigm and conceived human history through multiple layers by arguing how culture changes based on time scales. This approach was also adopted by archaeologists when trying to perceive idiosyncratic differences between an assemblage and other comparative material.

Nautical archaeology is a fairly new subfield that developed in a similar manner to the mainstream discipline: from antiquarian salvage to scientific endeavor. The early pioneers were concerned with providing a database of shipwrecks excavated and reported in a controlled manner. Their findings dictated the subsequent questions and avenues for research on various topics attributed to each individual site. These initial efforts did not dissuade scholars from trying to answer more complex research questions about hull construction from the very beginning. Nevertheless, subsequent acolytes of the pioneers began to piece together hull construction characteristics from a growing publication of shipwrecks originating in concise periods. The various analyses from this time showcase a group of scholars attempting build a lexicon for describing a multilayered approach and attributing hull finds to a scientific typology unrelated to culture-historical descriptions.

Around the same time as these comparative analyses were being discussed, Patrice Pomey began utilizing the operational process originally relied upon in French studies of lithic manufacture. Pomey applied the developing lexicon for hull construction from earlier debates about Mediterranean finds dated to antiquity and the early medieval period. Eric Rieth also saw Pomey's application of the operational process as beneficial for discussing his own research on shipwrecks from other periods. Both scholars worked together toward pushing this analytic technique into the subfield as a better approach to building a shared lexicon for further discussions.

The operational process is conceived as a lexicon, methodology, and analytic technique that follows the step by step practice for producing a final product. Pomey and Rieth discussed this further by conceiving the definition of a ship into four systems that influenced the architectural project as a whole. All four systems necessitated that the hull shape, propulsion technology, function of the vessel, and the micro-society that lived on board as interdependent with one another. Each system influenced the entity as a whole which was first conceptualized and realized during the construction of a ship. How the vessel was conceptualized by the builder and the techniques they employed dictated differences identified in surviving archaeological material.

Rieth's previous research on late medieval and early modern Mediterranean shipwrecks utilized the handful of examples known at the time. In this dissertation over 40 wrecks with various levels of preservation and reporting were described as a dataset with several drawbacks. The archaeological literature spans a longer period of time than nautical archaeology has existed as a subfield, which means the level of description varies. Differences in the rigor of the fieldwork or parameters for the research design also limit certain information. Several of the wrecks in this dataset were recorded at the beginning of the previous century and their dating has changed due new comparisons with recent finds. Another group of wrecks are in the midst of analysis and their final conclusions will probably be released in the future. Even with these variables aside, the available material still provides a collection of characteristics that track nuanced regional changes in the adoption of frame-based construction throughout the Mediterranean.

Most shipbuilding during antiquity and the early medieval period followed a shell-based approach. Shipbuilders relied on a longitudinal conception where the hull planking dictated the form and the frames were inserted as a complementary support network. Strength was mainly derived by edge-joinery between strakes using a pegged mortise and tenon system. Framing was composed of half-frames that alternated with full floors and butted upper futtocks in parallel lines across the hull. This system began to change toward the end of the AD first millennium, when planks and their associated mortises and tenons became thinner. Thick planking in shell-first construction swelled the seams between strakes closed and the entire hull was covered in pitch inside and out. Thinner planking requires caulking to be inserted in seams to seal the hull and exert pressure between strakes for additional rigidity. Half-frames were phased out and full floor timbers with alternating short arms became customary butting associated futtocks. Earlier preferences for connecting the frames to the planking with treenails were also replaced by the exclusive use of iron fasteners.

Debate continues when frame-oriented hulls became widespread, but frame-based shipbuilding was the dominant method after the new millennium. Throughout the late medieval and early modern period keels are straight for round ships and rockered on longships to improve their sailing qualities and anti-hogging due to shallower hulls. Shell-based construction relied on a keel rabbet as part of the pegged mortise and tenon system to connect with the garboard. The rabbets on flat-bottomed hulls were no longer a necessity. They do, however help in ships built for carrying heavier cargoes, they provide strength where the keel only butts the endposts, and they are used in complex wineglass hull forms. The scarfing of the keel to the endposts by shell-based methods was phased out for round ships in favor of simply butting these components together. Some evidence still exists for scarf usage, especially between the front end of the keel and the stem but segments between keel timbers are not connected in this manner. Longship construction appears to continue scarfing to ensure longitudinal strength.

Late medieval frame-based construction originally followed the shell-based practice of long-armed floor timbers that butted short-armed futtocks. This method is replaced by full floor timbers that stagger or overlap with futtocks. Few scarfs are present between these elements, except at key frame stations. The appearance of scarfs at every frame station suggests that the adoption of frame-based techniques in the Western Mediterranean was delayed and adopted this technique as part of the assemblage process. These scarfs are shallow and was likely a method for orienting the timbers that were fastened together. Only predesigned frames contained scarfing and most frame stations near the endposts had components simply butted together. The need for ribbands to orient the framing correctly and to create molds for endpost frames is evidence that shell-based practices continued into frame-based shipbuilding. Similarly, the frame scantlings for earlier ships appears consistent to those used in antiquity and only increased toward the beginning of the sixteenth century.

Internal longitudinal assembly follows a supportive role like framing in shell-based practices and becomes more important after the transition to frame-based construction. For instance, the keelson in shell-based construction is sometimes connected to the keel with bolts between frames. Early frame-based shipbuilding continued this practice and it is unclear when the transition to drilling through the floor timbers occurred, although the earliest evidence for this method is in the fourteenth century. Evidence for bolting floor timbers to the keel does occur in shell-first shipbuilding but this was a necessity for reinforcing the complex wineglass hull forms. Stringers are found intermittently in shell-based construction, presumably also in a supportive role for keeping the frames aligned and providing longitudinal strength. These elements gain a more active role in frame-based construction by reinforcing the overlap between the floor timber and first futtock juncture. Stringers in the middle of futtocks appear to follow a function similar to that found in earlier shell-based practices.

Ceiling is intermittent on ships and provides a protective barrier for the framing and a cargo platform. Early box-like frame-based ships and subsequent vessels with an exclusively round or wineglass shape often include a transverse platform in the hold due to their profile. Several examples of mainmast steps from frame-based hulls suggest a lineage that began with shell-based examples. Mediterranean mainmast steps are a composite that rely on the sister keelsons seen in shell-based construction to support an unfastened keelson or mast step timber. Later examples comprise mast step partners that are linked with keys and wedges inserted on top of the keelson to create the mortise for the heel of the mainmast.

Axial-based ships were not the only example of construction found throughout the Mediterranean. A smaller set of ships were identified as following a bottom-based tradition that traced to an earlier period. The common characteristics of this group included a plank keel with accompanying strakes that together formed a flat-bottomed hull. Earlier ships follow the shell-based frame pattern using long-armed floor timbers and short-armed futtocks, while the later examples show the same transition to overlapped floor timbers and futtocks. Earlier ships had a similar flat bottom with outward-angled sides that were later replaced with a curved profile. Vessels from this group operated in riverine, coastal, and offshore waters. More information and finds are necessary to understand the development (or adoption) of this construction technique in the Mediterranean.

Few examples of upper hull assemblies survive from the late medieval and early modern period. The general trends in frame-based construction include shelf clamps reinforced by being fastened to an accompanying wale on the outside face of the frames that support a complex of beams and ledges to create the deck. Both iconography and archaeological materials suggest that through-beams were utilized until the fifteenth century. Through-beams originate in shell-first construction to reinforce the shape of the hull and provide a platform for the deck. Their presence on frame-based ships suggests a similar concern due to the light scantlings of the framing or the overall shape of the vessel. Longships for example, needed reinforcement of their long narrow design and through-beams also supported the outriggers. Most sixteenth-century ships with upper assemblies include larger frames and additional internal reinforcements for supporting the upper castles.

External covering of frame-based hulls was comprised of either generic planking or wales. Few examples include bilge keels and their presence suggest ships that were made for coastal beaching. Bilge keels also reinforced the accompanying stringer at the juncture between the floor timber and first futtock overlap. There is an anachronism apparent on several ships where the bilge keel is absent amidships, but a wale appears on the same strake at the stern.

Planking is much thinner on frame-based hulls than on earlier shell-based examples, although the thickness is still dependent on the overall size of the ship and its purpose (longer voyaging vessels often include thicker planking).

Wales provide an external longitudinal reinforcement for the hull and are seen on ships regardless of the construction methodology. Compared to the internal longitudinal assemblies, wales seem to maintain importance throughout Mediterranean shipbuilding. They initially appear at the waterline with the number of strakes depending on the size of the ship and any additional decks. One trait shared by all longitudinal components (external and internal) is the tendency to cut recesses for them to fit snugly on the framing. The process adds reinforcement to the hull form that would not necessarily be the same if these components were placed flush against the framing and nailed down.

Previous studies argue that the fastener preference in shell-first construction was a mixture of treenails and metallic bolts and spikes. During the transition from shell-based to frame-based construction, treenails became less ubiquitous and iron fasteners dominate. Earlier frame-based ships suggest that keeping planking attached solidly on the framing called for multiple fasteners per station. After the maturity of the methodology, there appears to be an agreed-upon standard of two iron fasteners per frame. Besides vessels that operate mainly in freshwater environments, treenails only appear on ships associated with the Iberian Peninsula and later eastern shipwrecks. The reasoning behind the western application of treenails is either a continuation of earlier regional practices or influence from the Atlantic. Application on eastern ships suggest their use for temporary (although non-removable) cleating before the insertion of iron fasteners.

Although caulking is not unheard of in shell-first construction (mainly to seal the seams of repaired planking or for adjustment between strakes), it becomes ubiquitous for frame-based shipbuilding. The continued practice of sealing the entire hull inside and out with pitch is clearly a technique carried over from earlier methodology. Few examples only have the outside hull sealed and use lead sheathing. Unfortunately, there is limited evidence to know if the lead is also a continuation of the earlier technique or outside influence. The increase in the overall size of Mediterranean ships by the early modern period suggests vessels became greater investments that owners wanted to protect against marine organisms.

Dendrochronological studies are becoming more prevalent in, and integral part of, new archaeological projects. They are applied more often in Northern European shipwreck investigations with some recent work devoted to the forestry surrounding the Mediterranean. Previous studies on shell-built ships along the French coastline suggest carpenters were clearly cognizant about their timber selections. Reports from late medieval and early modern ships mostly identify the species of timbers without further analyses. So far, it seems that shipbuilders chose hardwoods when available and otherwise depended on lesser quality materials that grew in the vicinity of the shipyard. Oak was the predominant species for framing, while pine or similar softwood is used for planking. Prevalence in fir on certain ships may suggest hardships in obtaining better wood for construction or repair.

Pomey and Rieth’s application of the operational process focused on the architectural aspects from archaeological remains. Their approach explains the principle and methods of shipbuilding and initial organization of the archaeological material in groupings within concentric architectural circles. Not satisfied with this organizational scheme, Rieth experimented with ship types organized by the geometry of the hull cross-section. In this case, ships throughout antiquity and the early medieval period with similar hull forms and located in the same regions were grouped together regardless of their construction methodology. The different construction techniques become the explanatory evidence for progression in technology by the shipbuilders. This approach also included more descriptive culture-historical connotations by addressing the shared hull type as related to the predominant group known to occupy this coastal space within Rieth's period of interest (Hellenistic, Roman, and Byzantine).

As a similar experiment, this dissertation examined the shipwreck corpus from the late medieval and early modern periods organizing the material based on the same outline as Rieth. The results were nine different categories that included shared construction features and transitions within certain groupings. Besides the lack of data from shipwrecks dating to this period, this approach is hindered by the appearance of categories with similar hull forms or construction techniques. Rieth envisioned this organization as a method for understanding the origin of hull shapes across the Mediterranean. Its application to shipwrecks from later periods suggest greater complexity due to the exchange of thoughts and ideas between builders. Another concern is that shipbuilders presumably relied on whatever work might become available, which could lead to craftsmen producing different hull forms while using the same techniques.

The operational process applied by archaeologists examining the development of other traditional crafts in communities around the world. These analyses organize distinctions between archaeological assemblages as the physical manifestation of social practice theory. Practice theory discusses the interplay between structuralism and agency, explaining how both aspects apply to daily social interactions. Scholars entwined practice theory with social learning theory, which explains how craft production is a communal process. Members who participate in learning (in a shipbuilding apprenticeship program, for example) are participating in a community of practice that implies social systems that influence the process of production. Ethnographic and archaeological research suggests that communities of practice were geographically bound following the same operational process of manufacture. Stages within manufacture share overlapping domains that comprise a final product from this practice, while the inclusion of flair or decoration are culturally based. Craftsmen may compose a constellation of practice due to migrations from different regions and the original orthodox method could become heterodox when adopted by outside groups.

This dissertation’s application of practice and social learning theories to shipbuilding suggests that the Mediterranean comprised multiple communities of practice. These groups shared similarities and differences in how they built ships in shell- and frame-first construction. The transition from shell- to frame-based shipbuilding was non-linear, which affected how the actual practice was carried out between western and eastern groups. In this analysis, shipbuilding in the late medieval and early modern era was already a heterodox system that included an orthodox practice using a single-master frame in the northern Italian Peninsula. The fact that this method of design and assembly was carried to the Atlantic-Iberian coast suggests a constellation of practice between these groups. As a multistage process, shipbuilding also follows domains of practice between the liveworks, deadworks, rigging, and decoration. These domains are both sequential and overlapping, while the last domain is also related to communities of identity (cultural significance).

Archaeological remains also provide further context about the conception and design of shipbuilders. Shell-first construction was preconceived in a longitudinal vision that became reality as each subsequent strake was attached and adjusted to create the hull. Predetermination exists in shell-built hulls due to simple proportions that were based on a linear unit and that certain strakes could act as markers for a uniform hull. State shipyards likely influenced craftsmen to create similar hull shapes by using temporary molds or to speed up production by preassembling strakes before fitting them on a hull. By the time the widespread adoption of frame-based practices occurred, the same concerns of related proportions continued, with key frame stations erected first to dictate the hull form. Key frames were organized on the same shared proportions as the rest of the hull and their placement related to the length of the keel. Design and modification of key frames relied upon a master frame template and rising tablet that became ubiquitous tools throughout the Mediterranean. So long as each frame was straight on the keel, the predesign could extend close to the endposts. Predetermination of endpost frames was intermittent and often relied on falling back to shell-first conception by utilizing ribbands instead of planking to dictate the forward most and aftermost sets of frames on a hull.

Limited documentation of shipbuilding in antiquity has left the archaeological remains as the main source for our understanding construction. Shipbuilders may have utilized sketches to convey their ideas to financiers of building projects, but these drawings were not used as part of the construction process. Surviving documentation for shipbuilding in the late medieval period survives mainly in the form of construction estimates with brief mentions of template use. Building estimates were often kept because these were state enterprises concerned mainly with longship design where the overall length and the placement of the wale supporting the outrigger were the main concerns. In a similar manner, the appearance of the first treatises on ship construction in the fifteenth century stem from officials of the Venetian arsenal trying to preserve the hull form of ships constructed by a recently deceased master builder. These documents and others created a corpus that was exploited by individuals invested in writing about the basics of shipbuilding but were not necessarily builders themselves. This interest led to composite notebooks and nautical treatises that showcase a concern for longship design with limited information about round ships due to the latter being built by private industry.

Even if these early documents were not necessarily written by shipbuilders, they still conveyed information about how the hull was designed. Longships were dictated by their overall length, while round ships followed proportion parameters based on the keel, beam, or another key timber. These proportions stem from a linear unit and also dictated the rising and narrowing for the frames. Concern about the narrowing of deck space toward the endposts developed a method for tilting the upper futtocks to compensate. Geometric progressions were also shown and provide evidence for how the incremental changes between frames were created.

Documents from the sixteenth century were written by shipbuilders or possible members of the Venetian arsenal. These sources report hull construction features and methodology for design which are similar to that of the previous century. Both discuss the drawing of a square utilizing the rake and height for endposts or half-beam and height for the master frame. Applied approaches discussed by the shipbuilders also differed from the text, such as the application of a wooden slat bent to create the side profile of the master frame rather than relying on an existing template. Proportions were important and described by some authors, but the discussion of actual work in the shipyard by the builders also explains why not every shape or length is derived from proportions themselves. Cords draped from poles or between hull elements provided the curves necessary rather than specific measurements.

Most of the treatises from the seventeenth century follow the earlier fifteenth-century precedent of being conceived by authors with an interest in shipbuilding but who were not actual practitioners. Only an anonymous manuscript at the end of the century provides a first-hand account of longship construction which explicitly states a proportional relationship between most construction elements that was not acknowledged previously. The other contemporary treatises are equally focused on longship construction with misinformation or no information about round ship design.

Discussions about the round ship types were pulled from other sources or from existing ships that were built in a different tradition altogether but with the methodology from the Mediterranean applied. Additionally, these sources discuss the need for conceiving the endposts and master frame using a compass on paper that could be transferred to the shipyard. There is a lineage in recording ships between these three centuries with the initial goal to record the ideal shapes before the actual ships became lost. The fact that shipbuilders followed a similar narration format for describing hull design suggests the continuation of a method that was not originally conceived by the fifteenth-century scholars. Toward the end of this period discussion about designing ships on paper began to circulate and from which naval architecture would begin to grow into a distinct discipline.

Contemporary archaeological evidence supports several aspects of the documents, while also providing further evidence not directly addressed in them. Ship design for most of this period relied on dual master frames placed near the center of the keel. On either side of the master frames were a pair of intermediate frames that indicated the beginning of the rising and tailframes that marked the end of the predesign section. These key frames were standard on most frame-based ships with minor differences regarding placement. Only a small subset of shipbuilders from the northern Italian Peninsula relied on single master frames. Several ships include markings for the centerline and turn of the bilge, aspects reflecting part of the design process. There is also evidence for identifying frames with roman numerals to assist builders during the manufacturing process by indicating where each frame belonged on the axial timbers.

Roman numerals helped position frames on the keel and correctly orient the overlap between floor timbers and futtocks for fastening them together.

Several vessels that are frame-built and utilize a keel have narrowed framing but do not include a rising foot. This observation suggests a mixing of design with bottom-based construction. Other differences include the absence of tilting the futtocks and canting them outward instead to provide additional deck space. Several western sixteenth-century hulls also suggest the use of a half-circle arc for form not identified on any earlier ships. This same single arc was also applied to create wineglass shapes by reversing the curve to extend the floor timber to the keel. Each of these differences indicates that the conception and design of Mediterranean hull forms during this period is much more complex than initially perceived.

The earlier transition from shell- to frame-first construction was not linear and the archaeological material suggests for now that it began in the east and was slowly adopted in the west. Frame-based shipbuilding in the late medieval and early modern era was in some instances a maturation period. How effective the frame-based techniques adopted by different communities were varied based on the distance from the epicenters of this change. Techniques that worked well in shell-first construction or had no new equivalents remained as part of the novel tradition. Problems that arose in this new methodology were also answered by the employment of earlier practices. Frame-based shipbuilding was also not the only technique present, as bottom-based construction continued to be utilized for various ships. These two techniques did not necessarily operate separately, and later ships presumably reflected shared ideas.

Although the corpus of shipwreck material from this period is plentiful, it is not exhaustive with regard to surviving hull material. There is a dearth of knowledge about the adoption of frame-based construction in the west and the same can be noted for eastern shipbuilding in the early modern period. Correspondingly, the available documentary record is largely centered around a specific state enterprise in the Adriatic – the Venetian arsenal- and does not always reflect the available archaeological assemblage which is predominantly from other regions. Ideally, as comprehensive studies of shipwreck material continue in the future, new discoveries will fill in the missing pieces. In the meantime, further research into Mediterranean shipbuilding during the late medieval and early modern period should be considered closely due to its significant influence on major technological changes that took place in vessels built in later Atlantic and Northern European shipyards.

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APPENDIX A

PERMISSIONS

TEXAS A&M UNIVERSITY

Charles Bendig <cdbendig@tamu.edu>

Inquiry about using Serçe Limani and 16th c. Yassiada site plans for dissertation

INA Archivist <archivist@nauticalarch.org> Mon, Sep 28, 2020 at 7:57 PM
To: Charles Bendig <cdbendig@tamu.edu>

Hey Charles,

Thanks, Jose and I are doing fine...just staying in and working from home! Hope you're doing well?

I finally heard back from everyone and as expected, Cemal, George, and Fred were happy to grant permission.

The credit line for Serce Limani should read "Image: George Bass and Fred van Doorninck. © Institute of Nautical Archaeology."
For the Ottoman Wreck: "Image: Cemal Pulak. © Institute of Nautical Archaeology."

I've attached the images I found in the projects' respective folders, but I wasn't sure if these are the ones you're referring to. If not, could you please send the example photos you found so I can see if I can find them in the physical archives to get you better copies?

Thanks,
Grace

INSTITUTE OF NAUTICAL ARCHAEOLOGY

Grace Tsai | Archivist
Institute of Nautical Archaeology (INA)
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www.nauticalarch.org

TEXAS A&M UNIVERSITY

Charles Bendig <cdbendig@tamu.edu>

Permission to use Lomellina imagery in my dissertation

guerout max <mrgueroutmaxadrien@9business.fr> Fri, Sep 25, 2020 at 7:56 AM
To: Charles Bendig <cdbendig@tamu.edu>

Dear Charles,

You can use all material already published in Archaeonautica n°9 : http://www.persee.fr/web/revues/home/prescript/revue/nauti or drawing based on this material with your proper interpretation.

1 - The section represented on your drawing is amidship, so I don't understand the representation of what you call **Stempost** which cannot be visible at this level.

2 – Your representation of the **ceiling** upside of **mast step partners** and **keelson** is not accurate. As you can see on Archaeonautica n°9, page 70, the **ceiling** is supported by what I call in French : **traverse**.

3 – Note that **mast step partners** and **keelson** are parallel and contiguous

4 – Note also that the **lower whale** at the level of the first deck don't exist where you draw it, for a good representation, look ay the page 98 of Archaeonautica

5 – At the **stringers** inside of the hull match outside either **whales** or oak **planking** instead of usual pine planking.

Cordialement

Max

De : Charles Bendig [mailto:cdbendig@tamu.edu]
Envoyé : jeudi 24 septembre 2020 23:18
À : guerout max
Objet : Permission to use Lomellina imagery in my dissertation

Gmail

Charles Bendig <cdbendig@otrms.com>

Request to use Mortella III site plan in my dissertation

SEAS <archeo.seas@gmail.com> Mon, Sep 21, 2020 at 3:50 AM
To: Charles Bendig <cdbendig@otrms.com>

Dear Charles,

This is a nice work! I am pleased you are doing research on Mortella III architecture. Of course I give you my authorization to work on our drawings and to publish your own interpretation/additional drawing/colours on them mentioning the original author. 2019 excavation report is not published yet, but you can refer to its content with the following reference: Cazenave, A.et al., 2020, 'Mortella III 2019 excavation campaign report', Unpublished report kept by the French Ministry of Culture (DRASSM).
I sent you by Wetransfer the general planimetry of the Mortella III site and I took advantage of this sending to add the English version of my book on Mortella III wreck.
Unfortunately, we were not able to excavate this year. Covid 19 didn't allow us to gather our team for that. Mortella II wreck was scheduled this year. I hope we will be able to carry out the operation next Spring. Ribadeo excavation is planned on mid-October. I hope it will be possible to maintain it...
Wish you a good research!

Cheers,
Arnaud

[Quoted text hidden]
--

Researcher of the Marie Sklodowska-Curie Actions Programme (MSCA-H2020)

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TEXAS A&M UNIVERSITY **Charles Bendig <cdbendig@tamu.edu>**

Permission to Use a Overall Plan of Ribadeo in Dissertation

Miguel San Claudio <miguelsanclaudio@archeonauta.com> Sat, Mar 6, 2021 at 3:40 AM
To: Charles Bendig <cdbendig@tamu.edu>

Hola Charles!

Nice to talk with you, I remember you very well

Was a pity last year you can't come to Ribadeo. Anyway this year we'll back there in June. If you wish to join us, you know you're welcome.

Here: https://drive.google.com/drive/folders/1QgsPd8g0D8DuFAdhPQA4tH7ULcYaOpiY?usp=sharing you'll find drawings and photographs from Ribadeo you can use in your dissertation.

Please feel free to ask or increase any detail, I'll be very happy to help you in any way I can.

Yours

M

Miguel San Claudio Santa Cruz

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Pamela L Quick <quik@mit.edu> Tue, Mar 2, 2021 at 6:22 PM
To: Charles Bendig <cdbendig@tamu.edu>

Dear Charles,

Thank you for your message. We do allow students to include imagery from our books in their dissertation for noncommercial academic use only, so you may include the scans of the pages from the website listed below. Please indicate that the images are reprinted from *The Book of Michael of Rhodes: A Fifteenth-Century Maritime Manuscript, Volume 1,* edited by David McGee, reprinted courtesy of The MIT Press.

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With best wishes,

Pamela

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