A ROMAN SHIP SCUTTLED NEAR SALONA IN THE GULF OF KAŠTELA, CROATIA: EXCAVATION, RECONSTRUCTION AND ANALYSIS

A Dissertation

by

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

DOCTOR OF PHILOSOPHY

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May 2020

Major Subject: Anthropology

ABSTRACT

Salona (near present-day Split, Croatia), originally an Illyrian city with Greek presence along the eastern Adriatic coast, was conquered by Republican Rome in 76 BCE. Based on its central location in Roman Dalmatia, coupled with a protected harbor in the eastern Gulf of Kaštela and a connection to the hinterlands through the mountain pass of Klis, Salona was the natural choice for the location of the provincial capital. In 2002, the recovery of a 1000-liter perforated *dolium* in the Trstenik section of Kaštel Sućurac, only three kilometres from the ancient city walls of Salona, attracted the attention of archaeologists to significant Roman remains submerged near shore. In 2006 the outline of a wooden ship was identified, scuttled alongside a submerged wooden wall. In 2015, the ship was uncovered, labelled, recorded using photogrammetry, extensively sampled, then reburied for preservation *in situ*.

Without completely excavating the wreck, obtaining detailed measurements of all its timbers and conserving the wood remains, the analysis of the wreck and the reconstruction of the hull would depend on its investigation using various computer methods. First, a 3-D model of the ship's remains was generated using Agisoft PhotoScan. Based on this archaeological data, site plans were generated in ArcGIS to document the wreck. Analysis of the hull remains determined the ship to be a flat-floored, mortise-and-tenon constructed ship, dated to approximately the late 1st century CE and suitable for transport of heavy cargo, reflecting the apex of Imperial Rome's influence on the eastern coast of the Adriatic Sea.

A reconstruction of the ship's hull was undertaken in the Rhinoceros 3D modelling program by combining preserved hull curvatures, the full extent of wooden remains exposed on the seabed, and hypothetical hull height based on a review of contemporaneous ships. The Rhinoceros plug-in modules utilized to perform this reconstruction include an iterative draft and displacement calculator, which estimates the Trstenik ship displaced approximately 25 tons. This technique is suitable for extrapolation to other ancient wrecks recorded only by photogrammetry.

DEDICATION

To George Bass. Without him…nothing.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Cemal Pulak, and my committee members, Dr. Deborah Carlson, Dr. Irena Radić Rossi, and Dr. Daniel Schwartz, for their guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues, and the department faculty and staff for making my time at Texas A&M University a great experience. As a 'non-traditional' (i.e. 'old') student, I required a bit of extra attention to get over the tall hurdles—thanks to all the heavy lifters who boosted me up over the years.

I also want to extend my gratitude to the Institute of Nautical Archaeology (INA), which funded this excavation with the 2015 Claude Duthuit Archaeology Grant.

Finally, thanks to my mother for her encouragement to quit working and attend Texas A&M, and MOST importantly to my wife Marla for sticking with me even though I quit working to attend Texas A&M, with the unintended consequence of making us both quasi-Texan.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

All Ph.D. projects are team efforts, and there is no way to highlight every contributor whose experience, knowledge, and patience enhanced this project. It is particularly important to me to recognize the Texas A&M Nautical Archaeology professors who accepted me into their program despite woeful preparation and readiness to succeed on my part. Thank you for your blind faith in me and your support during my time in College Station; all of you were important to my academic success. A special recognition must go to Dr. Irena Radić Rossi of the University of Zadar, who graciously allowed me to co-direct the Trstenik excavation near Split, Croatia. She is the only person on the planet who could have allowed me to excavate a Roman-era ship while still a student; I will be grateful for that opportunity for the rest of my life. I also must recognize all of the hard work that went into the excavation and subsequent reconstruction. No matter how many names I list, some will be slighted, so let me recognize five Croatian contributors in Katarina Batur, Suzana Čule, Matko Čvrljak, Vedran Dorušić, and Ines Šelendić, and five Texas A&M classmates in Nick Budsberg, Jose Casaban, Arianna DiMucci, Chris Dostal, and Kotaro Yamafune. These ten individuals stand for all the local and international assistance I have received during my studies at Texas A&M. Their support and friendship, both now and in the future, are the best rewards I could receive. Photographic credit for underwater images used in computer modeling belongs to Sebastian Govorčin. Drone video and photography were

taken by Ervin Šilić of Novena Ltd. Multimedia. Artifact image photography credit is shared by many individuals, most notably Arianna DiMucci and Katarina Batur. Extensive laboratory determination of wood sample species was performed by Nili Liphschitz. With respect to manuscript preparation, I would like to recognize the graphic contributions of Andrew Fleming and Valerija Butorac, the Agisoft PhotoScan assistance from Kotaro Yamafune, the 3-D modeling contributions of Jose Casaban and Andrew Harrell, the historical research assistance of Ivan Radman Livaja, and the editing contributions of Rives Duncan.

Funding Sources

The majority of my academic funding at Texas A&M University came from the US Department of Veterans Affairs Post-9/11 GI Bill, which paid tuition and a stipend for 36 months of study. Without that support, I would not have been able to attempt this degree program. With respect to this dissertation, the excavation at Trstenik would not have happened without the support of the Institute of Nautical Archaeology (INA) and its Claude Duthuit Archaeology Grant in 2015. I am honored by my designation as an INA Research Associate, a relationship which I hope to maintain for the rest of my life.

During my studies, I received financial assistance from the Anthropology Department of Texas A&M University through both travel funding and the paid opportunity to teach a course for one semester. I have also received travel support from Texas A&M University's Center for Maritime Archaeology and Conservation (CMAC) and from the AdriaS Project (Croatian Science Foundation project #IP-2014-09-8211). I am grateful for everyone's investment in my academic program.

NOMENCLATURE

ACSC	Air Command and Staff College
BCE	Before the Common Era
CAD	Computer Aided Design
CE	Common Era
CMAC	Center for Maritime Archaeology and Conservation
GIS	Geographic Information Systems
INA	Institute of Nautical Archaeology
NURBS	Non-Uniform Rational Basis Spline
RAM	Random Access Memory
TAMU	Texas A&M University

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1. INTRODUCTION

A somewhat unusual background with a twisted path carried me a long way, from farm country in western Kentucky and a career in the US Navy's submarine force, to nautical archaeology at Texas A&M University and the excavation of a Roman ship off the coast of Croatia. Among many influences and choices, three specific occurrences impacted me greatly, ultimately resulting in my approaching the field of nautical archaeology. First was an education at the US Naval Academy followed by 25 years in the US Navy's nuclear submarine force. While the Naval Academy did offer 'bull' majors when I attended (English, History, Political Science, and Economics), the vast majority of Midshipmen selected either an engineering major or a science/math area of study. I chose Chemistry. Hours in the laboratory coupled with mandatory core courses resulted in an education far from the tradition of 'liberal arts.' My two history courses, both 100 level courses taken during my freshman year, were "Western Society Since 1715" and "American Naval Heritage," providing me zero exposure to the ancient world. Subsequent service aboard multiple submarines left little opportunity to rectify this educational void.

In 1993, I had the opportunity to do a one-year exchange program with the US Air Force and attend the Air Command and Staff College (ACSC) at Maxwell Air Force Base, Alabama. This professional military school educates mid-level officers from all branches of the US Military as well as international officers from around the world on the planning of joint military operations, emphasizing the employment of air power.

ACSC approached military strategy first from a historical perspective. This became my initial exposure to Thucydides' *History of the Peloponnesian War*, Herodotus' *The Histories*, Sun Tzu's *The Art of War,* and many other works. I devoured them all. My recreational reading habits shifted to sea power of the ancient Mediterranean.

My first duty station after ACSC was as Executive Officer of *USS Archerfish* (SSN 678). *Archerfish* deployed to the Mediterranean in 1995, and between exercises and operations around the Mediterranean, the ship and crew enjoyed a three-day port visit in Bizerte, Tunisia. I was able to tour the ancient city of Carthage, including the remains of the Phoenician harbor. This gave me a physical connection to my historical readings. Not only had the Carthaginians launched their Punic war fleet to oppose Rome from this exact place, but remains of the slips used to haul up and launch their ships still existed. This stimulated my personal research in an entirely new direction: what other remains of ancient ships and sailing vessels survived to the present day? Research led me to the Uluburun shipwreck, George Bass, and ultimately the Nautical Archaeology Program at Texas A&M University. Reading as a hobby turned to aspiration, and 16 years later, with my children graduated from college, I was finally able to pursue formal studies in nautical archaeology at TAMU.

Every student of nautical archaeology aspires to excavate—fieldwork is where the action is. Timing becomes an important consideration to determine the intersection of academic studies with excavations in progress. My good fortune was performing my first year's fieldwork with Irena Radić Rossi of the University of Zadar. That fortuitously grew into an opportunity to jointly conduct an excavation that supported my educational goals while contributing to her research. While many shipwrecks exist off the coast of Croatia from all seafaring ages, the Trstenik wreck possessed multiple attractive attributes. The ship was scuttled only 50 m from land in 3 m of water, making it easily accessible to divers from shore while simplifying logistics. The ship was well-preserved thanks to its ancient disposal under rocks, and study of the ship could contribute to both nautical archaeology as well as an enhanced understanding of the shoreline complex where it was deposited. Additionally, the wreck site is near urban Split, Croatia, with multiple dive shops and a hospital equipped with a recompression chamber. Ultimately a single-season partial excavation of this site was undertaken as a cost-effective project which could provide significant archaeological information at low risk. The area around the wreck and the history of archaeological studies in its vicinity are discussed in greater detail in Section 3.

For speed of degree completion, developing a dissertation based on field work is not the ideal path. Timelines drag on, critical information is unavailable, and there is always the desire for 'more:' another season, additional measurements, 100% sample coverage, etc. The pursuit of omniscience and perfection must be balanced with both cost efficiency and the need to graduate in a reasonable period of time. The excavation of the ship at Trstenik becomes a case study in what archaeological information can be extracted from a single, short season at a site with a limited fieldwork budget and no funds to support detailed artifact analysis or wood conservation. Despite its 'limits,' I still managed to spend over four years working on the dissertation—longer than my entire undergraduate career.

This work is broken into eight sections. Following the introduction, Section 2 describes the geography, history, and trade of Roman Dalmatia, while Section 3 focuses on the geography, history, and recent excavations in the vicinity of the Trstenik site in the Gulf of Kaštela, Croatia. The next two sections describe the excavation season itself and how the information from the excavation was processed to document the archaeological information from the site. Section 6 describes the ship's hull remains in detail and Section 7 discusses the computer reconstruction of the ship; Section 8 concludes the work and proposes several courses of future action.

The following pages do not present the final answer for the Trstenik ship. Much information remains on the sea floor waiting to be collected, and the conclusions drawn here could certainly be significantly enhanced through complete excavation. However, every discovered shipwreck cannot be excavated over multiple seasons, conserved for display, and systematically studied for generations. This dissertation serves as one model for extracting maximum information from a site at low cost while preserving the site for potential future examination. Ultimately, this work reflects an appreciation for the amount of knowledge available at thousands of underwater sites around the world and stands as a cost-benefit example for consideration while planning future work.

2. BACKGROUND AND HISTORICAL CONTEXT

2.1 The Geography of the Roman Province of Dalmatia

Discussion of Dalmatia as a geographic region along the eastern coast of the Adriatic Sea must begin by selecting a historical period of interest because the borders of the region vary greatly over time. Regardless of time frame, the stark geography of the landscape significantly impacts any analysis of settlement, trade, and economy of the region, its native peoples, and any immigrants to the area.

Modern-day Dalmatia, a region of the country of Croatia, is significantly smaller than the Roman province of Dalmatia. Today, Dalmatia is considered a maritime-focused area, which encompasses the majority of the Croatian coastline, including numerous islands and rocky outcroppings along the southern coast of Croatia. Today's Dalmatia also encompasses the Dinaric Mountain chain, an extension of the Alps running alongside the Adriatic coast. These mountains still form a barrier between the sea and coastline of western Croatia, and the 'hinterlands' of the central and eastern portions of the country. Figure 2-1 indicates the present-day boundary of Dalmatia within Croatia.

Figure 2-1. The Present-Day Boundaries of Dalmatia within Croatia. (credit: Valerija Butorac)

The Roman province of Dalmatia was created during the early Roman Empire, following military operations in 6-9 CE. Tiberius executed Augustus' orders to quell the Illyrian revolts and completed his mission by establishing the provinces of Dalmatia and Pannonia through division of the province of Illyricum. Džino notes that

> Illyricum is probably the most artificial of all Roman 'colonial artifacts' in western Europe, a very loose space for which we cannot pinpoint a certain political institution, a shared sense of identity amongst the indigenous population, or clear geographical markers. To make things even more difficult…the term Illyricum was used in different circumstances and was manipulated for different reasons in the past...Geographical features are much more helpful in defining areas such as Hispania, Britain, or Italy for example.[1]

[1] Džino 2016, 74.

This somewhat ill-defined Illyricum was split into two provinces: Pannonia to the north and east and Dalmatia to the south and west.[2] This action was contemporaneous with the loss of Varus and his three Roman legions in the Teutoburg Forest, which tempered any Roman desire to conduct further conquests in favor of consolidation and pacification of these geographically large areas.

The boundaries of the province of Dalmatia are not specified exactly but are known generally to include the eastern portion of the Istrian Peninsula, the islands, coastline and western interior of Croatia, most of Bosnia and Herzegovina, the northern part of Albania, and a portion of western Serbia. Figure 2-2 shows the approximate boundaries of Roman Dalmatia, overlaid on a map of the modern Balkan countries.

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[2] See Section 2.2 for a historical summary of Dalmatia.

Figure 2-2. The Roman Province of Dalmatia. Provincial boundaries are shown overlaid on a modern geographical and political map of the region. The red square highlights the Gulf of Kaštela. (credit: Andrew Fleming)

Strabo did discuss the coastline of Roman Dalmatia. He begins in the north by describing the Istrian Peninsula, then moves clockwise around the Adriatic. He mentions the tribal areas of the Iapodes and the Liburni, then proceeds southward to the city of Scardo (Scardona) and the river Krka, the island chains off the coast including the islands of Issa (Vis) and Pharos (Hvar), the seaport of Salo (Salona), and the mountains that cut Dalmatia into two parts, one facing the sea and the other inland.[3] He was clearly knowledgeable of the region, and his description is easily recognized in the modern geography of the region.

[3] Strab. *Geog.* 7.5.3-5. For a detailed discussion of Strabo's description of Illyricum see Džino 2008.

Geographical constraints significantly impacted Roman Dalmatia. Wilkes provides a geographical outline of the region, illustrating the impacts of several constraints of the natural environment.[4] The coastline of Dalmatia is very rocky, deeply indented with small rock-bound harbors, and screened by multiple layers of island ranges. Immediately inland of the coast, much of the region is mountainous, providing a geographic separation between the narrow coastal/island region and the eastern hinterlands. In antiquity there was no continuous coastal road, and coastal and island settlements were largely disconnected except for sea transport. The width of the coastal plain varies from almost nonexistent in some areas, to large fertile plains able to support agricultural populations.

A topographic study has developed the following definitions to classify the various land masses of Croatia's coastal sea area:[5]

- Island - a piece of land completely surrounded by the sea, with an area larger than 1 km^2.
- Islet - a piece of land with area between 0.01 and 1 km^2.
- Rock or rock awash - a piece of land with an area less than 0.01 km^2. The difference between rock and rock awash is that a rock is always visible above sea level, while a rock awash is sometimes submerged below sea level.

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[4] Wilkes 1969, xxi-xxvii.
[5] Leder et al. 2004.

Ultimately a total of 79 islands, 525 islets, and 642 rocks were identified in Croatian waters (of which only about 5% are permanently inhabited). These total to 1,246 land masses, all of which are named. Six of the islands are larger than 200 km^2 and immediately apparent when viewing a chart: Krk and Cres to the north in the Bay of Kvarner, Pag just north of the Zadar/Nin region, and Brač, Hvar, and Korčula extending south from Split. Two large peninsulas are also apparent: Istria to the northwest and Pelješac to the southeast. There is a stark contrast when comparing the heavily islanded coastline of Dalmatia and the eastern Adriatic seaboard against the flat, virtually island-less Italian coastline to the west.

Land access from the coast inland to the hinterlands was limited to several mountain passes. For example, the most important passes in antiquity to cross the Velebit mountain chain, a southern extension of the European Alpine range separating the northern Roman Dalmatian coast from its hinterlands, were the Vratnik Pass, which crossed the Velebit near Senj, the Oštarijska Vrata Pass near Karlobag, and the Prezid pass near Obrovac in the vicinity of Zadar, which provided access to the hinterlands at the southern end of the Velebit. Another important pass farther south through the Dinaric Alps was the Klis Pass above the Gulf of Kaštela near Split, which provided access from Salona to inland legion outposts.

Access from the Adriatic Sea inland via rivers was limited. Most drainage from Dalmatian inland areas flowed north and east to the Sava River and then to the Danube, ultimately draining to the Black Sea rather than finding a passage through the Dinaric Alps to drain to the Adriatic Sea. Only four navigable rivers flow into the Adriatic Sea through Dalmatia. Listed from north to south, they are the Zrmanja with its mouth near Novigrad, the Krka with its natural harbor at Šibenik, the Cetina which reaches the coast at Omiš, and the Neretva (the largest river of the province) with its outlet at Ploče. As a group, these rivers are of little use for inland communication, as much of their courses flow underground in the karst region of the mountains and many above-ground sections are only navigable for short distances. Only the Neretva reaches from the interior all the way to the sea without disappearing somewhere in the mountains.[6] Although the Jadro River is important to the discussion of Salona and its harbor, the Jadro is actually more of an outlet for a mountain spring and drainage from precipitation. This non-navigable river is only about 4 km in length. An additional limitation of the ancient usefulness of the four somewhat navigable rivers was the location of Classical, then Republican, settlements. Many of these settlements were not close to the mouths of rivers. Two examples include Narona (modern Vid), which lay about 20 km from the mouth of the Neretva, and Scardona (modern Skradin), about 20 km from the mouth of the Krka River. Narona, for example, underwent significant contraction as Salona ascended in importance during the empire, declining in the height of the *Pax Romana* as the provincial capital flourished.[7]

The Velebit range, a mountainous spine extending south from the Alpine range and bisecting northern Roman Dalmatia, became a major boundary between the inhabitants of the coastal areas and the native peoples of the inland areas. The craggy

[6] Glicksman 2009, 22.
[7] Lindhagen 2016, 242-3.

nature of the coast also made land connectivity between coastal settlements challenging. The end result was the development of a significant maritime tradition to conduct trade and interconnect the different peoples living along the Dalmatian coast. This gave rise to significant contact between the province and the peoples living along the Italian peninsula, facilitating the spread of technology during the conduct of economic activity. In contrast, the mountainous wall of the Velebit, coupled with poor river access and minimal passes through the range, kept the native tribes of the hinterlands relatively insulated from the coastal tribes and made Roman contact into the heartland of the province more tenuous.

Rome selected Salona to be the capital of the province of Dalmatia. The city existed, with native population, prior to the arrival of Romans. The first historical mention of the city of Salona was in Appian's *Illyrian Wars*, in which he documented a Roman military leader's wintering over in Salona during campaigns against Illyrian tribes in 119-117 BCE.[8] Recent excavations indicate that the original city was somewhat to the north and west of the eventual Roman location and may well have been destroyed during the fall of the Delmatae to the Romans in 76 BCE.[9] While the exact timing of Republican occupation of towns along the Eastern Adriatic coast is somewhat murky, and in many cases cannot be pinpointed to Caesar or Octavian, the establishment of a *conventus civium Romanorum* (an association of Italians living on foreign soil) at

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[8] App. *Ill.* 11.
[9] Marin 2006, 73.

Salona during Caesar's proconsulate is well documented.[10] Matijašić notes "Caesar certainly supported the idea of the local Roman settlers, mainly merchants, craftsmen and sailors, organizing into informal communities within the territory of local inhabitants, in that case the *Delmatae*."[11] Based on fragments of Greek inscriptions found in the area, Caesar was clearly involved in Salona civic activities by 56 BCE at the latest, during the first triumvirate when he was proconsul of Cisalpine Gaul, which included Illyricum.[12]

Geographically, it was logical to situate the capital here. Salona was located on the Gulf of Kaštela, a large inlet protected by the Marjan Peninsula (the present-day city of Split) and the island of Čiovo (Figure 2-3.). The Gulf of Kaštela is approximately the midpoint of the Adriatic coastline of Roman Dalmatia, and the city of Salona became a major focal point for the inland construction of Roman roads connecting military outposts across the province. These inland thoroughfares provided access both north and south between legionary hinterland outposts such as Burnum and Tilurium as well as east/west routes across the province in the direction of the Danube River. While these Roman roads may have taken advantage of previously existing routes, several inscriptions document the construction of at least six separate major routes linking major military centers near the Adriatic to Roman military outposts in the hinterlands.[13]

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[10] *BAlex.* 43, Caes. *BCiv.* III-9.
[11] Matijašić 2018, 71.
[12] Wilkes 1969, 37-9.
[13] *CIL* III, 3198a = 10156 + 3200 and *CIL* III, 3201 = 10159 plus 3198b = 10156b. These broken fragments, reused in buildings constructed in Split, clearly reference distances with respect to Salona. See Wilkes 1969, 452-5 and Babić 2007, 161 for additional discussion.

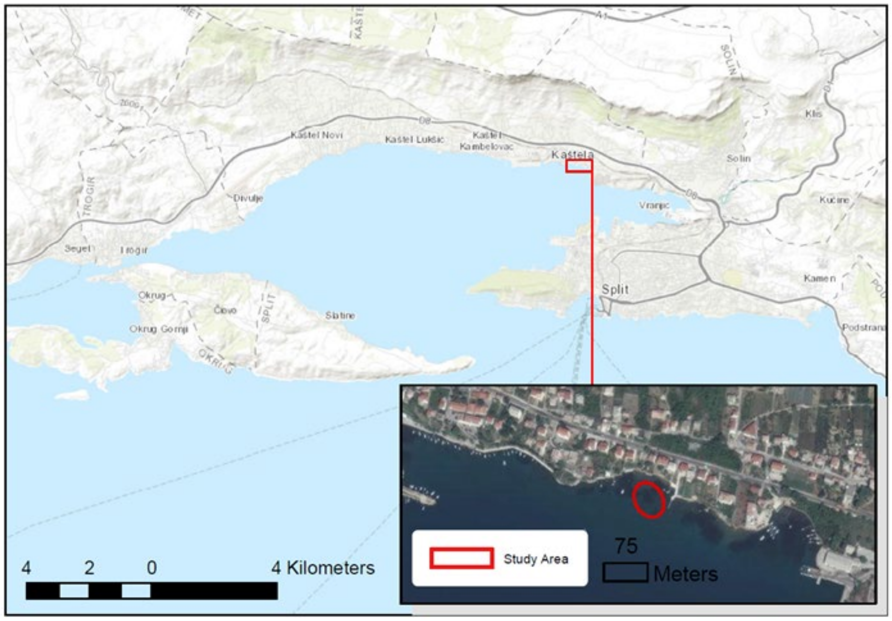

Figure 2-3. The Gulf of Kaštela. The red square highlights the Trstenik section of Kaštel Sućurac, where the 2015 shipwreck excavation took place. Red circle of the inset marks the shipwreck location. (credit: Andrew Fleming)

These roads would have been built by a combination of legionnaires and native labor, including prisoners of war, in the decade following the suppression of revolt in 9 CE. While this Roman road network may not be particularly dense, it does capitalize on natural topography and effectively utilizes important access routes to link the easily accessible coastline with the interior hinterlands. As Stipčević notes, “Roads were of great strategic importance to the Romans, enabling them, when at war, to move quickly from one point to another. They were used, however, equally often for moving merchandise and mail, and, last but not least, they served as bearers of Roman civilization."[14] Salona would have had a pivotal position from the perspective of both land and sea communications and transportation, commanding roads leading through the pass at Klis, influencing control of the Cetina River as it flowed toward Omiš, and handling sea cargo through the protected Gulf of Kaštela.[15]

2.2 Summary of the History of Dalmatia

2.2.1 Prehistory

It is unfortunate that ancient written sources discussing Illyricum and Dalmatia are particularly sparse. As Džino notes,

> Insufficient evidence remains a great, almost unbeatable curse…upon Illyricum and its historians. It is the main reason why the indigenous peoples of Illyricum still remain 'people without history'…and why Illyricum is still one of the least popular regions of ancient Europe for research for ancient historians.[16]

The prehistoric tribes of the Roman province of Dalmatia are traditionally lumped into the broad category "Illyrian." This labeling results in the incorrect assumption that the regional native peoples were united in language, culture, and purpose. In fact, there is no archaeological evidence of cultural unity across the peoples traditionally labelled by ancient Greek and Roman sources as Illyrian.[17]

Wilkes reviewed almost 100 years of studies of Illyrian names and summarizes by describing three "onomastic provinces" in the area of Dalmatia. The southern

[14] Stipčević 1977, 66-7.
[15] Unfortunately the exact location of the harbor at Salona is not known. See Cambi 2001, 142.
[16] Džino 2010b, 177.
[17] Glicksman 2009, 11.

province includes modern Albania and continues north along the Adriatic coast from the south to the area of the Neretva valley. The middle Dalmatian-Pannonian province is considerably larger in area, including the Adriatic coast between the Krka and Cetina Rivers as well as a large portion of Bosnia. Wilkes couples the above two Illyrian provinces with a Venetic province to the north that includes the Liburni, the Istrian Peninsula, and the region of Slovenia beyond the Julian Alps. He further notes that there is a measure of overlap between these linguistic regions, indicating that the languages spoken were somehow related if not altogether common.[18] Even these divisions are incomplete; for instance, the Liburni are typically considered to represent a single large tribe, but Roman boundary stone evidence shows they actually were subdivided into various smaller tribal groups with unique urban centers.[19] The lack of any indigenous narratives of these peoples from their own perspective necessarily forces viewpoints based on historical documents to have a decidedly Roman perspective.

Additionally, the native tribes of Dalmatia have different origins. This naturally results in different traditions.[20] For example, the Liburni appear to have always had a seafaring tradition. They have occupied the central coast of the eastern Adriatic since at least their first contact with Greeks, who sailed north into the Adriatic in approximately the 8th century BCE, and likely earlier. The Liburnian center of power was

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[18] Wilkes 1992, 69-71.
[19] Čače 2006, 75-8 and Glicksman 2009, 11.
[20] See Džino 2010a, 104-8 for a discussion of the non-homogeneous population of Illyricum, cultural identity, and the impact of misleading nomenclature and arbitrary Roman administration imposed upon native peoples, with respect to analysis of the "Dalmatianness" of Roman sailors from Dalmatia based on tombstones found in Misenum and Ravenna.

approximately where Zadar is located today, and geographically that location, with two rows of islands clearly visible from land, required an extensive nautical tradition to utilize the sea, control the area, and move between settlements. Studies of prehistoric hill fort activity in this region indicate that fortifications were used only intermittently, likely during times of strife. In periods of peace, Liburni life was coastal and oriented toward the sea.[21] Continuing research of Liburnian hill forts is beginning to uncover prehistoric occupation details, as well as measure the impact of Romanization of the province.[22]

Linguistics continues to add to the mosaic of interconnecting Illyrian peoples, highlighting the fallacy of assigning a single term to encompass a wide diversity of cultures. As early as 1976 Katičić noted that all of Illyricum could not be regarded as a single linguistic area. He coined the term "North-Adriatic" to specifically recognize Liburnians as part of a much larger onomastic complex, extending in a wide swath from the Histrian and Venetic tribes of the Istrian Peninsula to the valleys of the eastern Alps.[23] Džino also documents that the Liburnian language belongs to the same linguistic group as that of the Veneti of the northern Adriatic region. While noting archaeological evidence of inter-cultural connections between the Liburni and central Illyrian tribes prior to contact with the Roman Republic, he highlights sea and maritime connectivity as more of an influence on the Liburni than continental contact with other native tribes

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[21] Batović 1973 discusses the evolution of Eastern Adriatic hill forts over prehistoric, then Roman times. The article (in Croatian) is summarized in French (pp. 153-65) and includes 108 photographs and illustrations on unnumbered pages.
[22] Zaro and Čelhar 2018, particularly with respect to Nadin-Gradina (Roman Nedinum) near Zadar.
[23] Katičić 1976, 177-9.

from the interior of the region.[24] Evidence of Liburnian-style ship construction has now been dated to as early as the 12th-10th century BCE. At Zambratija on the north-eastern promontory of Istrian Peninsula, a Bronze Age shipwreck has been recently found and studied. This vessel had a center keel-like timber, characteristic lacing to connect planks in the shell-first construction method, and frames with rounded upper faces, narrow bottoms, and no notches on the frame bottoms subsequently inserted and lashed in place to provide structural support.[25]

In contrast, the Delmatae were an inland tribe from the east that immigrated to the eastern Adriatic central coast in approximately the 3rd century BCE.[26] The first appearance of the warrior Delmatae in the historical record is in Polybius, who recorded the Greek inhabitants of Issa (modern Vis) requesting Roman help to defend mainland Greek settlements against incursions from the Delmatae.[27] One analysis evaluated the Delmatae as a recent social formation, not much older than its first mention in written sources, in essence being a political alliance of culturally similar clans rather than a distinct ethnic group. Based on ethnographies that could have mentioned them but did not, their foundation could be pulled forward to the late fourth/early third century BCE, perhaps even more recent.[28] The Delmatae had no seafaring tradition. Thus, it is no surprise that local seacraft built with local materials, techniques, and traditions are

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[24] Džino 2003, 20-1.
[25] Boetto et al. 2017. For a recent article that places the Zambratija ship in Mediterranean sewn boat context see Pomey and Boetto 2019, 8-10.
[26] Stipčević 1977, 33, 55-6.
[27] Polyb. 2.8.
[28] Džino 2013, 148.

known as "Liburnian." Nor is it surprising that when Romans periodically moved into Illyrian territories, the Liburnians were largely able to avoid conflict based on their sea mobility and ability to move and relocate. In contrast, the history of the Delmatae people, with their hostile land-oriented 'stand and fight' mentality, is filled with clashes as Romans and other people moved into and through the area.

2.2.2 Greek Contact

Recorded history of the coastal region that would become Dalmatia begins with contact between the tribal peoples of the eastern Adriatic coast and Greeks prior to the Classical period. Herodotus chronicled, "Now the Phocaeans were the first of the Greeks who performed long voyages, and it was they who made the Greeks acquainted with the Adriatic and with Tyrrhenia, with Iberia, and the city of Tartessus."[29] The site of Butrint (ancient Buthrotum) in southern Albania, visible from the Greek island of Corfu, has archaeological evidence of Greek occupation since at least the 8th century BCE. Several underwater sites near Butrint exhibit Corinth B type amphoras dated to as early as the 5th century BCE.[30] As the Greeks moved northward in the Adriatic, the coastal colonies of Epidamnus (Roman Dyrrachium, modern Durrës) and Apollonia were founded in the 7th century BCE, and the colony of Epidaurus, near present-day Dubrovnik, was founded in the 6th century BCE.[31] Continuing this northward movement, the Cnidians established a colony on the island of Corcyra Nigra (modern

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[29] Hdt. 1.163.1.
[30] Royal 2012, 437.
[31] See Wilkes and Fischer-Hansen 2004 for a detailed discussion of Greek colonization into the Adriatic region.

Korčula) in the 6th century BCE. More extensive colonization continued in the 4th century BCE, including the Syracusans on the island of Issa (Vis) and the Parians on the island of Pharos (Hvar).[32] Thus, despite the fact that there is clear written and physical evidence the Greeks knew the eastern Adriatic Sea and navigated the region establishing trading stations and emporia along the coast, their settlements were chronologically late to appear in the region of Dalmatia. When the Greeks did settle in the area, it was almost exclusively on the islands of central Dalmatia.[33]

Two points made by Wilkes and Fischer-Hansen are germane to the understanding of Greek settlements in the Adriatic. First, they disabuse the notion advanced from time to time that Archaic and Classical Greeks were either prevented or repelled from entering the Adriatic Sea by either climate or by tribal hostility. "The Adriatic was as much open to Greek seafarers as it was in a later age to the Venetians, who…controlled it for centuries."[34] Any perceived resistance to colonization and spread into the Adriatic was based not on resistance applied to the Greeks, but rather a lack of push into the region by the Greeks. Second, there is no reason to postulate tortuous overland contact between Greek city-states and the future region of Dalmatia, or to challenge the assumption that all Greek contact with the Adriatic was by sea from the south. Wilkes and Fischer-Hansen note the fantastic quality of tales of overland contact and hypothesize that a combination of the disappearance and reappearance of rivers in

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[32] Wilkes 1969, 8-10.
[33] Sanader 2004, 8.
[34] Wilkes and Fischer-Hansen 2004, 322-3.

the Dalmatian limestone karst, the conflation of similar place names, and the parallels between native and Greek myths stimulated the imagination of storytellers.

Despite these multiple colonization efforts and the gradual but continual movement from south to north along the eastern Adriatic coast, Greek presence in the region remained sporadic and limited in both settlement density and geographic control. Neither ancient sources nor archaeological evidence indicate the founding of any Greek settlement, emporion, or polis in the Adriatic Sea or north of Epidamnus (modern Durrës in northern Albania) before the 6th century BCE. Apparently Greek interest in the Adriatic region began in earnest upon recognition of commercial opportunities associated with the Po River valley on the northern Italian peninsula.[35]

While Greeks and native peoples were in contact prior to the arrival of Republican Rome, in no way should this be considered any sort of hegemony or control exerted by the Greeks over the native peoples. With the exception of the establishment of colonies on the larger islands of the central Dalmatian coast by the 3rd century BCE, there was no extensive Greek effort to populate the region. Wilkes surmises that the native coastal people offered little to the Greeks for exploitation or exchange and any wealthier society in the hinterlands would have been difficult to reach from the sea. Rather than Greeks exercising hegemony over native peoples, by the middle of the century all of the Greek settlements of Dalmatia with the exception of Issa (Vis) were subject to the Illyrian kingdom, and this situation set the stage for Issa's appeal for

[35] Kirigin 2006, 19.

Roman aid in 229 BCE that was at least partially responsible for the first Roman Army crossing the Adriatic and entering the region.[36]

2.2.3 Contact with Republican Rome

The first documented history of Roman interaction in the geographic region that would become Dalmatia was in the 3rd century BCE and is today known as the First Illyrian War. Multiple ancient sources discuss both motivations and military actions of the conflict. The consensus of historians today is that the narratives of Appian and Cassius Dio offer complementary data to allow a more precise reconstruction of the course of events, together providing better source material than either Polybius for the first two Illyrian wars or Livy for the third.[37] According to Polybius, Italian merchant vessels were continually under threat from Illyrian pirates, and their activities threatened trade between the two Adriatic coasts. In Appian's version, Roman presence was requested by Issa to protect the last independent Greek colony from Illyrian kingdom encroachment. Dio actually cites both causes as justification for Roman military intervention. Analyzing these sources, Šašel Kos considers both causes complementary; on its own, an appeal from Issa may not have been weighty enough to stimulate Senatorial military action. She combines a request from Issa with the economic importance of Adriatic trade and notes the convenience of allowing the Romans to mask their policy of expansion behind a request from an ally for defense. Ultimately the

[36] Wilkes 1969, 12. The pre-Roman inland situation in Illyricum is well summarized by Džino 2012b.
[37] Šašel Kos 2004, 148. For ancient sources see Polyb. 2-3; App. *Ill*. 7-11; Cass. Dio 12, 20; and Livy 42-45.

continued expansion of Illyrian King Agron's power in the region must have been the decisive factor to convince Rome to conduct war in the region.[38]

The First Illyrian War (229-7 BCE) was a Republican Roman combined campaign against the southern Illyrian tribe of the Ardiaei led by Queen Teuta (widow of the Agron mentioned above), whose piratical practices combined with aggressive land incursions provided adequate *casus belli* to justify the initiation of military operations. The Romans employed a consular army in conjunction with naval forces, marking the first incursion of Roman troops across the Adriatic Sea. After two years of fighting the rise of the Illyrian state was checked, Teuta was defeated and dethroned, and Teuta's former ally Demetrius of Pharos was installed as a Roman client manager. Demetrius failed to remain loyal. His attempt to take advantage of Roman distraction with the Carthaginian conflict escalation which became the Second Punic War resulted in the Second Illyrian War (219 BCE), when Republican forces removed Demetrius from power. The Third Illyrian War (168 BCE), two generations after the first two wars, resulted in the near destruction of the Ardiaei kingdom. However, despite these repeated victories in Illyrian territory, Republican Roman authority was never extended much beyond the coastal zone, and even the territory under Roman control provided little more than an entry point for subsequent Roman incursions.[39] The end of the Third Illyrian War in 167 BCE marked the beginning of Roman dominion in the eastern Adriatic. The

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[38] Šašel Kos 2005, 259-60.
[39] Zaninović 2010, 15.

division of the landscape of Illyria into three separate parts should be regarded as the origin of the Roman concept of Illyricum.[40]

Republican conflict was not solely located in the southern Adriatic Sea, northern Ionian Sea, and the southern part of Illyricum. The founding of Aquileia in 181 BCE brought Republican citizens in conflict with natives living on the Istrian Peninsula, including the Histri who had earlier allied with Demetrius. After a protracted campaign Rome conquered the peninsula in 177 BCE. Over the next century, most Roman military activity occurred in central Illyricum, with repeated conflict against the Delmatae in 155 BCE, 119 BCE, and ultimately with the conquest of Salona in 76 BCE. Other conflicts included an expedition in 135 BCE against the Ardiaei and Pleraei in southern Illyricum, which resulted in the resettlement of the repetitively offensive Ardiaei to the hinterlands where the tribe, now disassociated from the sea and unaccustomed to the new environment, essentially vanished from history.[41]

Thus, the Republican Roman impetus to expand into the Adriatic Sea and beyond into the Balkans was based on both military interests and enlargement of the area of regional influence. Roman interest in the area waxed and waned over a 150 year period based upon the reliability and performance of Illyrian client kings, resulting in recurring Roman military activities against coastal tribes until the city of Salona was captured in 76 BCE.[42] Under the Republic Dalmatia was never constituted as a regular province

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[40] Livy 45.26 and Šašel Kos 2013, 174.
[41] Zaninović 2010, 16-7.
[42] App. *Ill.* 8-11; Polyb. 3.16-19; Eutr. VI.4. For a summary of Roman-Illyrian interactions from 230-59 BCE, see Wilkes 1969, 13-36.

with regular Roman governors. Rather, it was a place where Rome had some ancient alliances with one or two Greek communities, and where fighting would break out from time to time. Wilkes suggests this low level of Roman interest prior to the civil wars reflects the fact that Illyria lay on no major trade route and, with the exception of the potential nuisance of piracy, had no importance for connectivity with the eastern Mediterranean. This lower priority level meant no Roman armies were permanently stationed along the eastern coast of the Adriatic Sea. Instead, late Republican Roman armies were sent to Illyria to fight, either to train for a future civil war or to gain reputation and glory for its commander.[43]

The conquest of Salona in 76 BCE resulted in what Bartel termed "colonialism with acculturation of dominated groups."[44] In this scenario, the archaeology shows the arrival of foreign elements (in this case, also recorded in ancient sources) and the gradual acceptance, forced or otherwise, of Roman material culture. Bartel notes that this is foremost a psychological phenomenon which leaves no archaeological evidence but may be inferred from archaeological interpretation. Colonialism with acculturation, as in the case of Salona and the province of Dalmatia, may be differentiated from "imperialism with acculturation," which Bartel believes is best reflected in the Roman Imperial era by building programs executed in provinces distant from the Italian peninsula where Roman legions were basically the only foreign presence. The shipwreck found at Trstenik is archaeological evidence that this acculturation impacted shipbuilding techniques in the

[43] Wilkes 1969, 36.
[44] Bartel 1980, 16.

vicinity of Salona. The 1st century CE laced ships of Zaton as well as a recent discovery of a contemporaneous laced ship on the Dalmatian island of Pag, both less than 200 km travel distance from Salona, illustrate that Liburnian lacing techniques were still in use where Roman influence was less pervasive and local shipbuilding traditions survived and flourished.[45]

In a recent analysis, Džino and Domić Kunić examined the entire spectrum of Republican Roman conflicts in the area of Illyricum between the First Illyrian War and the creation of Illyricum as a Roman province. They approach the region not as an area of desired conquest, but as a space that was developed and shaped through its extended interactions with Rome. They note a total of only 13 conflicts sanctioned by the Roman senate over a 170-year period in and adjacent to future Illyricum. While some of these conflicts are not datable and the quality of the historical references varies widely, they postulate that all major conflicts are known. Based on the relatively low frequency of these military campaigns (averaging one conflict every 13 years), Džino and Domić Kunić suggest that the Roman elite looked on the eastern Adriatic as a peripheral but still significant area with respect to successful functioning of an imperial periphery. Ultimately, they suggest that the area of the eastern Adriatic in the 3rd century BCE was shaped as a fluid "frontier zone" between Macedonia and Northern Italy—a zone of interest, but not one of conquest for the Romans.[46] This frontier zone results in an area of interaction that connects, rather than separates, Roman provincial administration and

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[45] Brusić and Domijan 1985, Gluščević 2004, Boetto and Radić Rossi 2017.
[46] Džino and Domić Kunić 2018, 79-80.

indigenous polities. Republican Roman strategy to interact with the frontier zones was usually based on indirect control through alliances, with military interventions conducted in the central and southern Adriatic region during most of the 2nd and the first half of the 1st centuries BCE executed to protect indigenous allies. Rome preferred this indirect control both because of the unwillingness to establish a provincial policy framework as well as the absence of any permanent Roman military presence in the area. No permanent military garrisons or fortresses were established on the eastern coast of the Adriatic before Octavian's campaign against Marc Antony.[47]

This complex shaping of an entire region over centuries impacted the native population in a variety of ways. Repeated contact with Republican Rome over generations modified their behavior and taught negotiation skills. Local communities learned to balance resistance with acceptance of interaction, ultimately driving indigenous people toward a more complex society which transformed their identities and eventually prepared them for future provincial society.[48] Ultimately, this early minimal amount of contact with hinterland tribes extended the amount of time required to modify tribal leader behavior with respect to Roman incursion. Later, more rapid expansion of Roman power in the region accelerated both the speed and intensity of cultural transformation in these Illyrian indigenous societies.[49]

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[47] Džino 2013, 156.
[48] Džino and Domić Kunić 2018, 83.
[49] Džino 2013, 157.

Šašel Kos notes the difficulty of establishing an exact date for the creation of the province of Illyricum. After the founding of Aquileia (181 BCE), Roman army operations were directed against various tribes and peoples later included within the province of Illyricum, so certainly Roman influence in the region can be postulated to have begun in the 3rd century BCE at the latest.[50] Šašel Kos further notes various proposed dates for the founding of the province, ranging from as early as 167 BCE to as late as 27 BCE during the reign of Augustus. While she recognizes that most scholars credit Caesar with the formation of the province, she ultimately concludes that no province existed in the region at the time of Caesar's death.[51] In contrast, Džino and Domić Kunić date the formation of the province to the *Lex Vatinia*, a law passed in 59 BCE which created Illyricum as an attachment to Cisalpine Gaul.[52]

While the province may have been constituted by Sulla, Caesar was probably the first to assign a governor to Illyricum, and from 58 BCE Caesar himself was in charge of both Cisalpine Gaul and Illyricum. It was most probably Octavian who organized Illyricum as a Roman province from an administrative perspective.[53] However, the degree of Romanization depends upon the amount of influence, and the influence of Rome was felt more profoundly in urban areas and along the coastlines where access could be more easily established and maintained. As Stipčević notes,

> even the most superficial analysis of the archaeological material from that period reveals that the process of Romanization did not proceed evenly everywhere.

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[50] Šašel Kos 2005, 240.
[51] Šašel Kos 2000, 283-4.
[52] Džino and Domić Kunić 2018, 79.
[53] Šašel Kos 2005, 242.

> The urbanized centres, whether along the coast or inland, were almost completely Romanized; the people there spoke and wrote in Latin and lived the life of any large town in the Roman Empire. The situation outside these centres was, however, quite different. The Illyrians…[spoke] their own national language, worshipped their own gods, kept their traditional burial rites…and retained their own socio-political tribal organization, which was amended to suit the Roman administrative and political structure whenever necessary.[54]

Stipčević goes on to discuss the Roman tolerance of indigenous culture. As long as the vanquished people remained loyal to Rome, the Romans were much more interested in a peaceful labor force and the availability of soldiers than they were in the Romanization of natives in occupied territories. Šašel Kos concurs, observing that the advanced stage of Romanization of most areas of Liburnia during Caesar's interventions in Illyricum in the 50s BCE resulted in entire communities as well as their Liburnian ships and crews maintaining loyalty to Caesar over Pompey during the civil war. She does postulate that a strategy of separating Liburnia from Illyricum could have been employed, since the Liburni were more Romanized than the wilder Delmatae to the south and into the hinterlands. She notes that the subsequent histories of Illyricum, then Dalmatia reflect a more esteemed status held by Liburnia within the province.[55]

Caesar's foundation of Roman colonies along the eastern Adriatic coast almost certainly including Salona, Narona, and Epidaurum, and perhaps also at Lissus and Iader, reflects his policy of rewarding Roman citizens settled in major coastal cities, who ultimately supported him in turn against Pompey's forces. In contrast, evidence is lacking regarding settlements in areas controlled by the Delmatae, likely indicating less

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[54] Stipčević 1977, 65.
[55] Šašel Kos 2000, 300.

Romanization of the hinterlands, where ultimately a Delmatae army was generated in opposition to Caesar which took Promona in 50 BCE. Only the Delmatae remained thoroughly hostile to Caesar and maintained consistent support of Pompey's forces throughout the Illyrian civil war campaigns.[56] This hostility is ultimately reflected in the name chosen for the southern half of Illyricum after its division. The moniker "Dalmatia" certainly reflects the notoriety of the most well-known native people of the region, particularly given the amount of Roman blood spilled against the rebellious Delmatae tribe over the centuries.

2.2.4 Transition from Republic to Empire

With Salona a Roman possession from 76 BCE onward, central Dalmatia became a base for Roman influence including both trade and military operations. Additionally, this gave Rome a center of operations from which to facilitate control of the coast. As Wilkes notes, "the creation of a powerful Roman community on the eastern side of the Adriatic would have helped to curb the power of the Delmatae, who had acquired an unpleasant habit of either routing or harassing every Roman force sent against them."[57] By the time of Caesar, Illyricum was a Roman military province, but not a previously conquered, well-organized territory; Caesar himself governed Illyricum together with Cisalpine Gaul.[58] Probably in 50 BCE, Caesar experienced a setback when the Delmatae occupied Promona, a Liburnian town. The Liburni appealed to

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[56] Šašel Kos 2000, 299-301.
[57] Wilkes 1962, 322.
[58] Šašel Kos 2005, 337-8.

Caesar, who sent a military detachment against the Delmatae. The Roman force was soundly defeated. Further action against the Delmatae was not taken due to Caesar's military campaign against Pompey.[59] During the civil war, Caesar's efforts against Pompey caused his interests in Illyricum and other provinces not directly involved in the conflict to fade.

Octavian (later Augustus) conducted three major military campaigns in the western Balkans: operations against the Iapodes, Pannonians, and the Delmatae in 35-33 BCE; a campaign against Illyrian tribes led by Agrippa, then Tiberius in 13-9 BCE (the *Bellum Pannonicum*, described in the *Res Gestae* 30); and suppression of a rebellion in 6-9 CE.[60] In Octavian's first Illyrian campaigns the Delmatae yet again proved most formidable, fielding 12,000 fighters under a united command, reflecting lessons learned from a century of warfare with the Romans. Octavian's defeat of this army at Promona and the recapture of five legionary standards lost during the time of Caesar was one of the greatest achievements of his Illyrian War.[61] While some analysts consider Octavian's military conquests in Illyricum as little more than training maneuvers, in fact this was the first true conquest of these native tribes, enabling Octavian to proclaim himself the liberator of Italy while simultaneously establishing his own military reputation. It was essential for Octavian to acquire fame as a successful general, and his

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[59]App. *Ill*. 12.
[60] See Wilkes 1969, 46-77, Šašel Kos 2005, 393-471, and Džino 2012a for detailed discussions of Augustan campaigns in Illyricum. This time period is covered in Cass. Dio 49.36-38 and exhaustively covered in App. *Ill*. 16-28; Appian's description was almost certainly directly copied from Augustus's lost *Commentarii* rather than an independent analysis of military operations.
[61] Šašel Kos 2018, 44.

achievements in Illyricum allowed him to promote his image as a victorious military commander who could match his reputation to Caesar's.[62] The only triumph celebrated during Octavian's long reign was a three-day event held 13-15 August 29 BCE. The first day commemorated his victories in Illyricum and the recovery of legionary standards, ultimately commemorated in the *Res Gestae* 29.

Tiberius's victories in the Pannonian War of 11–9 BCE were important for the further conquest of Illyricum, extending the domain of Rome to the Danube. Of note, the only classical author to mention specific names of tribes subdued in the *Bellum Pannonicum* was Suetonius; his statement that the Delmatae and Breuci were subdued has been confirmed by the 1982 discovery of an inscription in Aphrodisias Turkey.[63] However, there was likely some exaggeration for political means of the extent of capitulation of the region. The extension of the Roman frontier may in fact have largely comprised native tribes agreeing to accept client status rather than actively combatting military occupation. There was no clear concerted push to the Danube River before the middle of the 1st century CE, and direct military control of the lower Danube may not have been established until as late as the Trajanic period.[64]

The rebellion of 6-9 CE was the final recorded resistance to Roman authority in the region and has been described as "less an indication of native compliance than of the state of human exhaustion to which the Illyrian lands had been reduced."[65] This

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[62] Šašel Kos 2018, 47-8.
[63] Suet. *Tib*. 9.2; Grbić 2011, 133-4.
[64] Goodman 2012, 249.
[65] Wilkes 1992, 207-8.

dominant victory was unfortunately overshadowed by the Varian defeat in the Teutoburg Forest, also occurring in 9 CE.[66] At the commencement of the rebellion, it is estimated that five legions were stationed in Illyricum. Following the rebellion, two legions were kept in Dalmatia: VII at Tilurium and XI at Burnum.[67] In 42 CE the governor of Dalmatia attempted to lead Dalmatian legions to revolt against Claudius, but the army deserted the governor, earning the two legions the title *Claudia pia fidelis*. Well before the end of the 1st century CE security demands elsewhere in the empire caused the Roman military presence in Dalmatia to be reduced from a major military command with two legions to an unarmed province with a police force of three auxiliary military regiments, occasionally supplemented by temporary military detachments.[68]

At the conclusion of the 9 CE rebellion, the province of Illyricum was divided along the southern confines of the Sava valley into Upper and Lower Illyricum, which became Dalmatia and Pannonia, an arrangement that remained unaltered for the next three centuries.[69] Šašel Kos notes

> the large province of Illyricum can be regarded in many aspects as a strategic failure. The province was too diverse, reaching from the 'civilised' and urbanized coastal part, the heir to the Illyrian kingdoms, and Liburnia with its own specific culture, to the Iapodian and Delmataean hinterlands, as well as the central and northeastern Pannonian peoples, living in villages, some of whom even lacked centralised rule.[70]

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[66] Velleius Paterculus, a legate of Tiberius in Illyricum, documented that word of the defeat of Varus and the massacre of his legions arrived only five days after the successful repression of the rebellion. Vell. Pat. 117.
[67] Šašel Kos 2011, 114.
[68] Wilkes 1969, 80-1 and Keppie 1996, 388.
[69] Wilkes 1992, 209. Kovács 2014, 40-57 disputes the specificity of the 9 CE date, offering multiple theories, but ultimately fails to fully support any one date, stating only that the split certainly occurred before 50 CE.
[70] Šašel Kos 2015, 79-80.

As with the predecessor Illyricum, the boundaries of Dalmatia and Pannonia were somewhat fluid. Particularly in Pannonia, the Roman frontier shifted with new conquests, treaties, and annexations, and the entire course of the Danube may have not been firmly in Roman hands before Claudius.[71] The final conquest of the native tribes concurrent with clear consolidation of power in the hands of the Romans in the region must have impacted the cultural character throughout both provinces. However, archaeological evidence demonstrates stronger Roman cultural impact along the coast, likely caused by a combination of frequent Roman interaction coupled with an influx of immigrants to the more easily accessible coastal areas.[72]

The division of Illyricum into Dalmatia and Pannonia after quelling the 9 CE rebellion produced a bifurcated region with significantly different levels of Romanization. The Dalmatian coast was rapidly urbanized, in no small part due to sea lanes of communication and trade, and the area was sufficiently pacified to remove all standing Roman garrisons by the end of the 1st century CE. It is germane to note the Roman governor maintained his residence on the periphery of his province, further stimulating coastal Romanization in comparison to limited Imperial influence measured in the hinterlands.[73] This urbanization of the coast may be tracked by excavation of shipwrecks and study of changing amphora styles during the Imperial Roman period.[74]

[71] Šašel Kos 2015, 66.
[72] Glicksman 2009, 14.
[73] Wilkes 2000, 587.
[74] See Jurišić 2006 for a summary of maritime trade in the Roman province of Dalmatia based on the types and styles of amphora finds. For a broad overview of trade in the Roman world based on amphora types see Peacock and Williams 1986.

Meanwhile most ‘urban’ areas of the interior, particularly on the inland side of the Dinaric Alps, developed as little more than villages.[75]

Wilkes estimates that at the formation of Dalmatia, the total population of the province was about 700,000 and that the water supply of the provincial capital of Salona was sufficient to support around 40,000 individuals.[76] A more recent estimate taking cisterns into account increases the capital city population maximum to 60,000 at Salona’s peak splendor.[77] While the Roman conquest of Illyricum that produced the province of Dalmatia and then designated Salona as the capital must have benefitted most residents of the capital city, it may have been traumatic for residents of many of the smaller indigenous communities. The imperial remaking of the province must have restructured power arrangements within these communities, likely via destruction, loss of life and a significant impact upon the former elite citizens including enslavement and resettlement.[78] It is at this time, the 1st century CE, and at this precise location in the center of the Roman area of influence—Salona, the coastal capital of the province of Dalmatia—where the shipwreck found at Trstenik was likely built, operated, and scuttled.

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[75] Goodman 2012, 249-51.
[76] Wilkes 1972, 753.
[77] Sanader 2014, 91.
[78] Džino 2014, 227.

2.3 Roman Maritime Trade in Dalmatia

2.3.1 Introduction

Studying shipwreck evidence with respect to trade in and across the Adriatic provides an avenue for the exploration of Roman influence into Illyricum and later Dalmatia via the sea. Wilson investigated in depth the challenge of quantifying Roman trade by examining various types of archaeological evidence, including shipwreck analysis.[79] He notes several issues of concern. First is bias caused by analysis of items surviving in the archaeological record such as ship remains, metallic ingots, quarried stone, ceramics and amphoras, while overlooking organic perishable items such as grain and other agricultural products, textiles, spices, papyrus, and basketry which do not survive for analysis. Another factor that impacts the analysis of Roman trade is a bias toward the analysis of long-distance trade, which is more clearly extracted from the archaeological record, as compared to short distance trade, which is very difficult to discriminate from local consumption. Finally, he recognizes the inability to estimate the total volume of trade based on the archaeological evidence found, even when comparing contemporaneous sites with similar artifacts. He concludes by noting

> there is little prospect of quantifying vague notions of 'trade' in the abstract; the question must be broken down into smaller parts—trade in what goods, between what regions, at what times?...we must accumulate large general datasets, probe more detailed case studies, and then see how those studies affect our understanding of the total dataset again.[80]

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[79] Wilson 2009. His section on shipwrecks (219-29) relies extensively on information found in Parker, 1992.
[80] Wilson 2009, 245.

The study of the Roman-era shipwreck found at Trstenik is just such a case study, the analysis of which may add perspective to some aspects of local trade in the Adriatic Sea during the early Roman Empire.

The archaeological, epigraphic, and literary evidence for trade in the Roman Province of Dalmatia in the Imperial Age indicate that Dalmatia participated in a thriving Mediterranean commercial network with importation of cheap goods for consumption by native peoples augmented by a market for the import of luxury goods as well.[81] With respect to shipwreck analysis, the proximity of a wreck site to a particular port does not necessarily indicate any association between the two. As storms often pick up quickly and with little warning on the Adriatic Sea, modern sailing vessels often prefer to travel along the eastern (Dalmatian) coast of the Adriatic since the many islands and harbors along this coast provide many opportunities for shelter. In comparison, the western (Italian) coast is a sandier, less rocky shoreline with few prospects for sanctuary from bad weather. Ancient ships likely also preferred the eastern coastline. Additionally, the major port of Aquileia at the head of the Adriatic must have been both the destination and origin for many ancient Adriatic merchant ships. Therefore, wrecks discovered along the Dalmatian coast are not necessarily evidence of Dalmatian trade.[82]

Ancient ships tramping up and down the coast of Roman Dalmatia would have had many opportunities to trade along the coast. Wilkes broadly categorizes three types

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[81] Glicksman 2005, 222-4. See also Škegro 2006.
[82] Glicksman 2005, 193.

of towns in Roman Dalmatia which could have been potential destinations for merchants conducting Adriatic Sea trade:

1) Roman colonial settlements on or near the coast;
2) Indigenous communities of native peoples (Istrian and Liburnian) along the northern Adriatic coast, culturally linked to Venetic peoples of northwest Italy; and
3) Indigenous Illyrian communities.[83]

The tribal region of the Liburnians is known as an important source of raw materials for trade. For example, multiple ancient sources confirm the importance of Liburnian wool for Roman markets.[84] One study notes that while literary tradition may portray Liburnians as ancient Greek enemies, archaeological research suggests that maritime contact spurred the Liburnians to cooperate with foreigners from at least the end of the 4th century BCE. Trade became the most important factor in relations between Liburnians and foreigners entering the Adriatic Sea.[85]

This was certainly true for the Romans. Upon the creation of the province, Roman influence was largely felt along the coast. Most notably Salona and Narona, coastal cities lying on the best corridors leading to the interior, became major emporia during the late Hellenistic period (2nd-1st centuries BCE). These prime access points quickly attracted the attention of the Roman Republic and became major nodes for future

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[83] Wilkes 2003, 233.
[84] Mart. *Epigr*. 14.139; Plin. *HN* 8.191.
[85] Šešelj and Ilkić 2015, 428.

Imperial trade.[86] This coastal influence is well-illustrated by mapping the location of settlements in Roman Dalmatia (Figure 2-4). Clearly the impact of Rome was felt most keenly along the Adriatic coast and in the outlying island chains.

Salona benefitted particularly from Roman influence. It developed rapidly after being designated as the provincial capital. Its subsequent centuriation divided the best land among new settlers, and ultimately Salona rivaled Aquileia in the 2nd and 3rd centuries CE, at the height of the Empire.[87] Archaeological studies of the easternmost parts of the Roman province of Dalmatia confirm both the later, and slower, development of the hinterlands portion of Dalmatia.[88]

The fact that Rome stationed two legions in Dalmatia during the early Empire contributed to the rise of seaborne trade between the Italian peninsula and the new provincial region. Legionnaires and their officers were paid regularly and reasonably well. Their permanent presence generated a significant market demand which both Roman government and local individuals would strive to fill, particularly with respect to food, clothing, and equipment.[89] As noted by Borzić, "The camps are wealthy and strong consumer centres which attract a wide variety of regular and even luxury goods, well beyond the scope of what might be construed as 'proper' military logistics channels."[90] Also, the amount of local change generated by the arrival and stationing of

[86] Čače 2006, 67.
[87] Zaninović 1977, 781.
[88] Zotović 2002.
[89] Harris 2000, 730. Harris notes the Army could afford increased consumption based on the impact of tax revenues.
[90] Borzić 2018, 373.

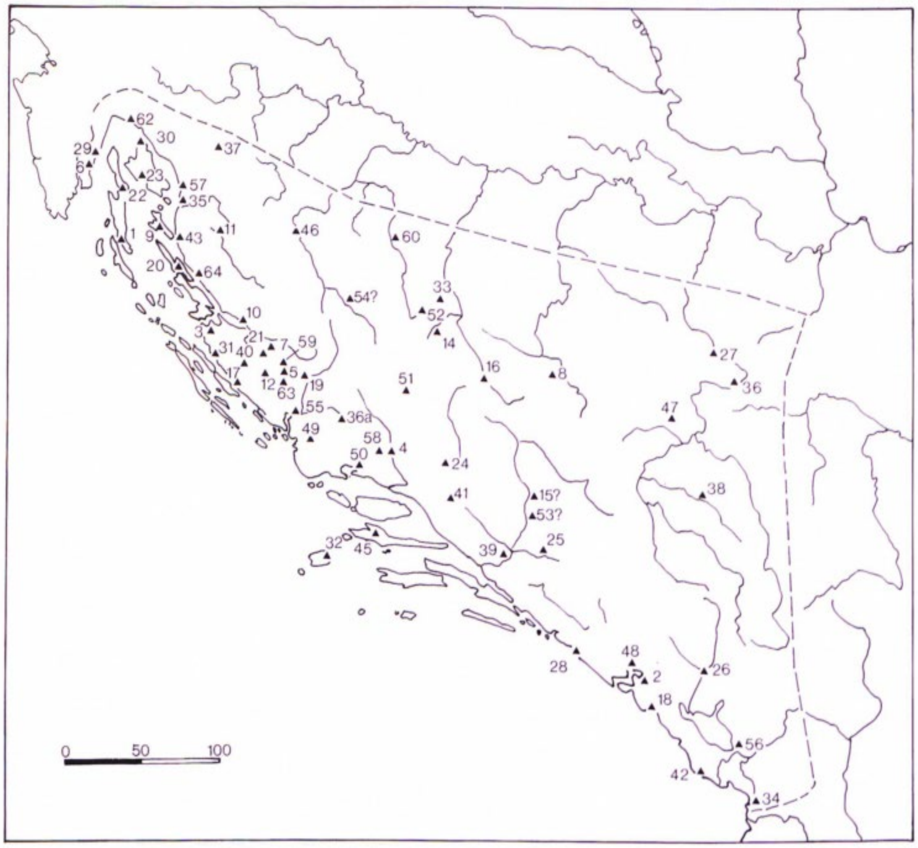

Figure 2-4. Location of Towns in Roman Dalmatia. Reprinted from Wilkes, 2003.[91] The density of coastal settlements found to date must reflect ancient preferences to inhabit areas along the sea, although future archaeological finds could possibly change the ratio of coastline to hinterland inhabitation. The dotted line represents the provincial boundary of Dalmatia. A total of 64 towns are identified with triangles.

a Roman legion into a new garrison would be more dramatic in regions that were more economically primitive.[92] Thus the arrival of legions in inland Dalmatia early in the 1st century CE, able to be supplied from mainland Italy with some modicum of difficulty via Adriatic sea shipping to Salona followed by overland transport through the pass at

[91] Wilkes 2003, 234.
[92] Hopkins 1980, 102.

Klis, would have stimulated economic growth along the entire length of that route. There is evidence that by the middle of the 1st century CE, native Dalmatians were being recruited into auxiliary forces supporting the legions, illustrating the impact of a foreign occupier's standing military force onto a native people's society and culture.[93] Recent excavations at Burnum and Tilurium confirm wide importation of wares from all around the Mediterranean. "The magnetic attraction of military camps must have impacted a much wider territory than camps themselves and their surrounding areas."[94]

The presence of the Roman legions in Dalmatia for known stretches of time also allows analysis of *tegulae*, bricks and tiles based on legionary stamps pressed into the ceramics. This evidence indicates that both Roman legions and auxiliaries manufactured and stamped their own tiles. With the exception of two instances of urban public buildings, these tiles were used exclusively for military purposes.[95]

Merely stating the location of a legion, for example "Legion XI at Burnum," does not adequately describe the impact of the Roman military on the region. Each legion endeavored to control its assigned region by stationing small forces in multiple locations. For example, while the main Roman force of Legion XI remained in Burnum, many auxiliary forces were spread around the area controlled by the Delmatae, including two cavalry detachments and two infantry cohorts stationed at Salona, as well as infantry cohorts assigned to Iader, Epidaurum, and Narona. Additionally, the Romans were very

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[93] Wilkes 2000, 600.
[94] Borzić 2018, 379.
[95] Wilkes 1979, 72.

aware of their lines of supply and communication and kept cohorts stationed at several locations along the road linking legionary bases Burnum and Tilurium.[96] Finds of 1st-century CE Roman military equipment in the city of Salona may reflect known legionary presence in the city itself or merely document social use of military paraphernalia (souvenirs, status symbols, votive offerings, etc.). Certainly there were kilns and metallurgy workshops in the city, but the extent of production for military purposes in relation to production for public consumption remains unknown.[97]

Caldwell notes "the movement of the legions out of Dalmatia in the early empire meant that few veterans settled in and around Salona. Instead of a military presence gone native, Salona experienced an influx of enfranchised native Dalmatians from the provincial interior at the beginning of Late Antiquity."[98] The converse of this analysis must also be true—the movement of legions into Dalmatia during the foundation of the empire meant that Salona experienced an influx of Roman ideas, Roman culture, and new technology. This is aptly reflected in the design and construction of the shipwreck found at Trstenik, built in the Roman pegged mortise-and-tenon technique—quite different from the native Liburnian laced construction method contemporaneously in use less than 200 km to the north.[99]

Specialization of ancient ship design to support a specific type of trade is problematic to hypothesize for smaller, more flexible craft. It is tempting to classify a

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[96] Wilkes 1996, 571-2.
[97] Ivčević 2013, 300-2.
[98] Caldwell 2012, 103.
[99] This Roman influence on traditional boatbuilding technique can also be seen in contemporaneous craft designed to operate both in the Adriatic and on Italian rivers. See Carlson 2011.

flat-floored ship such as that found at Trstenik as a purpose-built craft, designed for one specific load and repeatedly used as it was originally conceived, such as for transporting quarried stone or roughed-out sarcophagi. However, even a shipwreck found fully loaded can only be said with certainty to have carried that specific type of cargo on its last voyage. Coasters engaged in cabotage are not specialized; they carry what they find. In fact, cargo flexibility is key in merchant ship design, and a flat-floored bottom increases cargo capacity at the expense of seaworthiness, maneuverability and handling—an attractive tradeoff for coastal operations. As Finley notes, "ancient ships usually preferred to take short hops whenever feasible; the peculiar conditions of winds and currents in the Mediterranean, the absence of the compass, the limited ability to tack, shortage of storage space for food and fresh water were contributing factors."[100] Smaller ships operating up and down coastlines may be very efficient, and in fact in the 16th and 17th centuries many Mediterranean coastal merchantmen were still operating in the range of 20-40 tons burden.[101]

2.3.2 Shipwrecks and Trade

The highest Roman-era shipwreck density along the Dalmatian coast appears to have occurred in the late Republican and early Imperial eras, from the 1st century BCE to the early 2nd century CE.[102] It is likely not a coincidence that this time frame encompasses the years when Roman legions were stationed in Dalmatia and Pannonia.

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[100] Finley 1985, 130. For amplification of Roman ship size and cabotage see Houston 1988, 556-60.
[101] Harris 1993, 27 and Harris 2000, 715.
[102] Despite being somewhat dated, Parker 1992 remains the standard reference for Mediterranean shipwreck density in antiquity.

The potential cargo loads of the ship at Trstenik may be postulated by examining other Adriatic Roman shipwrecks dated to the 1st century CE. The remainder of this section will discuss trade by sea and ship cargo. Specific ship construction issues with respect to cargo carried will be covered in Section 2.3.3.

To perform a cursory study of ancient trade cargo variability, Parker selected 98 well-studied ancient wrecks, tabulating the categories of cargo resulting from the excavations (Table 2-1).

	Quantity	Percentage
Total Wrecks	98	---
Cargo types:		
Amphoras	92	94
Pottery	26	27
Metal and Ore	17	17
Stone and Tiles	9	9

Table 2-1. Ancient Ship Cargo Type Density.[103]

He notes the tendency for better-preserved, fully investigated sites to produce a larger diversity of cargo, especially pottery, compared with all catalogued shipwrecks. Additionally, he notes fully 50% of these wrecks carried homogeneous cargoes, with only one category of cargo represented in the wreck.[104] Unfortunately, organic loads are

[103] Parker 1992, 20.
[104] Parker 1992, 20-1.

perishable and not preserved and are therefore unrepresented in the above statistics. Jurišić notes that the above heavy, non-organic loads may preferentially cause ship hulls to survive because the massive cargoes press the wooden ships into the sand, preserving them. While Jurišić mentions the difference between port-to-port cabotage with frequent stops to load and unload, contrasted with complete cargoes loaded in one port and unloaded at a final destination, he does not propose any way to determine category of shipping based solely on shipwreck remains.[105]

Thanks to an extensive corpus of shipwrecks and archaeological excavations on land, amphoras are becoming a widely accepted dating tool for shipwreck sites. Amphoras have literally become the symbol for underwater archaeology in the Mediterranean. The omnipresence and survivability of amphoras allowed for repurposing and reuse, making it somewhat problematic to analyze ship cargoes and ports of origin based on amphora styles alone. While large-scale directional trade was performed in Roman Imperial times, most commonly reflected in the massive flow of grain on large merchantmen from Egypt to the city of Rome, the majority of shipping must have been conducted on smaller ships as cabotage, tramping up and down coasts while trading in mixed cargoes.[106] Tramping was less risky, required less capital, and served to distribute locally-generated surpluses in addition to the delivery of specific cargoes. Two main liquid products, olive oil and wine, were mostly shipped in amphoras. However, many other commodities have been found inside amphoras

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[105] Jurišić 2000, 9-10.
[106] Erdkamp 2005, 177-81.

including fruits, nuts, fish, fish sauce (garum), wood tar, beans, grains, vinegar, and many other substances.[107] The reuse of amphoras coupled with the wide spectrum of potential contents for both first and subsequent uses makes amphora analysis necessary, but not sufficient, to postulate a particular ship's point of origin, destination, and cargo.

In the 1st century BCE and 1st century CE one amphora style, designated Lamboglia 2, was utilized throughout the Adriatic. Found as single or scattered finds and in entire homogeneous cargoes, the Lamboglia 2 style became so prevalent that one author described them as "East-Adriatic Amphorae."[108] One difficulty is that, despite being a common amphora style throughout the Adriatic in the late Republic/early Empire time frame, no Dalmatian manufacturing workshop or kiln has been conclusively identified for Lamboglia 2 amphora production. While a kiln site has been discovered on the island of Pag, no Lamboglia 2 amphora sherds were found associated with the kiln. Future identification of such a site would support the hypothesis by Cambi that the Lamboglia 2 amphora form must have been copied by Dalmatian amphora manufacturers to support the export of contemporaneous Dalmatian wines.[109] An additional difficulty is that, due to geographic similarities, slip fabric analysis is not an effective tool to differentiate between a Lamboglia 2 amphora manufactured in one of several northern Italy locations and one manufactured at an unknown site in Istria or along the northern coast of Dalmatia.[110] Croatian excavations continue the search for

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[107] Jurišić 2000, 11.
[108] Jurišić 2000, 6.
[109] Cambi 1989, 321.
[110] Glicksman 2009, 200.

evidence of Lamboglia 2 amphora manufacture in Roman Dalmatia to complement the known manufacturing locations on the northern Italian peninsula.

Pottery items, like amphoras, are usually datable, and the original manufacture site for pottery may often be determined through a combination of typological style analysis, fabric characteristics, and mineral content. With both amphoras and pottery being extremely common on shipwrecks, the barge-like flat bottom structure of the ship at Trstenik would not have been designed to support solely those items in cargo. If there was a specific design choice made based on anticipated cargo, there are three non-agricultural choices to consider: *tegulae,* metals and ore, and quarried stone and sarcophagi.

Jurišić notes that while many shipwrecks are found with tiles and bricks because they were used to cover the main cabin and to fashion a foundation for the ship's hearth, five Adriatic shipwrecks contained large cargoes of *tegulae*.[111] Since several major production centers are known in northern Italy, it is tempting to connect these cargoes to such workshops, but the lack of any workshop stamps found to date prevents definitive sourcing. These large roof tile cargoes seem to indicate that either *tegulae* were an important import to Dalmatia, or there was a high-value, archaeologically invisible material that was traded in conjunction with, or in opposition to, these *tegulae*, such as timber or textiles. Italian *tegulae* sent to Dalmatia were most likely destined for the general market, feeding a widespread need for ceramic roofing material. This type of

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[111] Jurišić 2000, 39.

building material is in evidence broadly distributed along the coast, and the presence of products from a relatively large number of pottery works, both imperial and private, even within individual sites, indicates that *tegulae* trade was widely conducted by multiple local merchants rather than being a monopoly of one establishment over large Dalmatian markets.[112] This concept is supported by Morley, who noted "even the Roman annona depended on independent shipowners for its operations; the supply of the city of Rome and the army was inconceivable without a high level of existing private distributive activity."[113]

Based on shipwreck analysis and the general understanding of natural resource availability and manufacturing in Dalmatia and Pannonia during the early empire, it is difficult to specifically identify any material as a definitive export of the region. This is based on two independent situations: the preliminary nature of the study of Dalmatian production of archaeologically identifiable materials during this era, and the fact that the export of known Dalmatian natural resources such as timber, salt, and metals is either invisible in the archaeological record or untraceable to their point of origin.[114] Certainly ships which imported products into Dalmatia got underway for the next leg of their journey with some sort of cargo or saleable material loaded onboard to ensure proper ballasting to support shiphandling and sailing characteristics. It is simply economically unsound to sail with a full cargo of ballast stones. While additional research is

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[112] Glicksman 2009, 199.
[113] Morley 2007b, 91.
[114] Glicksman 2009, 224.

warranted, a summation of studies seems to indicate that these bricks and tiles from northeastern Italy, manufactured particularly in the area around Aquileia, were imported to Dalmatia and used in coastal settlements and near-coast hinterlands largely during the 1st century CE.[115] Regardless of trade or ballast, bricks were onboard ships, demonstrating a clear connection between mainland Italy and the province of Dalmatia during the 1st century CE.

Glicksman cites several literary clues for exports of Dalmatian material, including Dalmatian cheese, iron, timber, fish sauce, and olive oil. Additionally, she discusses the potential for the export of timber, limestone, metals, and textiles.[116] She bolsters her discussion by referencing funerary inscriptions that attest to trade in oil and wine (*negotiator olearius* found in Iader, and *negotiator vinarius* found in Salona). Unfortunately, these inscriptions may only reflect importation to support Roman consumption in Dalmatia rather than the export of Dalmatian products for consumption elsewhere.[117] Another funerary inscription that supports Dalmatian timber trade (*negotiatians materiarius*, a timber merchant, found in Salona) could reflect either timber export, or strictly internal trade from the hinterlands or other heavily forested areas into Roman provincial cities.[118] While underwater archaeological evidence of Dalmatian exports is sadly lacking due to the emphasis on organic materials, which do not survive in a shipwreck environment, one likely piece of evidence is the find of a 1st-

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[115] Wilkes 1979, 72. For a balanced discussion between brick trade and brick ballast, see Rico 2004.
[116] Glicksman 2009, 224-36.
[117] *CIL* III, 2936 and *CIL* III, 2131.
[118] *CIL* III, 12924.

century CE shipwreck near Cape Glavat on the island of Mjlet containing minium (unrefined lead ore) most probably sourced from mines in the interior of the province of Dalmatia.[119]

Finley notes only one potential example of the use of Roman taxation as a commercial lever to encourage the importation of Roman goods preferentially over the consumption of locally manufactured items. His reference is Cicero: “we are the justest of men, who do not allow the people beyond the Alps to plant olives and vines, so that our own olive groves and vineyards are worth more.”[120] Finley notes that there is no known comparable measure in Roman history. While Cicero is not historically infallible, it is difficult to imagine a fabrication of this magnitude. This discussion helps lend support to the notion that Roman oil, wine, and timber trading could have been stimulated by the importation of both raw materials and finished goods to a remote location that could well have produced sufficient equivalent products to satisfy local demand.[121] This goes to the central issue of demand, as noted by Garnsey and Saller, who note that the movement of foodstuffs, raw materials and trade goods “was stimulated by deficiencies, whether natural or man-made, permanent or periodic.”[122] Thus it is perfectly reasonable to postulate importation of roof *tegulae* into Roman Dalmatia by ship as some form of saleable ballast even if local Dalmatian kilns had the capacity to fully supply provincial needs.

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[119] Radić 2003, 160.
[120] Cic. *Rep.* 3.16.
[121] Finley 1985, 204-5.
[122] Garnsey and Saller 2015, 77-8.

Even Adam Smith, in the seminal work *An Inquiry into the Nature and Causes of the Wealth of Nations*, noted

> The corn which grows within a mile of the town, sells there for the same price with that which comes from twenty miles distance. But the price of the latter must, generally, not only pay the expense of raising it and bringing it to market, but afford, too, the ordinary profits of agriculture to the farmer….Compare the cultivation of the lands in the neighbourhood of any considerable town, with that of those which lie at some distance from it, and you will easily satisfy yourself how much the country is benefited by the commerce of the town. Among all the absurd speculations that have been propagated concerning the balance of trade, it has never been pretended that either the country loses by its commerce with the town, or the town by that with the country which maintains it.[123]

2.3.3 Stone Trade

One plausible hypothesis for the ship scuttled at Trstenik is its use in support of trade in either quarried limestone or semi-finished sarcophagi. There are multiple sources of quality stone quarries in or near the Gulf of Kaštela, including quarries near Tragurium, a city mentioned in Pliny's Natural History as a source of marble, and the well-known Roman quarries on the nearby island of Brač which supplied much of the stone used to build Salona.[124] Glicksman notes

> It is generally accepted that limestone from the quarries on the island of Brač was used for constructions at Salona and in the building of Diocletian's Palace, a commonplace which is supported by both epigraphic and archaeological evidence. However, there were no cities on the island of Brač, and as Salona is the nearest major city, it is probable that the island was located within the capital's *territorium*; our lack of understanding of quarry administration also inhibits our understanding of how the stone was transported between island and city and whether this use of the stone could clearly be identified with trade.[125]

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[123] Smith 1836, 155.
[124] Plin. *HN* 3.22. For an archaeological review of Brač, see Stančič et al. 1999.
[125] Glicksman 2009, 236. For a discussion of the paucity of data regarding ancient rural settlements and economic activities on central Adriatic islands, see Gaffney et al. 2006.

Additionally, sarcophagi in Ravenna have been sourced to the quarries in Brač, although the time frame is somewhat later than the period of operation of the shipwreck at Trstenik.[126] Cambi calculates that about 2,000 sarcophagi, whole and fragmentary, have been found at Salona, and of those only about 200 are clearly sourced to non-Dalmatian sources; the rest are made of local stone, carved in workshops located within the city.[127] This local manufacture of sarcophagi is consistent with Lo Cascio's analysis of imperial production. While knowledge of quarry management and marble distribution is incomplete, even if the Emperor claimed all marble from imperial quarries, there was certainly the possibility of "secondary diffusion" of material, and there is evidence of the direct marketing of manufactured marble goods, including sarcophagi, by imperial workshops or by the imperial administration.[128] This increase in demand for sarcophagi based on changing cultural behavior, which was satisfied through both local manufacture and importation from Proconnesus in the Sea of Marmara and other distant marble sources, must reflect both a healthy local economy and a concentration of wealth in the provincial capital city of Salona.[129]

Stone usage in the region that became Roman Dalmatia predates recorded history. The hill forts of the Liburnians were built with locally quarried limestone, and the arrival of first the Greeks, then Romans reinforced the necessity of defensive walls to protect urban inhabitants during times of strife. Werner notes many surviving Illyrian

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[126] Glicksman 2009, 230.
[127] Cambi 1998, 169.
[128] Lo Cascio 2007, 645.
[129] Glicksman 2010, 40.

city walls built after the arrival of the Greeks show evidence of Greek influence in their construction, including both chiseling techniques and artifacts found in the vicinity of the walls.[130] The use of lime mortar in the interior of Dalmatia did not begin until the arrival of the Romans; archaeology seems to indicate that limestone was burned locally to manufacture the lime. The wall-building techniques in the interior of Dalmatia did not usually differ greatly from the structures built along the coasts. However, coastal walls often used stone imported from nearby islands; examples of this include Posavski Gradac, which utilized stone from Korčula, and Diocletian's palace in Split, built with stone from Brać.[131]

If it is possible to associate the Roman-era shipwreck found at Trstenik with the transport of quarried stone, semi-roughed sarcophagi, or some other mined product from the island of Brač or another Adriatic Sea location to Salona, Split, or some other nearby demand center, the service of the ship must be understood in the context of the execution of Roman stone trade. Russell has made an extensive study of the economics of the Roman stone trade including the market for stone, the transport of stone by river and sea, the distribution of stone, the buying process, and the role of the state.[132] Several factors discussed by Russell must be mentioned.

First, it is extremely difficult to establish an accurate cost for transport. As Tchernia notes, "all in all, not much is known in detail about what proportion of total

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[130] Werner 1973, 182-3.
[131] Bojanovski 1980, 71.
[132] Russell's book (2013a) reflects six years of research, contains a 67-page bibliography, and is an indispensable resource for any attempt to understand this complicated economic sub-field. For supporting commentary on ancient contracts to transport marble, particularly to the city of Rome itself, see Fant 2012.

cost was transport cost in Roman times for different types of merchandise, and even less about transaction costs."[133] Diocletian's *Edict on Maximum Prices* (301 CE) attempted to stop runaway inflation that was crippling the Imperial economy, fixing prices for a wide spectrum of goods and services. This document has attracted great attention, largely because it is one of the few quantified references from official sources for costs during Roman times. Much of the attention to the Edict is critical in nature. For example, Arnaud challenges any price differentials based on the Edict as a "bureaucratic construct."[134] And, in an earlier work, Hopkins finds that regardless of costs, a significantly larger amount of goods must have been transported over land than by either river or sea.[135] However, Bartoli notes the fact that marble is even included in Diocletian's Edict is significant, suggesting that it must have been a heavily traded commodity, and regardless of whether or not quarries were state-controlled, there must have been a free market for marble outside of Imperial jurisdiction based on supply and demand.[136] Following Erim and Reynolds, Russell extrapolates shipping cost ratios based on Diocletian's Edict (Table 2-2):

[133] Tchernia 2016, 93.
[134] Arnaud 2007, 333.
[135] Hopkins 1983, 105. For expansion of the transport cost discussion, see Laurence 1998.
[136] Bartoli 2008, 332.

Sea: Land	Sea: River		River: Land	
	Upstream	Downstream	Upstream	Downstream
1: 42	1: 7.7	1: 3.9	1: 5.5	1: 10.8

Table 2-2. Transport Cost Ratios Based on the Price Edict of Diocletian (301 CE).[137]

While Diocletian's Edict was issued approximately 200 years after the building of the ship found at Trstenik, even if absolute values had inflated over two centuries, it is reasonable to assume that based on the general stasis of technology of the era, the relative cost ratios of transport did not vary appreciably during this segment of the Roman Empire.[138] For the Roman quarries on the island of Brač, comparison ratios are unimportant; the only way raw or semi-finished quarried materials could have been transported from the island to the mainland was by sea. The distance between Brač and Salona, about 30 km by sail, could easily be traveled in one day. Braudel notes that as early as the 3rd century BCE, favorable winds could allow a ship traveling at full sail to cross the narrowest part of the Adriatic, 72 km between modern Albania and the east coast of Italy, in a day.[139] Incidentally, the importance of Salona as a Roman port is confirmed by the Edict; Scheidel points out that of the 49 sea routes with identifiable origins and destinations listed in the Edict, three of them specifically end at Salona, and two others have their terminus specified as Dalmatia, which Scheidel infers to be Salona.

[137] Russell 2013a, 96, table 4.1.
[138] Morley 2007b, 97 and Hopkins 1983, 97.
[139] Braudel 1995, 125. See Casson 1951 for an earlier dicussion of speed under sail for ancient ships, which reviews ancient voyage records and concludes typical attained voyage speeds were four to six knots with favorable winds and two to two and a half knots with unfavorable winds.

Scheidel's analysis using the Orbis model (The Stanford Geospatial Network Model of the Roman World) found consistency in the Edict's route pricing based on estimated sailing time, and he ultimately concluded that the Edict was "a necessarily rough, but mostly sound, compilation of price proxies for plausible sailing times."[140]

It is perhaps significant that the scuttled wreckage of the Trstenik ship was found so near to one of the gates of Salona. The above ratios (Table 2-2) indicate that transport of quarried stone should be conducted by water for as long as feasible before transferring the heavy material to a land conveyance. The scuttling location of the ship could imply that it carried heavy cargo destined for Salona. Overland transport would have been minimized by cargo discharge very near to Salona's city walls, thus minimizing transport costs.

In his study of the construction of Greek architecture, Martin notes that texts describe ships transporting marble to Didyma as "with a double stern," meaning that these were barge-like craft with rounded ends, with a similarly shaped bow and stern, thus able to approach a mole or pier from either direction to simplify maneuvering and to facilitate loading and unloading. This design also allows distribution of the heavy stone cargo as near as possible to the centerline of the ship for sailing and stability purposes.[141] The shipwreck remains found at Trstenik (see Sections 5-7) certainly could fit this description of having a "double stern" as the forward and aft hull shapes are very similar and the ship is very symmetrically constructed.

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[140] Scheidel 2013, 468.
[141] Martin 1965, 165.

It is plausible that the shipwreck found at Trstenik was in service on a route (or routes) totally unassociated with Salona, yet was ultimately repurposed as a sea wall or cribbing reinforcement at Trstenik after its useful life had expired. However, it seems more probable that such a craft would not have traveled far from its normal sailing routes after becoming unseaworthy. Instead it likely would have been moored in a backwater area for some period of time, suffering further decay, before meeting its ultimate fate as a container of rocks stabilizing a wooden wall.

Rouge coined the term *naves lapidariae*, or specialized stone carriers, initially assigning the term to large marble carrying ships from southern Italy and Sicily.[142] His implication was that certain ships were specifically constructed for the purpose of hauling stone, including quarried rock and marble, sarcophagi, drums for use in the manufacture of columns, and other heavy cargoes. In an application of the term, the excavation team of the Skerki F shipwreck calculated a stone cargo weight of roughly eight tons and a total cargo weight of about 60 tons, and determined that based on ship size, the ship had not been "a typical *navis lapidaria*, since such ships usually carried cargoes of building stone weighing 100-300 tons."[143] In view of this size limitation, if the shipwreck at Trstenik was fully loaded with stone, it still could not be classified as a *navis lapidaria* due to its small size. Certainly it could have been a multipurpose craft, and would have been useful for transport of many types of loads, not just stone.

[142] Rouge 1966, 76.
[143] McCann and Oleson 2004, 98-9.

Beltrame and Vittorio analyzed the construction of several wrecks from the perspective of the marble trade, with the goal of determining if ships carrying rigid, heavy cargo were built in a special way or had a particular shape, or if marble carriers were the same type of ships that transported amphoras and pottery, which are well-documented in the iconographic and archaeological record. After analyzing the stability, sea characteristics, and sailing performance of multiple hull designs, they concluded that to date the available information does not allow the determination that *naves lapidariae* were special ships built only for the transportation of marble or other heavy loads. Rather, they suggest the possibility that these ships were normal strong ships which may have undergone some sort of partial transformation to facilitate carrying heavier cargoes including marble blocks.[144]

Russell has published extensively on the Roman stone trade, with an expanded view of all facets of the stone economy, including stone sources and quarries, different uses of stone (building material, sarcophagi, etc.), and all modes of transportation including overland, river, and ocean. He notes:

> Imperial quarries, then, were often worked by private contractors, who probably sold at least some of the material they produced, and it seems likely that non-imperial personnel were also responsible for shipping the decorative stones used at Rome in such quantities. There is no evidence at all for imperially owned transport ships and indeed the shipwreck data indicate that a range of sizes of vessels were used to move stone. The imperial administration probably paid private shippers to ship small consignments of material alongside their other cargo or hired whole ships for larger jobs.[145]

[144] Beltrame and Vittorio 2012, 141-6.
[145] Russell 2013a, 354.

This analysis fits well with the geographic situation of Trstenik, proximal to both Salona and Split. With the wreck site approximately 15 nautical miles from the northern coast of the island of Brač and its Roman quarries, favorable light to moderate winds from virtually any direction would allow the transit to be accomplished during the daylight of a single day, based on a transit speed of 2.5 knots. A strong *Jugo* wind blowing from the south or a strong *Bura* wind blowing from the north would allow for significantly more rapid transit if the desired direction of travel matched the intended course, but at much higher risk of swamping due to waves churned up by these strong steady winds. A storm or strong unfavorable winds would preclude sailing altogether.[146]

Two large, non-Adriatic contemporary stone carriers deserve specific mention. First is the Arles-Rhone 3 barge. As discussed by Russell,

> We are lucky to have one well-preserved river vessel from Arles which shows just how large these boats could be. The Arles-Rhone 3 boat was a flat-bottomed barge, 31 m long with a beam of 3 m, which sank with a cargo of roughly shaped limestone blocks, probably some time in the mid to late first century AD, perhaps even the early second century AD. The stone, of which it could have carried approximately 27 tons, was from the nearby Saint-Gabriel quarries and had probably been transported down the Rhone from Tarascon to the north. Similar flat-bottomed vessels have been excavated elsewhere and even though none of these others contained stone cargoes they certainly could have been put to this purpose.[147]

[146] For a detailed review of winds off the coast of Croatia and their impact on navigation from prehistory to modern times see Marelić 2016.
[147] Russell 2013a, 108. For details on the Arles-Rhone 3 boat, see Djaoui et al. 2011. Examples of other similar boats without cargo include the Mainz 6 and Lipe vessels, see Mees and Pferdehirt 2002.

While the time frame is reasonably contemporaneous, the extreme length and riverine operation of the Arles-Rhone 3 barge clearly places it in a different category than the ship scuttled at Trstenik.

The second large stone carrier of note is the Blackfriars 1 ship, discovered in 1962 in the Thames River at Blackfriars Road Bridge in the city of London. The ship was carrying a cargo of stone and dates to the mid-2nd century CE. It was excavated in 1963 inside a cofferdam and is an example of a stone carrying ship designed for coastal sea transport as well as river transport. Its cargo of Kentish ragstone was quarried near Maidstone (Kent) and the ship's final voyage must have been down the Medway River into the Thames estuary and then to London. The ship's construction features flush laid planking, clenched iron nails with cone-shaped heads, two keel planks instead of a traditional keel, massive floor timbers, and futtocks not attached to the floor timbers.[148] Milne takes issue with the nomenclature "Romano-Celtic" and "Gallo-Roman" as applied to the Blackfriars 1 ship. While Milne agrees that the construction technique owes little to the classic Roman mortise-and-tenon, shell-first Mediterranean construction style, he suggests that the Blackfriars 1 construction technique reflects Roman construction prowess applied to the availability of local materials (iron for nails and large timbers from nearby forests). He concludes

> vessels built especially for the fleet could not really be said to reflect a gradual, organic fusion of different traditions to produce a new 'Romano-Celtic' style:

[148] Marsden 1994, 76-9. Thirty years of analysis of the ship remains since the original publication (Marsden 1967) significantly enhanced the information available from this shipwreck.

> they were simply craft built to Roman specifications under Roman supervision but with whatever materials and labour were drafted in.[149]

While the design and the construction technique used for the Blackfriars 1 ship are significantly different than that of the ship at Trstenik, the hypothesis of applying modified Roman construction techniques to build a ship in a remote province for a specific type of cargo utilization is a noteworthy parallel to the Trstenik ship. Other shipwrecks with construction techniques more similar to that of the Trstenik ship, which were considered during the Trstenik ship's reconstruction, are discussed in Section 7.1.

As will be discussed in Section 3.1, the ancient course, depth, width, navigability, and shoreline of the Jadro River and the Gulf of Kaštela in the vicinity of Salona cannot be ascertained today. Yet, the conclusions of Kirigin cannot be overlooked; the Jadro River could not have provided a wide, deep navigable route for seagoing sailing ships to sail upriver to some offloading point to transfer cargo meant for Salona.[150] Thus the best method to offload heavy stone bound for Salona would have been to build some sort of pier facility abutting the sea coastline in the Gulf of Kaštela, easily reached by an inbound sailing ship. There, a ship could offload its cargo to a staging area that had immediate access to a road, allowing wheeled carts to complete the last stage of the journey.

The early Imperial importation of sarcophagi to Salona, either from nearby rough production quarries on Brač or at some other Dalmatian quarry, or from more distant

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[149] Milne 1996, 237.
[150] Kirigin, 2016, 141-5.

production sites in Italy or other locations followed by extensive transport, is extremely likely to have occurred based on Roman burial practices of the time. However, research to date has not located any imported sarcophagi dated to the 1st century CE. The vast majority of sarcophagi studied in Dalmatia, either imported or locally manufactured, have been found in or near Salona.[151] However, only 14 sarcophagi have been identified as products of the city of Rome, and the earliest of these consists of a fragment bearing the head of Oceanus and two sphinxes, which has been dated to before 170 CE, but cannot be conclusively pushed back into the 1st century CE. Most of the rest of the imported sarcophagi are datable to the 2nd-4th centuries CE.[152]

Russell's book on the Roman stone trade is complemented by an article he wrote contemporaneously to add additional detail to shipwrecks and the stone trade beyond what appears in his book.[153] In his analysis of stone-carrying shipwrecks, Russell lists 82 ancient shipwrecks containing stone cargoes in the Mediterranean. He notes the addition of a significant number of new stone carrying wrecks beyond Parker's 1992 catalog and points out that the distribution of the new wrecks does not exactly match the density of previous shipping conclusions. The stone wrecks that can be dated increase in density from the 2nd century BCE to a peak in the 3rd century CE, and then sharply drop in the 4th century CE, while other analyses peg the peak of overall Roman shipping in

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[151] Cambi 1998,169.
[152] Glicksman 2009, 205
[153] See Russell 2013a and 2013b.

the Mediterranean based on shipwrecks in either the 1st century BCE or the 1st century CE.

Russell postulates that the increase in stone shipments found on the seabed in the 2nd and 3rd centuries CE, at the same time the total number of shipwrecks was decreasing, was due to a change in sourcing of the stone and marble being shipped to Rome. He theorizes that over several centuries the source of stone shifted from the nearby northern Italian peninsula mines of Luna to more distant sources including Proconnesian, Pentelic, and Thasian sources in the eastern Mediterranean. Thus, while total Mediterranean shipping was decreasing, the number of miles being sailed by stone carriers was actually increasing even as the total amount of stone being shipped went down. Russell concludes "it seems likely, then, that fewer shipments of stone were dispatched in the 3rd than had been in the 2nd c. A.D., but that more of them were never received."[154] This trend gets reversed in the 4th century CE when stone shipments from eastern sources were redirected to Constantinople as demand in the Italian peninsula contracted, greatly reducing the total number of sea miles sailed by stone carriers. Russell rejects any argument that a degradation in ship quality or lesser involvement by Imperially-owned ships had any impact on this distribution.[155] Russell's argument is supported by Bartoli, who notes "there is a clear pattern of stone leaving the East and

[154] Russell 2013b, 348.
[155] Russell 2013b, 343-9.

arriving in the West in massive quantities. No western marble carriers carrying, for instance, Luna marble blocks have ever been discovered in eastern waters."[156]

"In aggregate terms, far more stone was quarried and consumed in building and sculptural projects between the beginning of the first century BC and the end of the third century AD than at any time previously and for at least 1,000 years afterward."[157] Of the 82 stone wrecks cataloged by Russell, six are located in the Adriatic Sea and deserve specific mention for comparison purposes to the ship found at Trstenik (Table 2-3). These six wrecks are all likely to have sailed within 100 years of the time of the Trstenik ship and all are of modest tonnage. Unfortunately, none of these wrecks has been archaeologically excavated, thus any potential hull remains are currently unavailable for comparison to the Trstenik ship.[158] In the case of the Tremiti Islands discovery, only a letter to the editor of a magazine survives to document the wreck.[159] Russell notes "since millions of tonnes of stone were transported by sea between the 2nd c. B.C. and7th c. A.D, and since all of the shipwrecks listed in the tables contain no more than a combined 10,000 tonnes, either Roman shipping was remarkably successful or, more likely, there remain many more wrecks to be found."[160] The site nearest to Salona is the wreck at Sutivan on the island of Brač, which was clearly carrying locally quarried material. While its destination was most likely Salona, it is impossible to do more than

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[156] Bartoli 2008, 165.
[157] Russell 2013a, 352.
[158] Miholjek and Mihajlović 2011 provides a concise summary of the five stone cargo finds along the Croatian coast, with photographs.
[159] Casson 1968, 219.
[160] Russell 2013b, 357.

Location	Site	Cargo	Est. size (tons)	Est. date
Near Salona	Cape Izmetište (Paklini islands near Hvar)	9 limestone blocks, 1 granite block, 2500 ceramic vessels	30-40	100-150 CE
Near Salona	Sutivan (island of Brač)	15 blocks, 2 limestone sarcophagi, 1 small column	<50	Early 3rd CE
South of Salona	Jakljan Island	3 sarcophagi	<10	Roman Imperial
South of Salona	Veliki Školj (islet near Mljet)	15 Proconnesian marble blocks, Spanish amphoras, eastern coarseware	<30	2nd CE
North of Salona	Cape Margarin (island of Susak)	Several blocks, 11 small white columns, roof tiles	30-40	1st CE
Italian coast	Tremiti Islands	Marble blocks and slabs	?	1st BCE-1st CE

Table 2-3. Shipwrecks Carrying Stone Found in the Adriatic.[161]

infer a terminus.[162] Reconstruction of the Trstenik wreck (Section 7) allows comparison of capacity to these stone carriers.

Casson has noted that ships carrying stone regularly would have been specially reinforced as well as "shorter and sturdier" than ordinary merchant vessels.[163] Certainly the ship found at Trstenik has significantly more framing per meter in the cargo area of the ship than typical craft of the era (Section 6.4.2). Even with this additional structural

[161] Extracted from Russell 2013b, table 1, 332-41.
[162] Mihajlović 2011, 34. The other four Croatian sites are briefly mentioned in Jurišić, 2000.
[163] Casson 1971, 173.

enhancement of a ship, Tchernia notes that typically the sum invested in the building of a ship was generally less than the cost of the cargo. Based on this cost, Tchernia postulates three typical methods to participate in seaborne Roman trade: as the ship owner, as a trader relying on ships owned by other people, or as a ship-owning trader, carrying his own goods on his own ship and also leasing space to other traders when the occasion arose.[164] Given those three choices, it seems likely that if the ship found at Trstenik were carrying marble or other quarried rock from nearby islands to Salona, it would have been operated by a ship owner unconnected with quarry ownership or operations, and captained by an individual connected to the ship owner, not the quarry. However, without a better understanding of the economic relationships between the quarries at Brač and the eventual consumer of the quarried stone or rough sarcophagi, it is not possible to rule out other ownership structures, including quarry management of ships delivering goods to Salona or other local destinations.

To conclude his discussion on specialization of ships to carry stone cargo, Russell notes

> There is little in the literary sources, then, to indicate that *naves lapidariae* were a distinct form of ship and this is supported by the archaeological evidence…Externally, then, many of the ships responsible for carrying stone probably looked no different from any other merchant ship. Perhaps this is why these vessels never earned themselves a specific name. This being said, we should not reject the idea of specialism altogether. Temporary reinforcement could certainly have taken place, even if it has yet to be identified archaeologically. More importantly, though, stone cargoes required special treatment. The loading and unloading of stone was a particular skill and shippers were clearly wary of overburdening their vessels. Certain shippers may well

[164] Tchernia 2016, 138-9, expanded in 150-3.

> have specialized in the transport of stone, even if their vessels were not themselves out of the ordinary.[165]

Consistent with this, the Trstenik ship, while sturdily framed, did not have any identifiable temporary reinforcement. Any discussion of the cargo-handling skill of the ship's crew or the pier staff in Trstenik would be pure speculation. While recognizing that many quarries were Imperially owned, it must be noted that there is no evidence for Imperially owned transport ships. Shipwreck analysis demonstrates through many examples that ships of all sizes were used to move stone. Russell concludes that Imperial quarry ownership was inextricably intertwined with private quarrymen, shippers, stone-workers, and other contractors.[166] With respect to the ship found at Trstenik, if it were involved in local stone trade between Brač and Salona, its captain would most likely have been a small local entrepreneur, and not an Imperial employee.

2.3.4 Scuttled Ships

The last asset available to a shipowner or trader when his ship cannot be economically repaired is final disposal of the hull itself. Richards proposes two methods for the eventual destruction or loss of a ship, shipwreck and abandonment, and states that every ship ever built must fall into one of those two broad categories of disposal. He goes on to divide abandonment into several subcategories, including "catastrophic abandonment," when deserting a ship becomes a prerequisite for life and the ship will soon become a shipwreck, and "consequential abandonment," when a ship is deliberately

[165] Russell 2013a, 130-1.
[166] Russell 2013a, 352.

wrecked to protect lives or cargo. In both of these subcategories of abandonment, the ship is a premature loss. His final abandonment subcategory is intentionally discarding or breaking up a ship, "deliberate abandonment." This includes scuttling, the deliberate sinking of a ship. Richards emphasizes the premeditation of deliberate abandonment. The disposal is a planned act executed without urgency, with the final resting place of the ship, the intactness of its hull, and the inclusion of any material within the hull totally determined by purposeful human decision-making and action.[167] Regarding the studies of abandoned watercraft, he notes that most studies of intentionally discarded remains fail to contribute to archaeological theory, perhaps because studies of abandoned craft concentrate on the remains of significant or famous watercraft at the expense of those that are more representative of human behavior and behavioral processes.[168]

In his study of cultural formation processes, Schiffer discusses various reuse processes including lateral cycling (change of user), recycling (artifact re-entry into a manufacturing process), secondary use (employing objects in a new use without extensive modification), and conservatory processes (collecting). His categories are not artifact-dependent, but instead rely on the behavioral motivations behind the reuse processes.[169] The scuttling of a ship to fortify a port structure, while not specifically mentioned by Schiffer, fits neatly into the secondary use category. This reuse parallels Schiffer's example of the subsequent use of a worn-out grinding stone as construction

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[167] Richards 2011, 859. For additional discussion see Richards 2008, 1-18.
[168] Richards 2008, 14.
[169] Schiffer 1996, 27-35.

material for a building. Implicit in the secondary use of some object is the value judgment that the object being reused is more valuable in its new function than maintaining it in its original role. This explains Schiffer's use of the term worn-out as applied to a grinding stone, meaning that it no longer had any value in its original function. However, it did possess some amount of value in its secondary purpose as building material, thus it was reused instead of discarded. Transferring this value judgment to a scuttled ship indicates that the value of the object as a ship must have been limited for one or multiple reasons, including: it was damaged and required some significant number of repairs; it was old and required some significant amount of overhaul; it was technologically obsolete, thus not competitive to operate, etc. Additionally, to justify the action of scuttling, the value of the parts of the ship not removed prior to scuttling (typically at least the keel and hull structure) must have been less than the cost of building a dedicated structure to perform the function of the scuttled ship. An ancient example would be filling the ship excavated at Trstenik with rocks and then scuttling it to bolster a sea wall/coastal port facility instead of simply strengthening the sea wall with fresh construction material. A modern example would be the intentional sinking of a ship to become a structure to support a reef and its biosphere instead of building, then sinking a unique structure to perform the same purpose. As Richards notes,

> The perception that economic benefits gained from salvage (mainly from the subsequent use or sale of hull material and fixtures) will be greater than any costs (such as wages or wharfage dues) is what inevitably guides ship breaking. Often the burden of having a derelict vessel, which continues to accrue fees and is in

> danger of sinking where it floats (causing further economic burdens due to removal and cleanup), may also guide the decisions to finally dispose of it.[170]

Richards sees the scuttling process as a combination of two abandonment processes: "de facto refuse," the leaving behind of usable materials, and "curate behavior," stripping sites of usable material for recycling. He also notes the frequent use of abandoned watercraft as "displaced refuse," the use of refuse to in-fill an unusable area to convert it into usable land.[171]

The salvage of the useful components of a ship, followed by scuttling its hull as a form of secondary use rather than completely breaking the hull must be differentiated from the behaviors Schiffer classifies as "scavenging" and "gleaning".[172] In scavenging, serviceable material abandoned by the original owner is claimed for reuse by someone else. For example, a deserted house might have its usable plumbing fixtures removed from it. In gleaning, the scavenging is actually done in secondary refuse areas. Examples would include searching a city landfill or dumpster diving. In the case of ship salvage or breaking, either the owner of the ship performs the action or the hulk is sold to an agent who then processes the ship. So, a ship being abandoned and later scavenged or an abandoned ship being gleaned is not equivalent to the end of life recovery of reusable components from a ship followed by the constructive disposal of the remaining hull. As Richards summarizes

> there is a convenience in selling off your vessel before it is useless, and always much organizing required in being the owner of a condemned ship. However, if

[170] Richards 2008, 23.
[171] Richards 2008, 58-9.
[172] Schiffer 1996, 106-14.

> the price is right, and the economic climate [is] good, the salvage, dismantling, and abandonment of a vessel becomes lucrative…this economic aspect to the salvage of unwanted vessels is an integral part of what makes an abandoned watercraft an archaeological site…furthermore, it is common to find abandoned vessels that have no masts, or evidence of rigging…the fact that the characteristic elements missing from abandonment sites center on the propulsion of a particular vessel illustrates their perception as composite objects. It also shows the easy reuse of major aspects of a vessel guides their salvage and hence facilitates their integration into the archaeological record.[173]

2.4 Context Summary

Maritime trade into and out of Roman Dalmatia appears to have reached its high-water mark quickly after the constitution of the province, during the first two centuries of the Empire in conjunction with the *Pax Romana*. While discovery and analysis of new shipwrecks beyond the well-excavated coasts of Spain and France may improve our understanding of the density and distribution of cabotage during the early Roman Empire, it is not realistic to imagine that the currently accepted peak of activity in the first two centuries CE might someday be determined as incorrect.[174] Imports have been shown to include olive oil and wine, *tegulae*, sarcophagi, and quarried stone. Exports, while less in evidence in the archaeological record, likely included raw materials such as timber, olive oil, salt, and ore. Trade was concentrated along the coast, particularly in the vicinity of the major Roman coastal cities, led by the capital of Salona and including Iader and Narona, while the Velebit mountains provided a challenging barrier between the coast and the hinterlands. Thus, the individuals to the east of the Velebit had to

[173] Richards 2008, 149.
[174] Morley 2007a, 572.

depend greatly upon local manufacture, while the Dalmatians along the coast would have had daily reminders of the Roman Empire based on items available for everyday use and consumption.

The evidence of sea trade in Dalmatia highlights the interconnectivity of the province to the Roman commercial network. The Dalmatian economy functioned on both a micro and macro scale, allowing exchange internal to the province, while also being both a supplier of natural resources to, and a hub of consumption for, distant Mediterranean markets. Just as the evidence of trade strengthens along the coast as opposed to inland, it must be noted that the hub of trade activity must have centered on the provincial capital of Salona. As Glicksman notes:

> Salona is a good example of how any Roman city, but especially one with a good port, could function economically on a variety of levels. Within Salona itself there were doubtless manufacturers, money lenders and service providers of all sorts, but on a broader local level, the city probably had a fairly specific catchment area in terms of agricultural supply and also supply for its manufacturers: clay, stone, wool, murex. To a certain extent, these agricultural and manufactured products served local needs, not only within the city but also its hinterland, but some of these products, cheese, for example, and textiles and sarcophagi, could have been shipped out to places further along the coast or throughout the Mediterranean. At the broad provincial level, *the placement of Salona was no accident* [emphasis added]; not only was it located on an excellent harbour surrounded by a relatively fertile stretch of coastal plain, but it is also situated directly below one of the very few passes connecting the coast with the interior. Salona then must have been the destination and point of export for much of the natural resources of the interior, and it is also probably through Salona that much of the settlements of the interior received goods from outside the province. As indicated by the vast quantities and varieties of imported material found in Salona and the surrounding area, Salona was clearly a keen participant in extra-provincial trade systems.[175]

[175] Glicksman 2009, 254.

Just as the placement of Salona was no accident, the scuttling of a ship able to perform both coastal and intra-Mediterranean trade within kilometers of the gates of Salona is also no accident; it reflects the ship's utility afloat during the 1st century CE as well as the critical need for stable harbor structures in the vicinity of Salona at the end of the ship's useful life.

3. THE SITE - THE ROMAN SHIPWRECK FOUND AT TRSTENIK, GULF OF KAŠTELA

3.1 Geographic Landscape of the Gulf of Kaštela

The Gulf of Kaštela is a very well-defined geographic entity along the eastern coast of the Adriatic Sea, near the major Croatian city of Split (Roman Spalatum). It is approximately at the midpoint of the Croatian Adriatic coast. Although the general direction of the Croatian Adriatic coastline stretches from northwest (Pula and the Istrian Peninsula) to southeast (Dubrovnik), the Gulf of Kaštela is oriented in an east-west direction, oval in shape except that the eastern and western boundaries terminate in clearly defined points instead of being rounded. There are three main components that define the Gulf of Kaštela: the island of Čiovo, which forms the boundary to the southwest; the Marjan Peninsula including the city of Split, which forms the boundary to the southeast; and the gently arching mainland coastline stretching east-west from the city of Trogir (Roman Tragurium) to the Vranjic Peninsula between Split and Solin (Roman Salona, the capital of the Province of Dalmatia). See Figure 2-3 for details.

The sharp angle at the western end of the Gulf is formed by the convergence of the mainland and the island of Čiovo at the island of Trogir. The city of Trogir is in three sections, with the largest portion by area located on the mainland, the historic city center on the tiny island of Trogir, and an additional urban area on the island of Čiovo. The three sections of the city of Trogir are connected by bridges. The eastern end of the Gulf of Kaštela similarly terminates in an unrounded vertex at the small peninsula of

Vranjic. The contrast between the eastern and western extents of the Gulf is that to the west, the closure is defined by the island of Čiovo. Access between the Gulf of Kaštela and the Adriatic Sea is provided at the farthest western extent of the Gulf of Kaštela through a small channel between the islands of Čiovo and Trogir. However, to the east, the closure is defined by the Marjan Peninsula and the outflow of the Jadro River, providing no access to the Adriatic Sea. The end result is two possible entrance or exit channels between the Gulf of Kaštela and the Adriatic Sea: the major passage to the south between the Marjan Peninsula and the island of Čiovo, almost two kilometers wide at the narrowest point, and the very small western passage between the islands of Čiovo and Trogir, less than 100 meters wide. Kirigin recently performed a detailed analysis of water depth, prevailing winds and their diurnal and seasonal variations, and the local geography of the Gulf of Kaštela, and illustrated his results by analyzing options to sail between the island of Issa (Vis) and the port of Salona. He concluded that both passages were utilized in antiquity, depending upon conditions, and that while favorable winds would allow this transit in a day's sailing time, unfavorable winds based on either storms or seasonality could essentially stop all traffic flow.[176]

Because the bay is oriented on an east-west axis with its major opening to the south, it can be viewed in two distinct parts: an eastern and western half. The eastern half, which includes the route to the mouth of the Jadro River and other mooring areas north of Split protected by the land of the Marjan Peninsula, is deeper and better-

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[176] Kirigin 2016, 143-7. For his detailed discussion of sailing between Salona and Issa, see p. 151-3.

protected than the western half, enhancing eastern suitability for serving as a harbor for ships. Additionally, the strong *Jugo* wind, which blows from the south to southeast quadrant in this region, has much greater impact on the western half of the Gulf of Kaštela. With a *Jugo* blowing from the southeast, there is no protection from waves whipped up outside of the gulf in the open Adriatic Sea rolling into the western third of the Gulf, making anchorages and even piers problematic to the west.[177]

The likely port near the city of Salona, the ancient Portus Salonitanus, would have been located in the northern section of the eastern part of the Gulf of Kaštela, at the southern edge of the city walls of Salona.[178] This area today is called the Port of Solin which refers to its position with respect to the city of Split and differentiates it from the large ferry and cruise ship harbor near Diocletian's palace on the southern edge of the city. The area where the ancient port of Salona must have been located is divided into two parts by the small Vranjic Peninsula, with the north side of the peninsula both wider and shallower than the south side (Figure 3-1). Just to the north of the Vranjic Peninsula is the mouth of the Jadro River, today more of a runoff creek than a river. It may have historically provided some ease of transport in the vicinity by poling a raft or towing cargo either from shore or from a small shallow-draft rowed craft, but certainly was not a navigable waterway. Despite the lack of hard archaeological evidence, that area today is noted on one modern topographic map as “remains of the ancient harbor.”[179]

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[177] See Kirigin 2016, figure 5, The Bay of Kaštela and the Main Winds, and figure 8, Perennial and Seasonal Wind Roses from the Meteorological Stations of Kaštel Stari and Marjan.
[178] See Cambi 2001, 142-4 for a discussion of the port of Salona.
[179] Berlengi 2006.

Excavations in 1979 concluded that settlement density was heavier in the western part of Salona than around the Jadro River and the eastern part of the city, where a branch of the Jadro must have flowed in ancient times. "Ancient Salona was obviously built on the

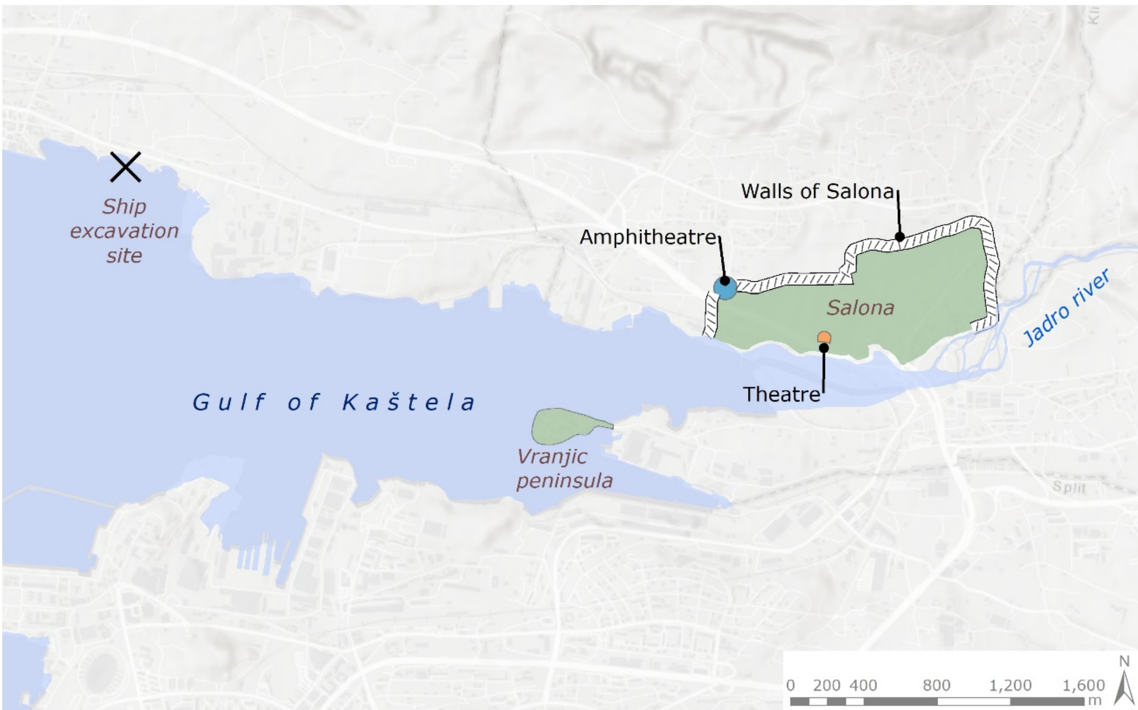

Figure 3-1. The Ancient Site of Salona at the Eastern End of the Gulf of Kaštela. The ship excavation site is 3 km to the west of the city wall. (credit: Valerija Butorac).

mouth of the river which had several courses in its delta which used to change or even disappear…this part of the city had several streams which did not belong to the main current but a larger area of the river delta."[180] Šašel Kos notes that the Salonitan harbor may have played a role early in the history of Salona in the subjugation of the

[180] Oreb 1984, 34.

Delmatae.[181] While there is no literary evidence of any Roman naval base near the city of Salona, recently analyzed funereal inscriptions lend support to the theory that there may have been some Roman naval outpost in the vicinity. This theory has yet to be supported by any archaeological evidence.[182]

Based on the very shallow delta coupled with silting and runoff from the steep terrain in the vicinity of the Jadro River, the delta and mouth of the river would not have been a stable geographic feature over time. Jurišić notes the impact of such a shallow bay coupled with the constant movement of the Jadro River, hypothesizing that maintenance of a harbor near Salona would have been constant, possibly so difficult that a separate (unknown) harbor site may have served the city.[183] However, Cambi observes that the inner harbor of Salona, protected by both the sheltered area of the Gulf of Kaštela and the river delta land in the immediate vicinity of the mouth of the Jadro River, would have provided shelter from winds and danger from all directions.[184] In fact, the most famous adverse wind of Croatia, the *Bura*, which blows with extreme velocity over the mountains from the north, does not significantly threaten ships or port facilities along the northern coast of the Gulf of Kaštela because there is no fetch, the distance a wind blows across the water to churn up large wind-driven waves, for a wind blowing from north to south near the shore. Based on personal experience, the most threatening wind in the region of Salona is the *Jugo*, a strong steady wind that blows

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[181] Šašel Kos 2012, 94.
[182] Kurilić 2012.
[183] Jurišić 2006, 191. Kirigin 2016, 141-5 discusses evidence for various Salona harbor locations, from the Vranjic peninsula to just south of the amphitheater, at the western extent of the city walls.
[184] Cambi 2001, 142.

from the south, which is the direction providing the most fetch to churn up sea state along the northern shore of the Gulf of Kaštela.

The modern city of Split (2011 population 178,000) is the second largest city in Croatia, behind only the inland capital city of Zagreb. Split dominates the eastern edge of the Gulf of Kaštela, particularly with respect to the sleepy modern town of Solin (2011 population 28,000), halfway up the mountain road to the city of Klis and the nearby eponymous mountain pass. However, in ancient times, the city of Salona was the dominant settlement of the region. Greek and Illyrian merchants clearly traded in the vicinity. Based on supporting walls dated to the 1st century BCE coupled with the discovery of Hellenistic pottery, it is probable that during the Hellenistic period Salona was already an urban settlement.[185] Historical Illyrian alliances and fragments of an inscription suggest the Greek settlements which later became the Roman towns of Tragurium and Salona were likely founded in the 3rd century BCE by Greeks from the island of Issa (Vis).[186] Recent excavations indicate that the Hellenistic 2nd century BCE settlement was situated to the north of the center of the future Roman colony.[187]

The first specific mention of Salona in ancient sources is a citation in Appian's *Illyricum* describing it as a city of the Delmatae in 119 BCE.[188] The original founding and location of Salona remain unknown, thus the actual impact of Roman contact prior to the Empire cannot yet be quantified. One plausible theory is that the original

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[185] Sanader 2004, 89.
[186] Kirigin 2009, 29.
[187] Marin 2002, 421.
[188] App. *Ill*. 11.

Delmetae city did not include a port, but Roman influence expanded the urban area to the sea.[189] The city flourished under Roman influence, and supported Caesar against the Delmatae during the civil war, while the Greek colony and Roman ally Issa supported Pompey. This began the decline of Issa and the rise of Salona, ultimately resulting in Salona becoming the capital of the Roman province of Dalmatia.[190] At its peak in the 3rd century CE, the population of Salona is estimated to have reached 60,000.[191] Salona became the principal port of the Adriatic, perhaps only rivaled by Aquileia. It was a cosmopolitan city with a multicultural population. While Salona's official language was Latin, Greek was spoken and written until late antiquity, which is demonstrated by inscriptions found on sarcophagi at Vranjic.[192]

Meanwhile, the area where Diocletian chose to build his palace does not appear in any ancient sources. The first mention of the name Split (Spalato) is found on the 13th-century parchment roadmap known as the Peutinger Table. While significant evidence of urbanization exists in and around the walled city of Salona, it is not possible to determine with certainty the exact degree of habitation the future location of Split had reached during the Hellenistic period, or even the extent of urbanization achieved during the Roman Imperial era, pre-Diocletian. The archaeological evidence is too scant to develop an urbanization timeline for Split prior to the dramatic impact of constructing Diocletian's palace during the late 3rd and early 4th centuries CE.[193]

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[189] Rendić-Miočević 1983.
[190] Sanader 2004, 89-90.
[191] Magas 2007, 19. This agrees with analysis performed in Wilkes 1972.
[192] Sanader 2004, 90.
[193] Sanader 2004, 99-101.

Nowadays, a sailor entering the Gulf of Kaštela would be in awe of the large urban city of Split at the south and east edges of the Gulf, with the contrasting images of Diocletian's Palace facing the Adriatic and the 35,000 seat Stadion Poljud, the home field for the Hajduk Split football club, visible inside the Gulf after rounding the Marjan peninsula. Two thousand years ago, a sailor entering the Gulf would have passed an undeveloped coastal peninsula which would someday become Split, and been in awe of the large urban city of Salona, with its impressive 18,000 capacity amphitheater, stone walls, and large harbor.

The sailing characteristics of the Dalmatian coast of the Adriatic are superior to those of the Italian coast because of the better shelter offered by its islands and anchorages. The Italian coast can be extremely dangerous, particularly during onshore gales, due to the lack of sheltered lees and the paucity of harbors to enter during bad conditions.[194] While the *Bura* wind is the most significant wind of Dalmatia, it is strongest further to the north, across the Velebit mountains. The *Bura* can blow in the vicinity of the Gulf of Kaštela, but at reduced strength. The southern/southeastern *Jugo* does impact the Gulf of Kaštela, although unlike the *Bura* it never starts suddenly; thus boats are able to reach a nearby secure anchorage.[195] The current Adriatic Pilot suggests the main sailing season to be May through October, with a short transitional period between summer and winter of about one month. During the transitional period,

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[194] See Adriatic Pilot (Thompson and Thompson 2016) for specific sailing conditions and instructions for the Adriatic Sea. For a detailed comparison of modern Adriatic sailing directions to likely routes in antiquity, see Kozličić and Bratanić 2006.
[195] Thompson and Thompson 2016, 4.

it notes that a few days of good sailing weather may be followed by a week of strong winds and heavy seas. Depressions can develop quickly, particularly in winter, which may move erratically (e.g. move at 20 knots, stop for several hours, then resume movement at 20 knots). Weather forecasts in the vicinity of these depressions often prove to be inaccurate. In good weather, the area has visibility that ranges between 2-8 nm. Fog is not a common occurrence in the Gulf, although an occasional thick band in the summer may last for several hours until burning off. Sea state is usually calm, but occasional strong winds can build seas surprisingly quickly, and a sudden shift in wind can generate a confused sea that is uncomfortable and dangerous for small craft. The tidal range in the general area of the Gulf of Kaštela is typically less than a half meter, and tidal currents are characteristically weak but can be noticeable, particularly in the gaps between islands. Any current generated by wind usually masks tidal currents. The exception to this generality is the immediate vicinity of Trogir at the western extreme of the Gulf where the normal westerly current may exceed 3 knots through the small gap (less than 100 m at its narrowest point) between the tiny island of Trogir and the island of Čiovo.[196]

Today, travel between Trogir and Solin can be done on a coast road that essentially hugs the northern coast of the Gulf of Kaštela. The distance between the eastern and western extent of the gulf is approximately 20 km.[197] There is fairly

[196] Thompson and Thompson 2016, 1-6, 163-83.
[197] Along this road just to the west of Solin, recent studies in support of excavations at the western necropolis of Salona hypothesize a route between Trstenik and Manastirine, connecting on towards the pass at Klis. Further work and excavations are required to confirm this hypothesis. See Šuta 2011.

dramatic terrain extending from the northern extent of the Gulf, with a fertile crescent of arable land immediately succeeded by rapidly ascending mountainous terrain that borders the entire gulf to the north. This mountainous area separates the coastal area from the 'hinterlands.' Above the modern city of Solin is the city of Klis which protects a well-known pass that allows access from the coastal region into the hinterlands and beyond; control of this pass has been of military and economic importance since Roman times.

The overall picture of the Gulf of Kaštela is that of a geographically isolated locale with its own micro-climate. It is separated from the hinterlands by a mountainous region to the north, protected from the Adriatic Sea by the island of Čiovo and the Marjan Peninsula, then shielded from the open sea to the south by the islands of Drvenik Veli, Šolta and Brač (Figure 3-2). There is no wide plain along the coast to allow easy access by travel along the coast. Detailed studies of Roman-era roads and boundary stones demonstrate that north-south land traffic between Aquileia and Dyrrachium passed well inland of Salona.[198] In fact, even today Split and Dubrovnik have not been connected by train. The large area of the Gulf of Kaštela would certainly have encouraged fishing throughout history, and Roman remains clearly indicate utilization of the sea for food and for the production of salt.[199] Sea level studies reviewing Adriatic

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[198] Wilkes 1974; Chevalier 1995, 18-20; Miletić 2006.
[199] Radić Rossi 2009b, 494.

Figure 3-2. Terrain Map of the Gulf of Kaštela. (credit: Valerija Butorac)

changes over the last 2000 years have determined a somewhat rising sea level, with an average post-Roman submersion of 1.5 m in the vicinity of Split.[200]

3.2 Roman Villas

Use of the term 'villa' is problematic when discussing Roman habitations. The word itself conjures various mental images in different individuals depending upon their background, area of study, and cultural exposure. Villa could mean a luxurious urban design such as the large Villa of the Mysteries excavated in Pompeii, with gardens, an

[200] Fouache et al., 2005, 132. Studies farther south near the island of Vis indicate somewhat more subsidence of about 2 m over 2400 years, see Faivre et al. 2010. More recent studies farther north in the Adriatic Sea find a someone lesser amount of post-Roman submersion of 0.4-1.1 m; see Marriner et al. 2014.

internal courtyard, an atrium, a triclinium, and other components memorized by undergraduate students of Roman history. The word villa is also used to describe a large rural complex which has both a residential and an agricultural aspect, such as the complex at the northern end of the bay of Caska on the island of Pag, which has been identified as an early 1st-century CE property of the senatorial family *Calpurnii Pisones*.[201] McKay classified Italian villas into three categories: *villa rustica,* an agricultural production facility based on the descriptions left by Cato, Varro and Vitruvius; *villa maritima*, a luxurious coastal estate for elites found at seaside locations such as Baiae and Puteoli; and *villa suburbana*, a luxurious and secure villa constructed as a response to population pressure, perhaps typical of wealthy new freedmen.[202] He notes "the Dalmatian coastline had been a favourite resort of Italian traders and immigrants from late Republic times and a major objective of Augustan arms. Salona, Iader and Narona were virtually Italian cities transplanted to congenial and productive terrain."[203] However, based on the unfortunate neglect of Balkan excavation at the time of his writing, McKay concentrated on the ruins available for study, including Diocletian's Palace and several large *villae rusticae,* including Doclea in Montenegro and Strupnić near Bosanska Krupa in Bosnia and Herzegovina. Thus, his analysis tends toward the exceptional rather than the more working, less wealthy installations exemplified by the site at Trstenik. In a more recent publication, Matijašić discusses

[201] Ruff 2017.
[202] McKay 1975, 100-114.
[203] McKay 1975, 202.

villas found and excavated along the Istrian coast. His assignment of *villa rustica* or *villa maritima* to different sites is based on the amount of decoration and luxury perceived to have been available.[204] His site plans show working areas and pier structures for both classifications of villa. By extension, should a large villa be discovered and excavated at Trstenik at some future date, it could be classified using either moniker.

An analysis of the landscape of Roman villas in Britain concludes "We can, therefore, see the villa landscape as a distinct and clearly related series of components. Most villas were agricultural estate centres, but some were related to 'industry', and a few may have been the palaces of magnates, without direct economic functions. The villa landscape comprised not only villas, however, but also rural, non-villa, agricultural communities…"[205] This vision of working Roman villas at the periphery of the Empire is more apropos to the facility at Trstenik than any of the definitions provided by McKay regarding massive complexes and wealthy estates. Marzano notes that the definition of villa changes over time, both in the Roman era and in modern analysis of archaeological and written evidence. Ultimately, she focuses on villas as centers for both social ritual and economic production in an extensive effort to apply modern economic theory (market economy, capital investment, profit) to Roman-era sites. She notes that even

[204] Matijašić 2001.
[205] Dark and Dark 1997, 75.

luxurious villas have an economic production component, and the density of that economic production evolves and shifts over the centuries.[206]

Glicksman comments on the indiscriminate use of the word villa, noting

> The Romans themselves seem to have had no uniform idea as to what classified a building as a villa, as can be seen from the rather vague and general definitions presented in the literary sources. As regards Dalmatia specifically, no standard has been employed in the use of the term *villa*, which can be found in the literature to identify nearly any form of Roman architecture which has not been given a non-residential and non-agricultural identity. Any building which shows any form of luxury or agricultural production is unsurprisingly termed a *villa*, although the scale of these structures is often unknown. More perplexing, however, is the apparent trend of using the term *villa* for any rural structure of unidentified function; luxurious residences within city boundaries are sometimes called *urban villas*. Surely, this generalised usage of the term renders it useless; a distribution map of so-called villa sites would only show the distribution of archaeological finds dated to the Roman period rather than saying anything significant about rural settlement in Dalmatia.[207]

She goes on to define a villa for her purposes as "any Roman-period structure situated in a rural location and showing evidence of both an agricultural and a residential function, regardless of size or perceived level of luxury."[208]

However, by her definition the land immediately adjacent to the site of the Trstenik shipwreck cannot be a villa. First, the site is not rural, located only 4 km from the likely sea gate to Salona, which would have been situated near the theater. A hypothetical, but plausible, western gate into Salona (near the amphitheater) would have been only 3 km from the site. Also, the land area in the vicinity of the ship suffers from

[206] Marzano 2007. While her work concentrates on central Italy, her use of specific excavations to discuss types of villas can be extrapolated to Dalmatia or other Roman provinces farther from the heart of the Empire.
[207] Glicksman 2009, 46-7.
[208] Glicksman 2009, 47.

a lack of excavation; many of the modern houses along the coast were built without any archaeological survey. In fact, one of the homeowners has a picture of the road being repaired in front of his house showing construction workers unearthing Roman graves under the damaged pavement. Thus, no actual nearby Roman building remains have been properly excavated, documented, or studied, so while it is virtually certain buildings existed in the vicinity of the site, labeling a particular site as a villa, as opposed to a *horrea* (warehouse or storage building) or some other plausible structure is problematic. Lastly, Glickman's definition requires evidence of an agricultural function, which can be inferred, but not conclusively shown, based on archaeological evidence. It is particularly difficult to designate land unimproved in antiquity along the northeastern coast of the Gulf of Kaštela as agricultural, given the proximity to the urban area of Salona, and the potential that a particular plot of land along the coast could well have been more valuable when utilized in support of some aspect of boatbuilding, shipping, fishing, or other maritime commercial activity associated with the Roman provincial capital.

A subdivision of terms often employed is to designate ornate houses owned by wealthy Romans as "urban villas" while a more rural structure, which supervised agricultural production, would be considered a *villa rustica*. Percival perceives that the fertile strip along the Adriatic coastline of Dalmatia was ideal for a "villa economy," with the potential for rich farmland, abundant supplies of fish, and a good Mediterranean climate. He concludes

> All the relevant evidence suggests that the original owners at least were Italian immigrants: the early date of the villas would suggest that they were the product

> of a culture brought ready-made from outside rather than of one acquired locally, and the dependence of the early owners on Italian imports, not only of the regular manufactured goods but of actual building materials such as roof tiles, points strongly in the same direction."[209]

His analysis of a culture "brought ready-made from outside" exactly correlates with the find of a first century Roman-style mortise-and-tenon built ship constructed near the Roman provincial capital of Salona, while laced boat technology continued to thrive contemporaneously less than 200 km to the north near Zaton and in the Bay of Caska on the island of Pag.

Even the ancient sources disagree on the components of a country villa. Cato wrote of such a villa in two units: the *villa urbana*, or dwelling-house, and the *villa rustica*, structures for all other purposes.[210] Meanwhile Columella divides his villa into three parts: the *villa urbana* or manor house, the *villa rustica* or farmhouse, and the *villa fructuaria* or storehouse.[211] Vitruvius provides guidance for urban and country construction, along with the admonition "If [*villae rusticae*] are required to be erected of more magnificence than ordinary, they must be formed according to the proportions laid down for urban villas described above, but with the precautions necessary to prevent the purposes of a country house being interfered with."[212] While providing some construction guidance, Varro discourages extravagance when building, praising the thrift of the ancients over the luxury of the moderns (although he lived in the 2nd-1st centuries

[209] Percival 1976, 88.
[210] Cato, *Agr*. II-4.
[211] Columella, *Rust*. I-6.
[212] Vitr. *De arch*. VI-6-5.

BCE), and states that farms should cost more than the dwelling houses erected upon them.[213] While the ancient authors may disagree, two common denominators were a location outside of the defined urban boundary and an embedded idea of productivity; "depending on location and available natural resources, an array of productions was possible, either to achieve self-sufficiency or for exchange on the market."[214] Percival notes that the ancient sources are as a group uneven in both reliability and distribution, and in general were more concerned with the practice of farming itself rather than with the villa as an institution; he summarizes:

> The literary sources are of only limited use: they give us a range of meaning but nothing which is really precise. A villa is a place in the country, normally (but not always) associated with farming, sometimes with connotations of luxury or relaxation, and in most cases a single house rather than a group of them…Villas were not things invented at a given point in time, but things that evolved gradually as part of a wider social and economic evolution. There is no reason to suppose that they formed a distinct and easily definable category to the Romans themselves, and to ask that they should do so to us may well be unreasonable.[215]

In his discussion on Roman ships and ports, Houston notes the likelihood that numerous minor local facilities supported beaching of smaller ships to support cargo operations in antiquity. His theory is a variation on the disproportionate weight given to inorganic archaeological remains, such as amphoras, because they survive, while organic material such as grain does not. Houston notes that large Roman ports had stone buildings and *horrea* to support cargo operations, and those operations were managed by

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[213] Varro, *Rust*. I-13.
[214] Marzano 2013, 6. She adds extensively to ancient sources, but ultimately concludes that more excavations are required to determine the variation of the ancient use of the term "villa" with respect to temporal and geographical variation.
[215] Percival 1976, 13-5.

Roman officials, based on inscriptions found in ports such as Ostia and Puteoli. Similar inscriptions are not found in locations where port operations would have been on a smaller scale, likely conducted without Imperial oversight. He also notes the common use of beaching to handle cargo in the modern era (citing British port operations in the 18th century). Houston concludes "The likely inference is that the vast majority of Roman ports were very simple, requiring little or no maintenance or administrative involvement."[216] Jurišić agrees, noting small-scale piers were commonly associated with seaside Roman villas and estates.[217] This description matches the site at Trstenik, a wooden pier only 3 km from a provincial capital, maintained by scuttling a small ship filled with rocks. The management burden for such a facility could have been performed by local residents, and any quarters would have been functional rather than opulent in nature.

Based on a summation of the above ancient and modern sources, the term *villa rustica* seems to be the most accurate description for a complex built to support maritime activities in the Gulf of Kaštela near the walled city of Salona. While the site is located near an urban area, it is 3 km outside the city walls, and although there is no evidence (to date) of the performance of any land agricultural management functions, the site is clearly not a luxurious *villa maritima*, designed as an escape from urbanity by elites. Future land excavations in the Gulf of Kaštela will be required to define the typical villa construction of the region and its metamorphosis over time.

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216 Houston 1988, 560-4.
217 Jurišić 2006, 191.

3.3 Modern Underwater Archaeological History of the Gulf of Kaštela and the Site of Trstenik

The abundance of sites being discovered in the Gulf of Kaštela is a direct reflection of ancient exploitation of the geographic advantages provided to the region. Fertile land, rich sea resources, fresh water, isolation from invaders from land, and protection from direct storm impingement from the sea all combined to make the region attractive to settlements since prehistoric times. Radić Rossi postulates that the amount of historical underwater finds in the Gulf of Kaštela region underestimates the utilization of the region in antiquity. She attributes the slow pace of initial discovery to several factors: exploitation of the sea basin in the Industrial Age resulting in pollution, which made the Gulf unattractive to scuba exploration; a heightened focus on terrestrial remains in the region; a water column that is often murky with vegetation, particularly in the summer months when the basin warms up; and a muddy, silted bottom that thickly covers ancient features and archaeological remains.[218]

As previously discussed, the Gulf of Kaštela is a large protected basin situated between the city of Trogir and the island of Čiovo to the west and the city of Split and the Marjan Peninsula to the east (Figure 3-2). Today, there are seven towns along the coast of the Gulf with the title "Kaštel" in their name. This is a remnant of the numerous medieval-era castles which dotted the coastline of the Gulf of Kaštela. From west to east, these seven towns are Kaštel Štafilić, Kaštel Novi, Kaštel Stari, Kaštel Lukšić,

[218] Radić Rossi 2009b, 490.

Kaštel Kambelovac, Kaštel Gomilica, and finally Kaštel Sućurac. The eastern-most town, Kaštel Sućurac, is situated most closely to the remains of the ancient city of Salona and contains the region of Trstenik where the 2015 ship excavation occurred. The regional appellation Trstenik is based on the Croatian word "trska," which translates to "reed" or "cane," indicating that this spot was always a marshy, swampy area. Recent geomorphological studies along the coast of modern Croatia have located numerous markers for the ancient coastline during the Roman era, establishing that the cumulative effect of tectonic activity combined with sea level changes has submerged the ancient coastline by an average value of 1.5 m over the last 2000 years.[219] This value of course has some amount of local variation, but that amount of vertical deepening over time appears consistent with the archaeological situation in the Gulf of Kaštela and lends support to the hypothesis that the ship excavated at Trstenik was filled with rocks and scuttled just below ancient sea level to strengthen and support the sea wall of a Roman villa outside the city walls of Salona.

Mardešić summarized thirty years (1970-2000) of terrestrial archaeological investigations in the area of Salona, which is abutted by Kaštel Sućurac. First, she notes most of the excavations carried out were "rescue excavations" as opposed to planned systematic excavations. Questions that remain unsolved include whether there was an Illyrian antecedent to ancient Salona and, if so, whether it lies under or in the vicinity of the Roman city's ruins. Despite several plausible assertions, no proof has been obtained.

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[219] See Faivre and Fouache 2003, and Fouache et al. 2005.

Similarly, she examines an excavation that attempted to locate the Delmatic port mentioned by Strabo.[220] That excavation only found remains for a storehouse or ship maintenance facility dated to the 1st century CE.[221] Ultimately Mardešić concludes "this Delmatic port has not yet been found, nor can we currently suggest an approximate position of the settlement."[222]

Džino analyzed chapter 7 of Strabo's *Geography*, noting his descriptions omit all of the numerous Roman colonies (Pola, Iader, Salona, Narona, Lissus) of the time and seem to describe an archaic political landscape of the 2nd and 3rd centuries BCE. He postulates that Strabo is intentionally minimizing the Romanization of Illyricum, choosing to paint the province as the boundary between civilization and barbarians. Džino considers Strabo in error when he describes Salona as the "port" of the Delmatae, considering the city a Hellenistic emporium taken over by Rome in the 1st century BCE, and that Delmataean Salona was a different site, farther inland.[223] "As a whole, Strabo's Illyricum is an unreal place existing neither in time nor space; it is an imaginary literary construction…"[224] Additional excavations and research are clearly required in the waters surrounding Salona to complement the sparse historical record.

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[220] Strab. *Geog.* 7.5.5.
[221] Oreb and Kirigin, 1980 describes this two-day drainage excavation in swampy ground near the mouth of the Jadro River just north of the Vranjic Peninsula, which located ceramics, stones, and other filler debris thrown in among wooden stakes dated between the 3rd cent. BCE and the 1st cent. CE.
[222] Mardešić 2006, 82.
[223] Džino 2006, 123.
[224] Džino 2008, 192. In contrast, see Šašel Kos 2017 for a detailed expose on Tiberius's activities in Illyricum based on analysis of Strab. *Geog*. 7.

Initial underwater finds in the Gulf of Kaštela were made as early as the 19th century when Roman inscriptions and sarcophagi were located along the Vranjic Peninsula just to the south of the theater and amphitheater of ancient Salona (Figure 3-1). These sarcophagi became the first documented underwater archaeological finds in Croatia.[225] While large port facilities that sustained the ancient city of Salona remain unlocated, Cambi credits both sides of the small peninsula of Vranjic as part of the actual spacious part of the harbor area that supported Salona. He describes the remains of several Roman structures to the south of the city walls of Salona in the vicinity of the theater, noting that they were most likely *horrea* (warehouses/storage facilities) built on wooden poles over swampy ground, and postulates that there was a gate in the Salona city wall that exited the city in a southerly direction near the theater, and terminated in the city's port.[226] Cambi notes that these facilities have never been excavated. A visit to the area in 2015 revealed significant building of modern facilities including a large railroad switching yard and a petroleum tank farm. These modern structures, coupled with the geographic instability of the adjacent Jadro River delta area, result in an inability to fully comprehend the ancient shoreline or accurately understand the nature and structure of the harbor of ancient Salona. Unfortunately, this situation is not localized, and reflects a regional post-World War II imbalance that favored economic expansion without regard to the preservation of cultural heritage. Fortunately, this

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[225] Bulić, F. 1899, 1900a, 1900b.
[226] Cambi, 2001, 142.

attitude appears to be reversing in the present day, based on significantly expanded recognition of and concern for historical heritage by all generations of Croatians.

The next documented underwater find in the Gulf of Kaštela occurred in the summer of 1958, when a deposit of amphoras was discovered near a popular swimming area in the Spinut region of Split.[227] Unfortunately, the site was quickly stripped of amphoras by bathers, and few examples survived to be studied by Cambi in the 1970s. The site originally contained 40-50 amphoras, three of which were eventually acquired by the Archaeological Museum in Split. Of interest, the amphoras Cambi located were of the Dressel 20 type, a globular Spanish design most commonly dated to the 1st-3rd centuries CE, typically used to transport highly prized Iberian olive oil, although reuse of amphoras for other cargo cannot be ruled out. Cambi determined that this was a fairly rare type of amphora to be exported to the Adriatic Sea. His research located only two other examples of underwater Dressel 20 finds: an unknown site near the island of Dugi Otok, and a site near the city of Fažana on the Istrian Peninsula.[228] In 1974 Cambi revisited the site at Spinut and conducted a small excavation. He located additional amphoras, both whole and fragmentary, of the Dressel 20 and African cylindrical style, and concluded that rather than remaining as evidence of an ancient shipwreck, the amphoras were intentionally deposited at the site in a reflection of Roman-era long distance trade between Dalmatia and either Spain, Africa, or both regions.[229]

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[227] See Cambi 1975 and Cambi 1983 for discussions of the Dressel 20 amphoras from Spinut and their associated stamps.

[228] Cambi 1975, 121. He was able to locate a single amphora from each site, one on display in a restaurant in Biograd and the other on display at the amphitheater in Pula.

[229] Cambi 1983, 363-9.

Subsequent research and excavations throughout Pannonia, Histria, and Dalmatia have located more than 20 sites with Dressel 20 amphoras, found on land, in shipwreck cargo, incorporated into coastal structures, or simply discovered as a lone amphora located underwater. Borzić and Ožanić Roguljić hypothesize that a decline in local agricultural production may have contributed to the gradual infiltration of Hispanic olive oil into the Eastern Adriatic in the late 1st and early 2nd centuries CE, but ultimately even after analysis of 40 Dalmatian and Pannonian sites with Hispanic product remains, over 20 of which included Dressel 20 amphoras, they regard the total amount of evidence as too small to draw a definitive conclusion.[230]

Modern discoveries of ancient sites continued in the Gulf of Kaštela in the late 20th century, including the identification of the Hellenistic/Roman site of Antički Sikuli in the Resnik area of Kaštel Štafilić, the western-most Kaštel in the Gulf about four kilometers from Trogir. Major excavations at Antički Sikuli have taken place over the last 25 years, identifying two separate phases of construction: a Delmatae settlement with Greek planning influences from the 2nd and 1st centuries BCE, and a second settlement built over the first during the 1st to 4th centuries CE. Roads, cisterns, villas, and multiple burial sites were located, while recovering metal, bone, and glass objects; columns made of Proconnesian marble; hundreds of coins; and over four tons of amphora and *tegulae* fragments.[231] The underwater discoveries in this area occurred in

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[230] Borzić and Ožanić Roguljić 2018, 519.
[231] See Kamenjarin and Šuta 2011 for an excellent summary of excavation campaigns in Resnik/Antički Sikuli, including trench diagrams and artifact catalogs. For earlier underwater excavation history of the area see Brusić 2008.

2005 during rescue archaeology just off the coastline in preparation for the installation of a sewage discharge pipe. Submerged artifacts identified in the approximately one-meter thick layer from antiquity included pottery sherds and well preserved vessels, wooden dishes, a two-sided wooden comb, and fishing weights and hooks, as well as stone blocks that may have belonged to the defensive walls of the first phase of the settlement, and potentially indicate the presence of some level of Roman port facilities.[232] Also in 2005 and 2006, a Vranjic Peninsula waterfront reconstruction and enlargement project was halted on 12 separate occasions to conduct rapid archaeological rescue excavations, recovering a wide variety of artifacts including sarcophagi fragments, statues and statue heads, and a fragment of a Greek inscription likely repurposed during Roman times for embankment construction.[233] These sites, along with other sites with wooden constructions and pylons throughout the Gulf of Kaštela (from Trogir in the west, to Spinut in the east), testify to the widespread inhabitation and Roman employment of the entire Gulf of Kaštela during the first two centuries of the Empire.[234]

3.4 History of the Trstenik Ship Excavation

While certainly Kaštel Sućurac residents of every generation were aware of Roman archaeological evidence throughout the region, modern attention to the Trstenik section of Kaštel Sućurac was first attracted in 1995, when Dragan Delić, the president of a local cultural preservation group, noted a rectangular construction in an aerial

[232] Radić Rossi 2005a; Radić Rossi 2008a, 291; Kamenjarin and Šuta 2011, 44-53.
[233] Radić Rossi 2008c.
[234] Radić Rossi 2009b; Radić Rossi 2012, 296.

photograph, just to the north of the road paralleling the coastline.[235] This visual detection, combined with the discovery of a small temple in the area at the beginning of the 20th century and the recovery of multiple Roman artifacts during the construction of a modern house, led Delić to hypothesize that the area supported a *villa rustica* during the early Empire. In his newsletter to the cultural preservation group, he mentioned that local fishermen were also aware of "large jars in the mud," which Delić also associated with the potential *villa rustica*.[236] However, news of these jars was not immediately passed to Croatian archaeologists, and a delay of seven years ensued before an excavation campaign was organized and initiated in October 2002. A seven-day underwater campaign was conducted, which quickly revealed the richness of the site. A 1000-liter perforated *dolium* (Figure 3-3) was recovered from shallow water near the shore.[237] To date this is the only complete intact perforated *dolium* known in the Mediterranean.[238] Fully conserved, the *dolium* is 160 cm in height with a maximum width of 140 cm. An internal layer of pitch suggests the container was originally

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[235] Radić Rossi 2006a, 48.
[236] Radić Rossi 2006a, 48-9.
[237] Radić Rossi 2004.
[238] Radić Rossi 2008a, 292 and Radić Rossi 2009b, 491. Additional fragmentary remains of perforated *dolia* have been found on the island of Vis, see Borzić 2009, 87-8 and Pešić 2008. For an overview of Croatian perforated *dolia* fragmentary remains (eight sites total) see Radić Rossi 2008b and 2009a.

Figure 3-3. Perforated *dolium* Recovered at Trstenik, Kaštel Sućurac in 2002. The *dolium* is on display in the Croatian Maritime Museum in Split, Croatia.

probably used for the storage of wine, then was repurposed, likely as a fish or shellfish habitat, by cutting or punching 58 rectangular holes measuring around 2 x 2 cm into the upper portion of the *dolium*. During the recovery of the perforated *dolium*, multiple indications of Roman port activity were noted in the vicinity, including a wooden wall running parallel to the shoreline for approximately 50 m and a deposit of globular Dressel 20 amphoras contained within a construction of wooden pylons (Figure 3-4).

Figure 3-4. Dressel 20 Amphoras and Wooden Pylons during 2006 Excavation. (credit: I. Radić Rossi).

As discussed in Section 3.2, the evidence found in the sea lends credence to use of the term *villa rustica* as an appropriate term for the Trstenik site. First, the Dressel 20 amphoras found discarded in the vicinity do not constitute a large trash heap of antiquity where dumping went on for years, but rather are a small cache of Iberian olive oil containers, very rare for the entire Adriatic, and certainly delivered at one time and consumed as a group in one location, rather than being acquired over time, or consumed in multiple locations and re-consolidated for disposal. Second, the perforated *dolium* that attracted the original attention to the site has a capacity of approximately 1000 liters. Based on its repurposing as a storage facility for live fish, its capacity alone would not have supported a large fishing operation or commercially viable storage or supply center but would have been sufficient for storage and meal preparation for a small family group, although there may have been additional perforated *dolia* that did not survive. Lastly, the wooden posts and wooden sea wall are not equivalent to the commercial-grade pozzolana used to build large pier facilities such as those found at Cosa and Ostia, but rather are almost identical in magnitude to the small harbor constructions in the bay of Caska on the island of Pag, near the villa associated with *Calpurnii Pisones.*[239]

The Trstenik site was revisited over multiple years to continue site analysis, particularly the excavation of the Dressel 20 amphoras within the wooden pylons, as well as a more accurate measurement of the wooden wall.[240] In 2006 four additional Dressel 20 amphoras were located and subsequently removed for conservation and study. While defining the western extent of the wooden wall, the outline of a wooden ship was identified, with a bow and stern just visible in the surface layer alongside the wall, measuring approximately 12 m in length, at a water depth of about 1.5 m.[241]

In November 2012 a limited partial excavation of the Trstenik ship was conducted. The western part of the ship was excavated and roughly cleaned by removing the stones used to scuttle the ship along with accumulated sediment. In the central area of the ship, a cross section was cleared. Sections of the keel, 39 frames, 31 pieces of inner planking, and one wale were identified in the uncovered portion of the hull structure.[242]

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[239] Boetto and Radić Rossi 2017; Ruff 2017.
[240] Radić Rossi 2004 and 2005b.
[241] Radić Rossi 2006b and 2007.
[242] Radić Rossi and Lete 2012, 721.

Infill with rocks and scuttling near shore of this type have been noted at the *villa rustica* at Caska on the island of Pag, where two laced Liburnian ships and one contemporary Roman-style mortise-and-tenon constructed ship were filled with rocks and intentionally scuttled next to wood constructions near the coastline.[243] Initial radiocarbon dating of the Trstenik ship determined an age of 2005+60 years before present, dating the wood felling to either the first century BCE or the first century CE, roughly contemporaneous with the ships scuttled at Caska.[244]

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[243] Boetto and Radić Rossi 2017; Ruff 2017, 19-20.
[244] Radić Rossi 2007, 458.

4. THE 2015 FIELD SEASON

4.1 Excavation Planning

To support project execution, a detailed project plan was developed in Microsoft Project to highlight critical paths, identify needed materials, and assign specific action items to individuals. The plan was based on previous excavations executed by the University of Zadar, particularly the initial investigation of this wreck in 2012, as well as recent similar shallow water excavations undertaken on Roman ships in Croatia, including two ships near Caska on the island of Pag and a ship near the city of Pakoštane. The planning was financially constrained to not exceed a total budget of $25,000, generously provided by the 2015 Claude Duthuit Archaeology Grant from the Institute of Nautical Archaeology.

Based on financial projections, the excavation was planned for a 22-day period on site, tentatively scheduled for March and April 2015 to avoid the short daylight hours and potential adverse weather expected in January and February, and to not conflict with other excavations scheduled for May and June. Additionally, a summer excavation was not ideal at this site because high water temperature and shallow water combine to encourage a heavy growth of algae on excavated wood in as short as eight hours. The project plan recognized that an excavation conducted over an extremely short period had to rely heavily on photogrammetry for the majority of data recording. Archaeology student volunteers were perfect to remove tons of overburden, dredge the silt and sand, and finely clean the ship's structure to support photogrammetry. Then photogrammetry could document the entire site rapidly for later scaled analysis of ship structure and construction techniques. Photogrammetric results could be augmented by hand drawings of selected wooden construction features which could be created on-site as time and personnel allowed. Without the technique of photogrammetry, months would have been required to record less data of lower fidelity.

Two fairly major excavation planning decisions were made strictly on the basis of equipment available in Croatia. First, the Trstenik site, which is only 50 m from shore and at a depth of 3 m, would potentially be an excellent candidate for a dry excavation using a cofferdam set-up. Such an excavation could turn a shallow underwater excavation into a dry land excavation, eliminating the need to dive, thus greatly expanding the amount of time spent working on and analyzing the wreck. For example, the seven-month, multimillion-dollar excavation of the 17th-century ship *La Belle* near Palacios, Texas in Matagorda Bay (1996-1997) was performed in a steel-walled cofferdam erected around the perimeter of the remains, with subsequent work executed using both terrestrial and underwater methodologies.[245] The cofferdam facilitated detailed mapping of the site throughout the excavation as well as meticulous artifact recovery procedures and detailed recovery of the hull. The semi-dry work environment made it easy for archaeologists to communicate and maintain vertical control, significantly improving the overall understanding of the wreck. A side benefit was the public access facilitated by the cofferdam, which resulted in public awareness and

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[245] See Hedrick et al. 2017 for a detailed discussion of the *La Belle* cofferdam excavation. This effort was the first time a cofferdam had been used in North America to excavate a shipwreck in dry conditions.

ultimately additional project funding. However, given the small budget and short excavation timeline for the Trstenik ship, coupled with the foreknowledge that the wood from the ship's hull was not to be excavated and conserved, but rather re-covered and preserved *in situ*, use of a cofferdam for this excavation was not feasible.

Second, once diving became the preferred method of excavation, the site's shallow depth and proximity to land demanded consideration of using a shore-supplied air system (familiarly known as "hookah"), which potentially could be a more efficient and economical technique than divers wearing scuba tanks. Hookah systems provide air to multiple divers via air hoses, typically fitted to full-face masks. The hoses are fed by a low-pressure gasoline or electric powered compressor, which could be run from shore, a boat, or a small platform positioned over the excavation site. Use of a hookah air system would allow significantly longer bottom times working over the wreck site. With no need to change out tanks, dives would be limited only by individual endurance based on hunger and body temperature. Hookah systems also remove the weight of the tank from the diver, making water entry and exit much less arduous. Additionally, because air in a tank is not being consumed, hookah diver buoyancy does not vary during a dive as it does with traditional scuba tank diving. The nature of an air-fed umbilical keeps all of the divers together over the excavation site, and when a full-face system is used to provide air to hookah divers, additional safety margin is provided because a suddenly unconscious diver continues to be provided with positively pressurized breathing air, rather than potentially spitting out a standard scuba mouthpiece. Finally, hookah systems are more economical to operate as neither scuba tanks nor an expensive high-pressure compressor are required for the excavation. These factors seem to combine into a significant advantage of a hookah system over traditional scuba, especially given the extremely short timeframe for this excavation.

However, use of a hookah system does have drawbacks. Hookah diving has earned a reputation as being less safe than scuba, largely because no formal training programs exist for hookah divers, resulting in individuals with no underwater experience diving in hookah and getting into trouble, tragically in some cases even dying. This lack of training and certification could be mitigated by familiarization dives, verifying certified scuba divers are proficient on hookah before being put to work on-site. Other drawbacks to hookah are less easily overcome. First, working tethered to an air hose while concurrently operating a water dredge and its associated water hoses is quite challenging due to significant tangling risk. This difficulty is multiplied when considering that many dive groups contain six to eight divers. The small shipwreck site would quickly become a spaghetti tangle of air hoses and dredge hoses as each individual attempts to perform assigned tasks without interfering with other excavators. Additionally, as more hoses and equipment are added immediately over the site, it becomes more difficult to protect exposed fragile wood components from excavation equipment. Ultimately, the decision boiled down to availability and training. Scuba bottles and a compressor were readily available, but a hookah system was not. And, as a hookah system had never been used by most of the student archaeologists, the decision was made to plan the excavation as a series of dives from shore with scuba tanks.

The project plan also relied heavily on the expertise and knowledge of Dr. Irena Radić Rossi, a noted Croatian nautical archaeologist on the faculty of the University of Zadar, Croatia, and co-director of the excavation. In addition to her knowledge, leadership, and indefatigable energy, she brought to the project the ability to rapidly process excavation permits while expertly navigating local politics. Her extensive network of students, former students, and avid archaeological amateurs did the heavy lifting (literally) for this project, and her decades of experience meant that the project benefitted from her access to a vast array of equipment and a deep stable of professionals. The project plan took maximum advantage of her expertise. The excavation could not have been undertaken without her leadership.

4.2 Excavation Execution

The excavation planning was continued after team assembly began in Croatia. Due to changes in planning for other excavations coupled with the desire to maximize student participation in the excavation, the commencement of work was delayed by three weeks from the initially projected start date. The author landed in Croatia on April 7th, 2015 and assisted with equipment purchase and organization of materials. Supplies provided by the University of Zadar were loaded in both Zadar and Tkon on April 13th and delivered to the team headquarters in Kaštel Sućurac, near Split.

The first day of diving occurred on the afternoon of April 16th with divers who were familiar with the site from the 2012 excavation campaign. They were able to mark the position of the wreck with buoys, begin the process of removing geotextile that had been placed over the site at the completion of the 2012 campaign for protection, and begin assembly of dredges and hoses to support the excavation.[246]

On April 17th, the second day of diving, an aluminum grid of 2 m x 2 m grid squares was assembled in shallow water, then walked out to the wreck site by individuals in scuba gear (see Figure 4-1). The grid was then positioned over the wreck

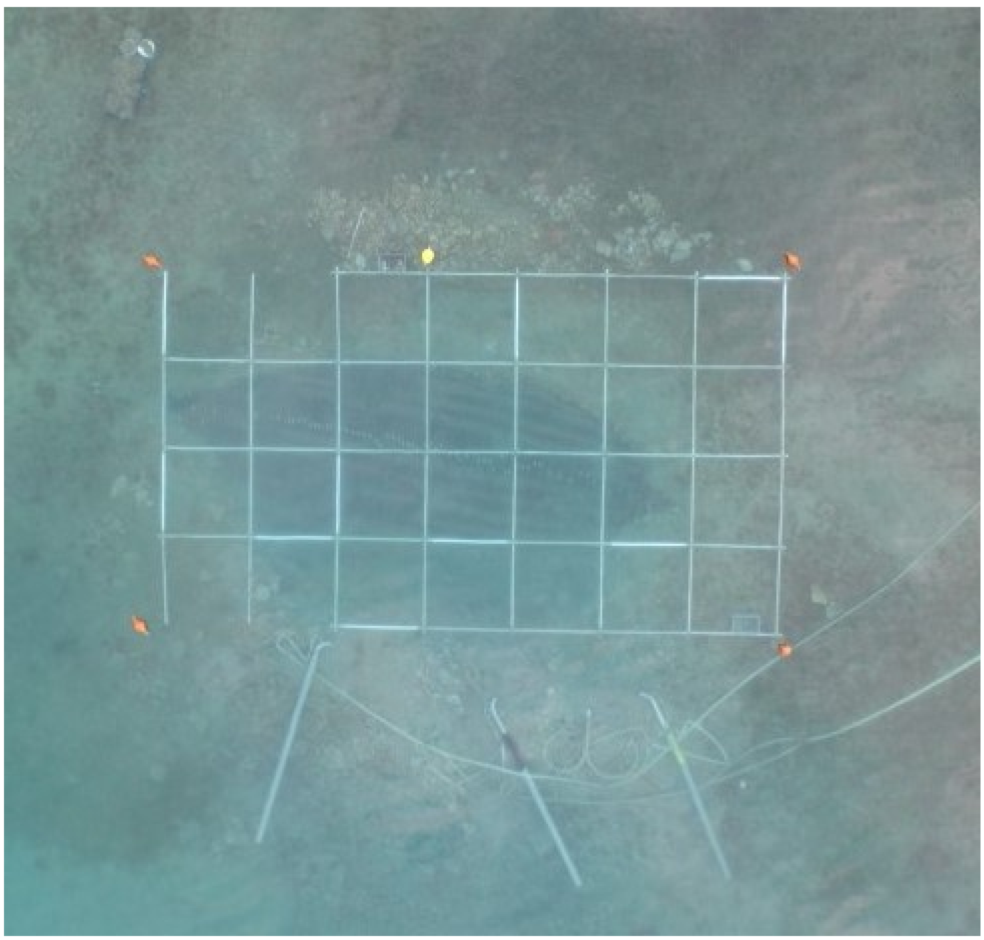

Figure 4-1. Aluminum Grid over Trstenik Shipwreck. North to top. (credit: Ervin Šilić).

[246] See Ruff and Radić Rossi 2015 for additional excavation information.

and levelled. The grid system served two important purposes. First, labeling the grid rows alphabetically in one direction and numerically in the other direction provided a geo-location system to use while excavating the overburden and rocks that covered the wreck. This allowed clear work location assignments for excavators and also provided a method to record any finds that were made during the removal of overburden, such as a ceramic sherd found while excavating grid square G-2, for example.

More importantly, the grid provided a strong rigid platform for divers to use to prevent any weight or stress from being exerted on the site during excavation. This added great flexibility to the work being performed at the site. During the initial site clearance, the aluminum grid provided a strong perch to stage plastic clothes baskets which could then be filled with rock overburden and efficiently carried away from the site. Additionally, divers could use the grid for leverage when prying up rocks, avoiding stress on adjacent areas. After the larger rocks were removed, the grid was strong enough to fully support the weight of three water dredges and their associated hoses while pivoting the suctions over the site and dredging in multiple locations. At the completion of the work day, the grid provided a structure to tie down dredging equipment to prevent any dragging over the site overnight by ocean current or potential storms, while keeping the equipment staged for recommencing work the following day. Most importantly, the aluminum grid became a diver suspension platform, allowing individuals to work just above the site without placing any unnecessary stress on delicate hull remains. The grid allowed both experienced archaeologists and novice students to overweight themselves while diving, lightly pinning them to the top of the grid for more efficient work, while minimizing the probability of any inadvertent damage to the site during excavation and recording. During the excavation, the size and shape of the grid was adjusted several times by adding additional bars to expand the grid coverage and optimize the platform shape. The corners of the grid were marked by buoys to highlight the work location to any passing small boats.

Due to various factors, team composition changed throughout the excavation, with additional team members arriving over the course of the fieldwork. The procedure followed was to provide an initial orientation dive, to show new arrivals the overall site layout, the grid location and the hull labeling convention. This initial dive also provided an opportunity for individuals to check their gear, determine if they would be warm enough in their wetsuits to work comfortably in the chilly water, and verify their buoyancy and weighting. Unlike recreational scuba, typically conducted at neutral buoyancy, site excavation is more efficient with divers heavy enough to be pulled downward, both for walking to the site on the bottom as well as allowing more leverage for rock removal or dredge operation. Also varying from recreational scuba, diver equipage typically did not include fins or a snorkel since it was a very shallow site, near shore, and with essentially no current or waves.

The excavation team was able to quickly establish and maintain a daily routine. Personnel assignments were made each evening, including breakfast preparation duties, a dive plan with work assignments for all planned dive groups and their timekeepers, scuba tank refilling, dive-log maintenance, and collation of individual dive logs into a daily excavation diary entry. A typical day began with breakfast at 7 AM, a briefing to all team personnel at 8 AM, and a standard goal of first divers in the water by 9 AM. Several shifts of divers would rotate, and a hot lunch was delivered to the house from a nearby restaurant. Diving continued through the afternoon followed by equipment cleanup, scuba tank refilling, documentation of the day's work in individual logs, photographs of any recovered artifacts, and dinner. The brevity of the excavation period demanded daily work to maximize data extraction. Once diving began, it continued without break for 24 straight days (two days longer than initially planned based on an efficient expenditure rate of funding), with the exception of one dive day lost due to poor weather.

The team headquarters was set up to maximize efficiency for all phases of the excavation. The house rented for the excavation was ideal. For habitability, it had a kitchen for food preparation as well as multiple bedrooms for team members. The dining area was used both for personnel briefings and data management. Excavation tasks were supported in multiple locations, including a small separate room utilized for digital photo processing, a large deck with clotheslines ideal for scuba gear cleaning and storage, and a smokehouse utilized for scuba tank refilling with a small portable compressor. The garage contained the main air compressor and was also used to store spare hoses, dredges and other excavation equipment. A concrete sea wall conveniently abutted the shoreline facilitating ocean entry and exit of the divers. Teo Kovač, owner of both the house and Kod Bunara, the restaurant that kept the team well-fed with delicious hot food, must be recognized as having been absolutely vital to the success of the excavation.

The lost dive day (Monday April 27th) was predicted several afternoons in advance when the wind shifted to blow from the south (*Jugo*), creating waves that adversely impacted the dredges' water pumps operating on the concrete sea wall. The waves also stirred up sand, silt, and sea grass near the shore causing repeated clogs of the suctions into the pumps. As a workaround, the water pumps were moved from the concrete sea wall to a nearby small pier. This resulted in the pumps being less impacted by the waves and allowed their suctions to draw from deeper water, minimizing clogs. While the excavation did experience two days of brisk wind from the north (the famous Croatian *Bura*), the excavation site was not impacted by wind from that direction and work was able to continue.

The support of local individuals and institutions was also crucial to the success of the excavation. The work attracted the attention of numerous individuals and organizations. Among others, the site was visited by local authorities and individuals from the Municipal Museum of Kaštela. A film crew from the Croatian national television channel (HRT) visited twice and provided coverage on the weekly show *More* (The Sea). Their footage included excavation team interviews and film of work in progress. Local divers were invited to participate in the excavation and several individuals volunteered their own time to participate in site work. Outstanding documentation of the site and surrounding area was recorded by Ervin Šilić, the Director of NOVENA Digital Media Studio. Unlike most underwater sites, which are farther from land and less conducive to aerial recording, the use of a drone to record the Kaštel Sućurac/Trstenik geographic setting was particularly striking.

A detailed log was maintained of equipment and consumable purchases made during the excavation. While it is impossible to be prepared for every eventuality, it is appropriate to factor lessons learned into planning for future excavations with the goal of continuous improvement. The most important time during an underwater excavation is any minute spent underwater, so any equipment or purchase that could increase efficiency while diving is particularly important. For example, during photogrammetry, the memory chip in the camera would quickly reach capacity, requiring the underwater camera team to exit the water, remove the camera from its waterproof case, transfer the data to a computer, reseal the camera, and recommence photography. Purchase of two of the largest available camera memory chips prior to the excavation would have significantly improved photogrammetric efficiency.

The second-most important time during an underwater excavation is time at the excavation site. Any preparation that can be done before arrival (pre-loading of spreadsheets, pre-printing of artifact tags, preparation of grid labels in advance, etc.) frees up time on site to allow for contingencies, work on emergent issues, or—even better—much needed sleep.

4.3 Labeling Ship Components and Completion of Excavation

A labeling scheme must be selected at the beginning of an excavation to allow ship components to be consistently labeled as they are uncovered, cleaned, and photographed. Such components include the stringers, the frames, the strakes, and the wales of the ship (Section 6). This labeling allows for consistent vocabulary when discussing locations and structures of interest and ensures that photographs always have consistent identifying labels captured in the frame to allow for quick geolocation. For the 2015 excavation at Trstenik, the labeling scheme from the 2012 excavation was continued for consistency with some modifications as work progressed.

Frame labeling began at the west end of the shipwreck (later determined to be the stern) beginning with the number F11, and each subsequent frame from west to east was incremented up one number. The ship was largely composed of consecutive floor timbers and associated futtocks rather than the more traditional Roman pattern of floor timbers and futtocks alternating with paired half-frames. Thus for each frame made of multiple components, the floor timber over the keel was labeled F#, any futtock to port was labeled F#-1, F#-2, etc. moving outboard from the keel, and futtocks stretching outboard to starboard were labeled F#-01, F#-02, and so forth. Any discrepancies noted during site plan development and ship reconstruction were adjusted either by adding "X" to the label of a frame component determined to be different, or by adding "A" to a new frame piece found between two frames (e.g. F31-X, F68A-1).

The ship's keel is made of a single piece of wood, with a single-piece stem and sternpost scarfed onto the keel at the forward and after ends. The keel was labeled K, the sternpost SRP, and the stem STP. Stringers were labeled S and numbered sequentially starting with 1 (e.g. S19). The 2012 excavation had used this system also, so stringers that had been labeled in 2012 were assigned the same number. If a piece of stringer was broken and not clearly part of an adjacent piece, it received its own number.

The garboard strake to the north (port) side of the keel was labeled SK1, and subsequent strakes were labeled by incrementing up in number moving outboard from the keel. The garboard strake to the south (starboard) side of the keel was labeled SK10, then also incremented up sequentially, moving outboard from the keel. As the excavation completed and photogrammetry began, it became apparent that this choice of strake labeling was not ideal, in that each side of the ship had 11 strakes, followed by the first wale; thus, both sides of the ship had an SK10 and SK11. To correct this labeling, in reconstruction the port garboard strake was labeled SK1P, with the number incremented moving outboard from the keel, and the starboard garboard strake was labeled SK1S, again incrementing numerically moving away from the keel. In this way, duplication of labeling was prevented between port and starboard, while making it clear which port and starboard strakes were the same strake during construction. For strakes that had a scarf, indicating that two pieces of wood were fastened together, labeling was updated during reconstruction to add "f", "m", "a", or "repair" to a strake label, to indicate whether the strake segment was forward, middle, aft, or was a repair inserted into a strake (e.g. S2Pa). After 11 strakes, the ship's first wale appeared. On site, numbering was done similarly to the strakes, beginning with W1 to port, and W11 to starboard. To match the post-processing labeling scheme of the strakes, in reconstruction the wales were relabeled W1P and W2P on the port side, and W1S, W2S and W3S on the starboard side.

Along with labeling, several schemes ensured smaller features were prominently highlighted so they would stand out in photos; these included white thumb tacks placed on top of treenails holding the frames to the planking, yellow thumb tacks inserted on top of pegs associated with a pegged mortise-and-tenon joint, and white wire inserted at planking seams to highlight individual strakes as well as hull repairs. Any small artifacts found (a total of 236, the vast majority of which were ceramic sherds) were assigned a sequential artifact number, photographed, and described in an artifact log (Table 4-1).

Artifact category	Quantity	Remarks
Ceramic sherds	200	Various colors, sizes, source objects (amphoras, plates, etc.)
Metal nails	23	Various lengths and diameters. Exact composition of metals not determined
Small lead objects	4	One is a seal; three unidentified
Glass shards	2	One clear, one greenish
Small metal disks	2	One unidentified coin, one possible (badly corroded) coin
Oil lamp	1	Excellent condition
Hexagonal brick	1	Each side 2 cm long, thickness 5.5 cm
Wooden toggle	1	Found broken in half; 20 cm long, 3.6 cm diameter; part of ship's rigging equipment
Wooden pulley sheave	1	5 cm diameter, 1.8 cm thick; part of ship's rigging equipment
Wooden post end	1	Found broken in two parts; one end hexagonally finished, with two 2 mm parallel grooves; 9.5 cm long, 3.6 cm diameter
TOTAL	236	
Biological Artifacts	Quantity	Remarks
Small bones	7	Various locations, sizes, sources
Walnut shell	1	
Nut shell	1	

Table 4-1. Artifacts Recovered at Trstenik in 2015.

Many times, removal of rock used to scuttle the ship resulted in “floating wood,” damaged ship components that began floating away as soon as they were no longer pinned down by rock or silt. When possible, such wood was fastened to adjacent ship structure using either thin wire or a wooden kebab-type skewer to hold the affected material in place. Wood that was too damaged to remain in place was removed to shore, studied for any diagnostic features, and considered for sampling based on its found location.

Based on the aggressive timeline of the excavation, the majority of data acquisition was planned to be documented through extensive photography, later to be turned into photogrammetry (Section 5). To maximize the accuracy of the data and allow extraction of archaeologically accurate data from the pictures, it was important to get the hull remains as free of dust and algae growth as possible. This entailed the use of the large water dredges to remove overburden followed by the use of smaller flexible hoses attached to the large water dredges. This allowed for hand-fanning to remove silt while searching for any small artifacts near the ship remains. To clean between frames and through limber holes under the frames, a small suction head was custom-built to fit into such narrow gaps.

It was particularly convenient that the grid could be in place to support fine cleaning of the ship’s hull, yet light enough to allow four divers to physically lift it above the wreck and walk it to an area adjacent to the excavation site, allowing photography to be performed without having the grid appearing in pictures. After completion of photography, the grid could be returned to its original position over the site based on footer foundation blocks to continue excavation and cleaning. Multiple rounds of photogrammetry were performed based on excavation progress, including one session with the stringers in place over the top of frames to document their positions, then a second complete session with the stringers removed to allow more detailed photography of the framing and planking construction. Lessons learned in support of photogrammetry processing are discussed in Section 5. Additional data was recorded via thorough visual inspection of each frame with information recorded in a spreadsheet in order to augment the photogrammetric results (Appendix A). To enhance ship analysis, detailed photos were taken of specific areas of construction interest. Additionally, over 400 wood samples from ship components were taken for tree species identification purposes.

The final day of photogrammetry occurred on Thursday May 7^{th}, the last day the excavation photographer was available. Friday May 8^{th} was used to document as much of the wreck by hand as possible. Saturday May 9^{th} was the final day of diving. This day focused on completing the reburial of the ship and covering it with geotextile, sand, and rock to preserve it *in situ* for any potential future investigation. The team completed site breakdown on Sunday May 10^{th}, and the excavation was declared complete.

A review of dive logs indicates a total of 267 dives were performed on the site over 24 days with a total bottom time of 624 hours. Based on 624 hours of bottom time obtained from a $25,000 grant, each hour on the bottom cost $40 to execute which included air travel, equipment transportation, room and board, dive master support, excavation equipment rental, and all other ancillary costs.

5. PHOTOGRAMMETRY AND SITE-PLAN DEVELOPMENT

5.1 Introduction

For the purposes of this project, the techniques employed to take photographs, process digital images via photogrammetry and extract data for archaeologically accurate reconstruction purposes were formulated by Kotaro Yamafune for his doctoral dissertation studies at Texas A&M University. This section will provide a summary of his Computer Vision Photogrammetry techniques, including photography techniques, digital photo processing with PhotoShop (Adobe) and PhotoScan (Agisoft) software, development of an accurate three-dimensional model for data analysis, and any specific methods employed for this project. Extensive enhancing information is available in Yamafune's dissertation.[247]

This section will discuss the preparation of the shipwreck site from the perspective of taking digital images as well as the subsequent processing of the images into a scaled 3-D photogrammetry model. It must be noted that technology continues to march on. Yamafune has improved and modified his techniques, and Agisoft has continued to improve the PhotoScan software, to include changing the name from PhotoScan to Metashape in 2018. The discussion below documents the steps performed for the study of the Trstenik shipwreck in 2015 and 2016 and should not be considered as current or state-of-the-art photogrammetry technique.

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[247] Yamafune 2016. Earlier applications of these tools in both deep- and shallow-water archaeology include Foley and Mindell 2002, Ludvigsen et al. 2006, and Foley et al. 2009.

The general outline of the technique is as follows:

1) Prepare the site.
2) Take digital photographs of the site.
3) Create site plans based on the orthophoto (high-resolution photomosaic based on the photogrammetric model).
4) Plot positions of visible scarves, treenails, pegs, stringers, and other information on the site plans.
5) Extract section profiles of frames from the photogrammetric model. Overlay available individual frame photogrammetry in comparison.
6) Construct section profiles.
7) Construct hull lines.
8) Apply interactive fragment model methods based on the hull lines in order to manipulate the photogrammetric model into a hypothetical original shape.
9) Plot positions of scarves and fastenings on the hypothetical original shaped photogrammetric models.
10) Analyze construction patterns of the boat (distance, angle, and positions of scarves and fastenings, and those relations).
11) Compare computer reconstruction to traditional and practical reconstruction results.

5.2 Site Preparation and Photography

The site excavation process has been discussed in Sections 4.2 and 4.3. A primary milestone of the excavation was to prepare the site for the photogrammetric process which is more than just taking pictures. Quality images with appropriate overlap are essential to the development of an accurate photogrammetric model from which precise archaeological data may be extracted. Poor, out of focus images, photographs taken at excessive focal length, and/or insufficient overlap between photographs can significantly impact processing quality and may not process into a model capable of producing accurate analytical information. True understanding of an individual ship's construction is best obtained through complete disassembly, scrutiny of individual pieces and associated tool marks, and conservation of each piece to facilitate future reconstruction and analysis. Unfortunately, this highly expensive process must be reserved for the few truly exceptional shipwrecks. Due to the extremely limited time and budget constraints of this excavation, collection of data using photogrammetry was deemed the best method to maximize information obtained from the excavation. The budget simply would not support any disassembly or conservation of the ship's hull.

As discussed in Section 4.2, the use of a sturdy aluminum grid structure allowed workers to suspend themselves over the wreck site while dredging, removing rocks, labelling ship structures, and performing fine cleaning in preparation for photogrammetry. This structure was indispensable in preparation for the picture taking process. Equally important was using a grid designed to be portable under water. After the site was cleared, labelled, cleaned, and deemed ready for photogrammetry, the grid was light enough to be lifted by four divers and walked off of the site. Grid removal allowed the photographer and his assistant to have unfettered access while swimming over the site to take photographs. Importantly, direct site photography also eliminated any potential for grid shadows produced by light from the sun or from the strobes used to appear in the photographs. Digital images with good color consistency and minimum random shadow effects enhance the ability of PhotoScan to mesh the images together.

Several models of digital single lens reflex (DSLR) cameras were utilized to document the excavation. As discussed by Yamafune, virtually any DSLR camera will take excellent pictures that are capable of being photogrammetrically processed by Photoshop.[248] The most important factor was finding and using a DSLR camera model compatible with the available waterproof housing in order to allow full camera operation while avoiding water damage. The Ikelite underwater housing with dome port (fisheye lens) to reduce underwater distortion available for the excavation was compatible with several Canon camera models. During the Trstenik shipwreck excavation, photography began with a Canon model 7D DLSR camera. After an equipment problem, documentation was shifted to a Canon model 40D DLSR camera. Both models fit inside the housing, allowed photography with strobe, and took excellent photographs.

The beginning of the photogrammetric process involves taking photographs of sufficient quality with appropriate overlap. It is important to plan the photo session to ensure that the maximum amount of useful data can be extracted from the photographs.

[248] Yamafune 2016, 10-3.

The creators of Agisoft PhotoScan recommend minimizing "blind-zones," and for this their overlap guidance is that two consecutive photos have a 60% side overlap and an 80% forward overlap for successful photogrammetric coverage.[249] Expanding this guidance to a wreck site results in multiple passes over the site, including vertical suspension looking straight down onto the site, and additional passes to take angled photographs about 30 degrees from vertical from all four sides to add depth and detail in the processing. Yamafune has expanded this guidance to portray one suggested 'flight path' over a wreck site to take photographs in support of photogrammetry (Figure 5-1). This methodology was followed at Trstenik with generally good results.[250]

One difficulty experienced in the processing of the photographs taken of this excavation was that sufficient photographic overlap of the relatively large (12 m x 5 m) site required a very large number of pictures (in excess of 3,300). Multiple runs of the Agisoft PhotoScan software at maximum fidelity resulted in days of computer processing, sometimes followed by a software freeze which required rebooting the computer and loss of time. Consequently, adjustments had to be made in PhotoScan settings to lower the processing fidelity such that the available computer could align and mesh the thousands of photos taken in a single run. Based on these processing challenges, a photogrammetry lesson learned is to lower the number of images processed in a single session. For example, the processing of this shipwreck site would have been significantly more rapid and smooth had the site been photographed in quarters,

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[249] Agisoft 2014, 5.
[250] See Yamafune 2016, 8-19 for an enhanced discussion of camera selection and overlap calculations.

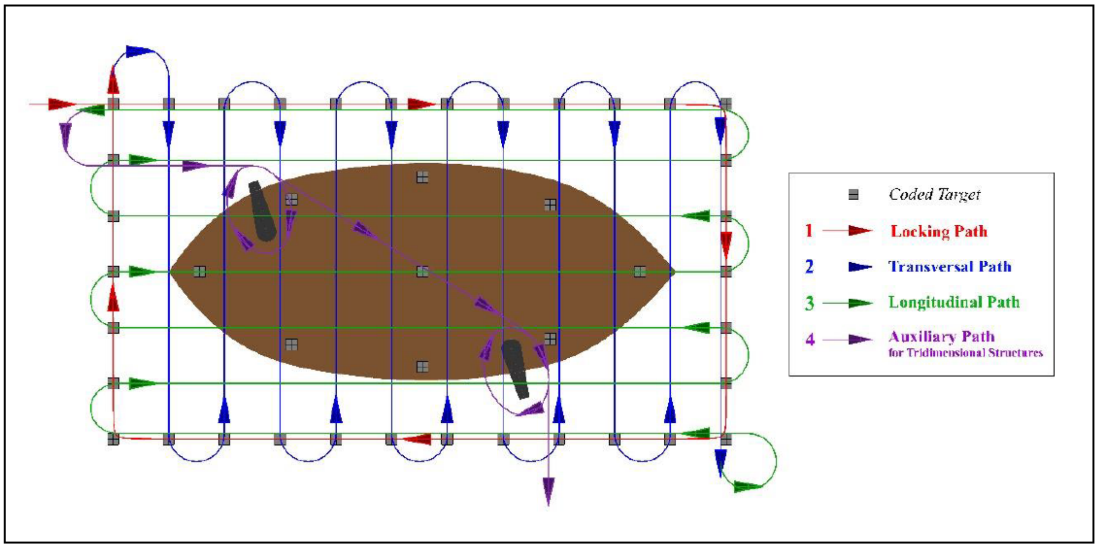


Figure 5-1. Recommended Flight Path for Photogrammetric Recording. Reprinted with permission from Yamafune.[251]

processing four groups of fewer than 1000 pictures at a time. The four resulting photogrammetric models (each displaying ¼ of the wreck site) could have been produced much more rapidly than one massive model. These four separate models could then have been merged to produce a composite 3-D model of improved fidelity in less time. It is certainly possible that in the future more powerful computers with both faster processors and larger amounts of random access memory (RAM) could obviate this recommendation. However, smaller sections with fewer than 1000 total photographs of coverage would be optimum for present-day PhotoScan processing, minimizing computer crashes and repeated restarts of the photogrammetry computer processing.

[251] Yamafune 2016, 28.

Two other enhancements are suggested during site preparation prior to taking digital images for future use in photogrammetry. First, the use of coded targets as provided by Agisoft is highly recommended.[252] These specially-shaped symbols enhance the ability of the PhotoScan program to align photographs prior to processing, thereby maximizing the digital data available to be processed. At this excavation, PDF targets provided by Agisoft were printed, laminated, and securely mounted with duct tape to inexpensive ceramic tiles to provide weight and keep the targets stationary during the photography session (Figure 5-2).[253] These targets were placed at the edges of the wreck site, carefully positioned to avoid any coverage of archaeological data, and thus appeared in multiple photographs taken during photography swims. Activating these targets in the PhotoScan software during photogrammetric processing enhanced the model output.

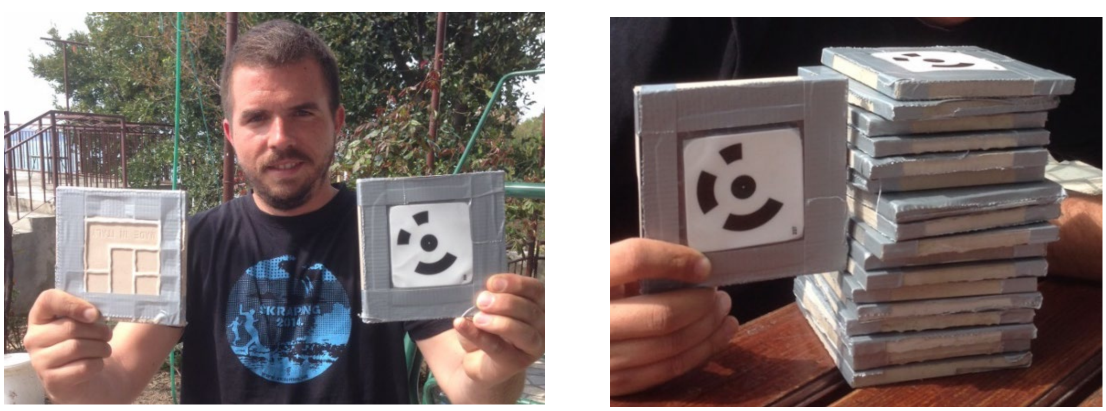


Figure 5-2. Agisoft PhotoScan Coded Targets. Targets were laminated, then taped to ceramic tiles for underwater use.

[252] Agisoft 2014, 37-8.
[253] See Yamufune 2016, 20-7 for an extended discussion of the preparation and use of coded targets.

The other site enhancement that significantly improved digital processing and subsequent model analysis was to scatter several meter scales around the site such that they did not obstruct any archaeologically significant data, yet they were photographed multiple times. These provided a known calibration length. During processing the exact scale of the site could be captured in the photogrammetry model by selecting points at the two ends of a meter scale, and constraining that distance in processing to be 1.0 m. Using several meter scales around the site provided multiple distance inputs, minimizing errors from photographic distortion.

Photos taken by the cameras were in “raw” format (file extension CR2), a format which maximizes the data saved to the camera chip but cannot be used by the Agisoft PhotoScan program to perform photogrammetry. For processing, this file format must be converted into a format recognizable by the program. Multiple formats are acceptable in PhotoScan, including JPEG, TIFF, PNG, and BMP. Many software programs are able to convert photograph file formats. This project utilized both Photoshop and Adobe Lightroom to convert files from CR2 to JPEG format, then performed subsequent processing in PhotoScan. Ideally, these conversions could be made on-site each night of the excavation after saving the raw photograph files from the camera memory card to multiple external hard drives for backup. However, if there is insufficient time or computer equipment available during the excavation, the conversions can also be undertaken after the excavation is complete.

5.3 Photogrammetry Model Development

The converted photos provided the input data to the Agisoft PhotoScan program. While PhotoScan was eventually able to successfully process several thousand photos to create a 3-D photogrammetric model of the site, the large quantity of data clearly stressed the software and associated computers during processing. Future photogrammetry efforts require a more powerful processing computer coupled with a workflow emphasizing multiple processing runs of fewer images recording a smaller geographical area, followed by merging the model subsection results into one composite site model.

The focus of this dissertation is the excavation and hypothetical reconstruction of the Trstenik shipwreck. The detailed operation and manipulation of the Agisoft PhotoScan program will not be discussed here as it was merely a tool used to obtain archaeologically significant data. PhotoScan was a means to an end. The summary below captures the high-level operation of the program along with any specific program settings used in this project.[254]

The general workflow for the Agisoft PhotoScan program is laid out below. Unmentioned in every step (but painfully known by computer users everywhere): ALWAYS save between every step of the process. This minimizes lost time caused by software glitches and step re-performances required during processing.

[254] Interested individuals should consult the Agisoft PhotoScan User Manual (Agisoft 2014), as enhanced by Yamafune's doctoral dissertation (Yamafune 2016), to obtain additional information on the operation of the computer program and optimization of its output.

1) Load photos. As discussed above, the format of the photos must be compatible with PhotoScan before loading into the software. After photos are loaded into the software, thumbnails of the photos may be reviewed, and any unwanted photos removed.

2) Activate coded targets. As discussed above, coded targets improve the program's photo alignment algorithm. The PhotoScan program must be instructed to search for targets in order for them to be detected in the images during the alignment process. User defined parameters for detecting markers in this project included selecting "Circular 12 Bit" markers (Figure 5-2) and setting marker tolerance to 80. One important parameter for the Trstenik project was to choose "Disable Parity." This was required because the printed markers came from an earlier version of the PhotoScan program than the updated PhotoScan version used to process the images. To ensure the program would detect coded targets printed from a previous version of the PhotoScan software, the parity check had to be disabled in order to make the detector work.

3) Check markers. By filtering photos by marker, it is possible in PhotoScan to sort the photographs by each detected coded target. Most targets will appear in multiple photographs, thus those coded targets will be useful in the photo alignment process. However, there will be a few markers that are misidentified by the PhotoScan program, and only one or two photos will be tagged to a particular marker. To improve the processing efficiency, coded targets associated with only one or two photos were de-activated in the PhotoScan

program before photo alignment.

4) Align photos. This process essentially involves the computer program to assemble a jigsaw puzzle of pictures of the site, overlapping each photo to adjacent photos. Operator selections used for the Trstenik project included using the default alignment options of "High" accuracy, "Generic" pair preselection, a key point limit of 40,000, and a tie point limit of 1,000. For some runs, pair preselection was changed from "Generic" to "Disabled" in an attempt to shorten processing time.
5) Build dense point cloud. Due to the large number of images being processed, options selected included either "Medium" or "Low" quality, and "Mild" depth filtering. Even so, these choices still resulted in some modeling runs that required days to complete.
6) Build mesh. After building the dense cloud in PhotoScan, a reconstruction volume bounding box was used to define the volume to be considered for building the mesh. This deleted points so distant from the main model that they would not even be visible on the computer screen. The selection tool was then used to highlight and delete any spurious points that were visible floating in geometric space not associated with the site model. Operator-selected parameters for building the mesh included setting surface type to "Arbitrary," source data to "Dense Cloud," face count to "Medium," and interpolation to "Enabled." For some runs which failed to build a mesh due to computer processing issues, interpolation was set to "Disabled" and face count to "Zero."

This reduced the ability of the program to automatically fill holes in the model, but still led to accurate results since only areas corresponding to dense point cloud points were reconstructed.

7) Build texture. For this process, mapping mode was left in the default “Generic” setting, blending mode was left in the default “Mosaic” setting, and texture size/count was set to “6000x3.” Exporting texture to three files avoided processing failures caused by insufficient RAM capacity when exporting high-resolution texture to a single file and also improved the resulting blend of texture onto the mesh. Under the advanced settings, the default option “Enable Color Correction” was deselected. This disabled the correction of extreme brightness variations which significantly shortened processing time. Such variations are not an issue in underwater photographs.

8) Scale constraint. A key output of the 3-D modeling process is an accurately scaled model. This is the point where deployment and photography of multiple meter scales at the site is crucial. The process begins by creating a marker at the visible end of each meter scale in the 3-D model. Photographs may then be filtered by the new marker, and each photo with the end of that meter scale should be examined, and the marker carefully positioned at the exact end of the meter scale. This iteration must continue until the two markers are positioned as accurately and precisely as possible inside the 3-D model. Then the two markers can be selected, a scale bar between the two points created, and that bar may be constrained to a distance of 1.0 m. This may be repeated for each meter scale

depicted in the 3-D model.

9) Build orthomosaic. The last step in PhotoScan is the simplest: build a photomosaic using the program's default options while recording the distance between two widely separated reference points. For the Trstenik orthophoto, the distance was recorded between reference points at the stem and the sternpost. This orthophoto may now be exported to Photoshop, and the scale adjusted until the dimensions in the Photoshop orthophoto exactly match the measurements taken in PhotoScan. At this point, there is a scaled 3-D model available for manipulation in PhotoScan and a scaled orthophoto ready to print to build a site plan in Photoshop.

The result of this process, repeated numerous times over several months to hone the results, was the creation of two unique scaled models in Agisoft PhotoScan, each based on thousands of pictures of the site, taken four days apart during the excavation. The model created from images recorded on May 3, 2015 (orthophoto in Figure 5-3) shows the ship with stringers still installed; the model created from images recorded on May 7, 2015 (orthophoto in Figure 5-4) shows the ship with stringers removed to facilitate study of the frames and strakes. Extensive credit must be given to Kotaro Yamafune for his assistance and patience during this phase of the project.

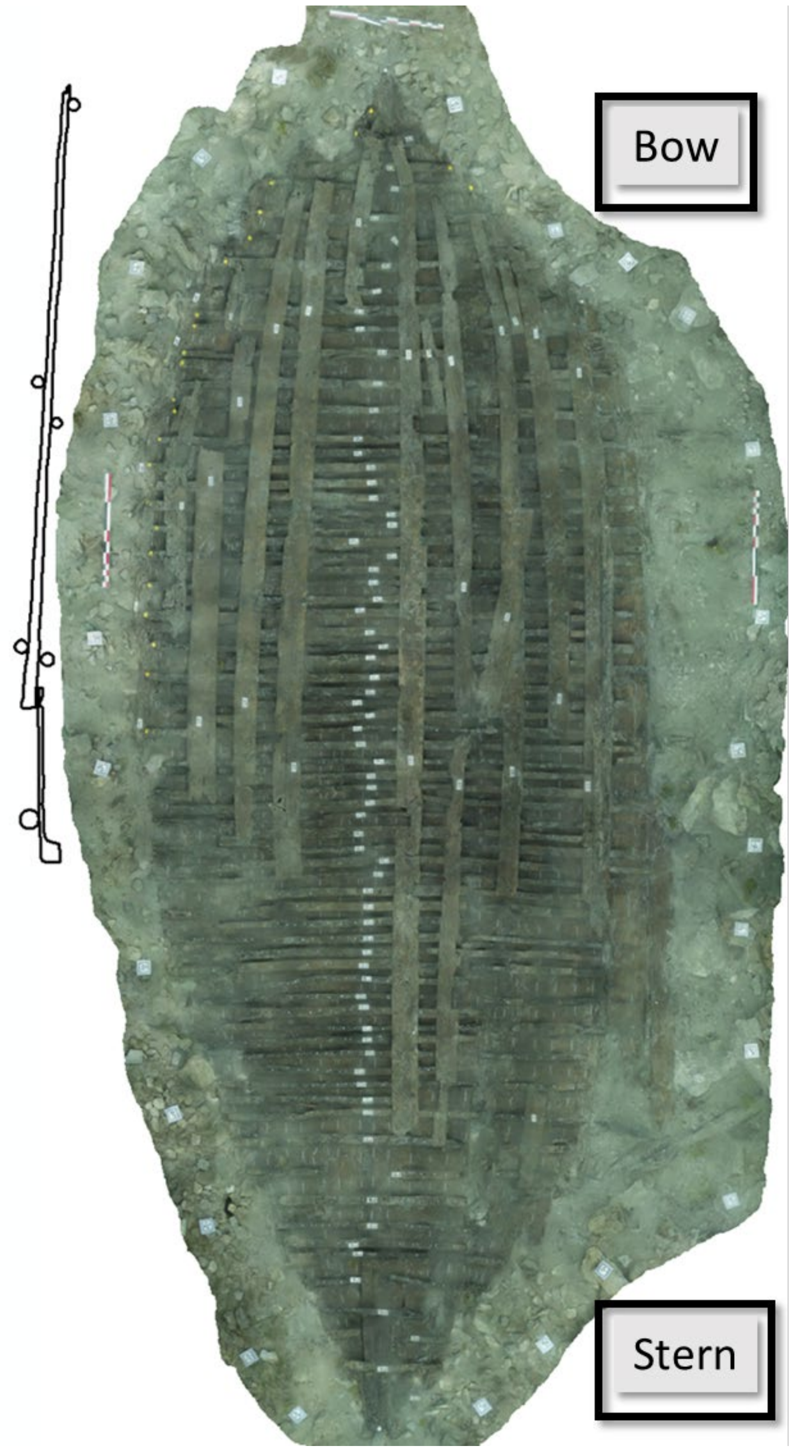


Figure 5-3. Trstenik Shipwreck Orthophoto with Stringers in Place. North to left.

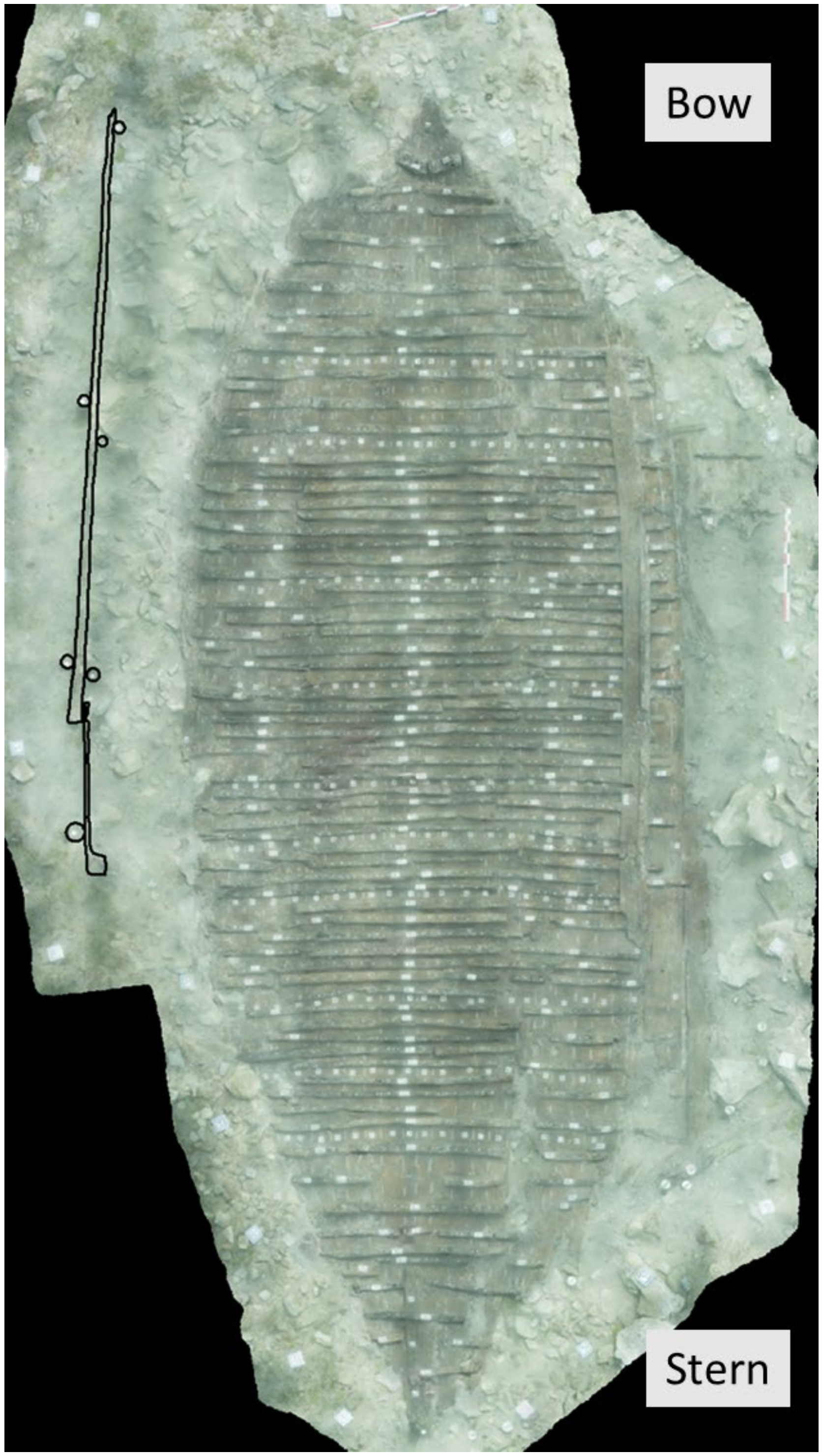


Figure 5-4. Trstenik Shipwreck Orthophoto with Stringers Removed. North to left.

5.4 Site Plan Development

The site plan was developed in two phases. After completion of photogrammetric processing and development of the two site orthophotos (Figures 5-3 and 5-4), both orthophotos were exported to Adobe Photoshop and each component of the ship was traced to highlight its position. The two site tracings were output at a 1:10 scale and printed on a single sheet of paper in order to study site details, correct labeling deficiencies, and perform preliminary analysis of tree species utilization by plotting wood sample results against sampled components (Figure 5-5). This by-hand analysis was useful for site comprehension, including component labeling consistency and identification of unlabeled or mislabeled components, as well as detection of inconsistencies between site plans made from photogrammetry taken on different dates. However, paper analysis alone was inadequate for detailed study of individual ship components.

The ultimate goal of the site plan phase of the work was the creation of a computer model of the site with multiple detailed layers including color-coded individual ship components in order to create thematic maps to analyze construction specifics, tree species, ship repairs, and many other details of the ship. To begin this computer model development, the two georeferenced and scaled orthophotos were imported into AutoCAD Map 3D, a software package which offers a wide range of Computer Aided Design (CAD) tools and allows output in the main data formats used in Geographic Information Systems (GIS) software. AutoCAD was used to trace a 2-D site plan directly from both orthophotos in real scale. These perfectly overlapping site plans

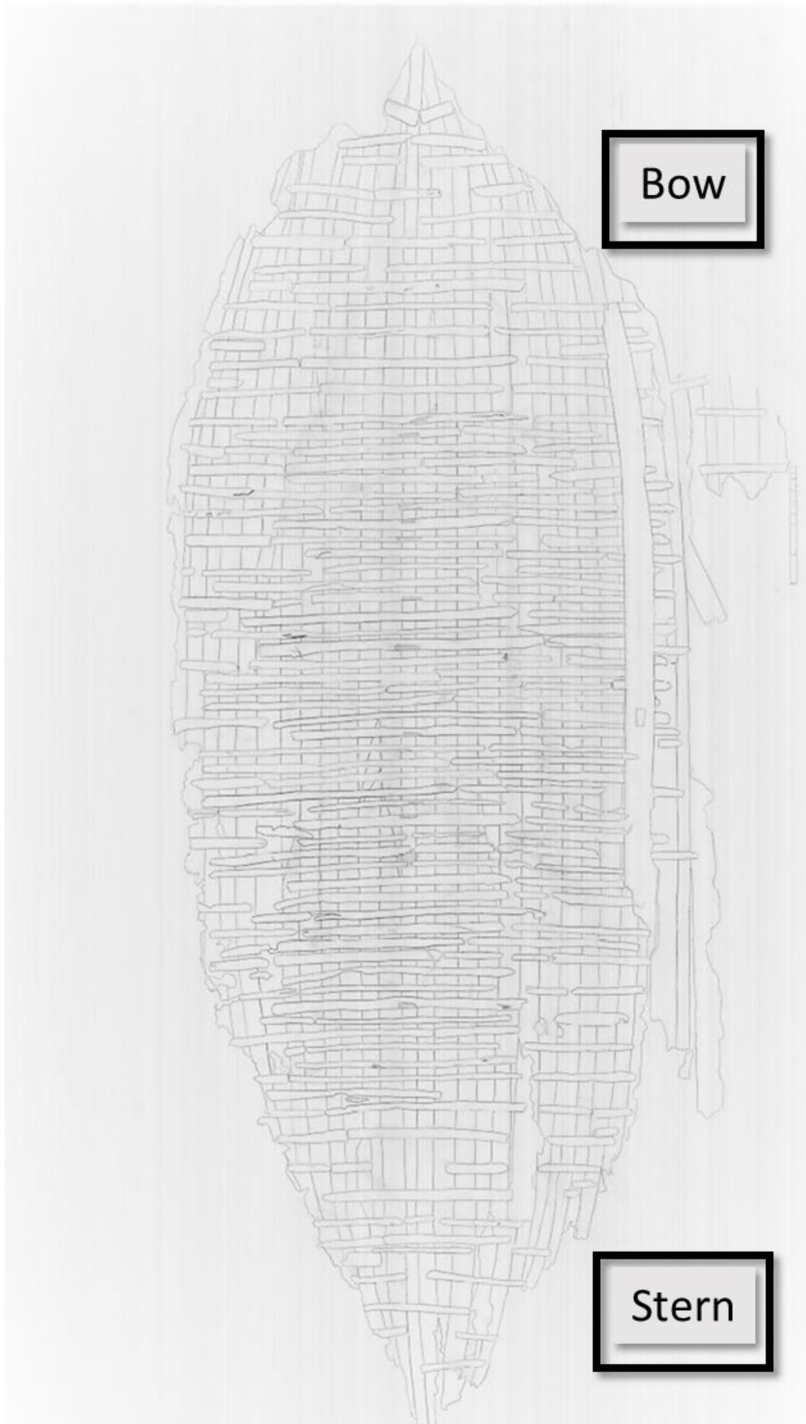


Figure 5-5. Line Tracing of Orthophoto without Stringers for 1:10 Hand Drawing Analysis.

could now be imported into the ESRI ArcGIS software, and the ArcMAP module was used to color-code layers and perform site analysis. The hull construction plan and the framing plan developed based on this process are shown in Figures 5-6, 5-7 and 5-8.

In order to analyze the photogrammetric information provided in the orthophotos and transferred into ArcMAP, the traced archaeological features and hull components were linked to data populated in an Excel spreadsheet to allow focus on specific construction aspects of the ship. The catalog included the individual hull components, as well as specific features noted on particular structures (for example, a catalog section was built specifically for notched frames, and a separate section contained the shapes of the individual notches). This ArcMAP layer structure allowed the overlapping of layers as well as the ability to build new layers to highlight wood sample results, the appearance of hull timbers, and any other observations or interpretations made regarding the hull remains, either during the excavation or during the subsequent ship analysis and reconstruction phases.

The GIS database was then used to perform different types of analyses by generating site-plan subsets of hull components (stem, keel, sternpost, frames, planking, stringers, and other components) to study dimensions, types of wood used for the construction of the hull, visible scarfs and butts, and other structural components. The analysis of the information provided in the different sets of plans generated with ESRI ArcGIS tools was used to help describe the ship and hull remains (Section 6) and subsequently became the foundation for the ship's three-dimensional computer reconstruction (Section 7). Because the computer-generated 3-D model developed in Section 7 has as its foundation the dimensional remains of the Trstenik ship itself, the development and extraction of the ship's lines (Section 7.3) are directly traceable to the dimensions of the hull remains and the preserved shape of the Trstenik hull, maximizing the reliability of conclusions drawn from the 3-D modeling.

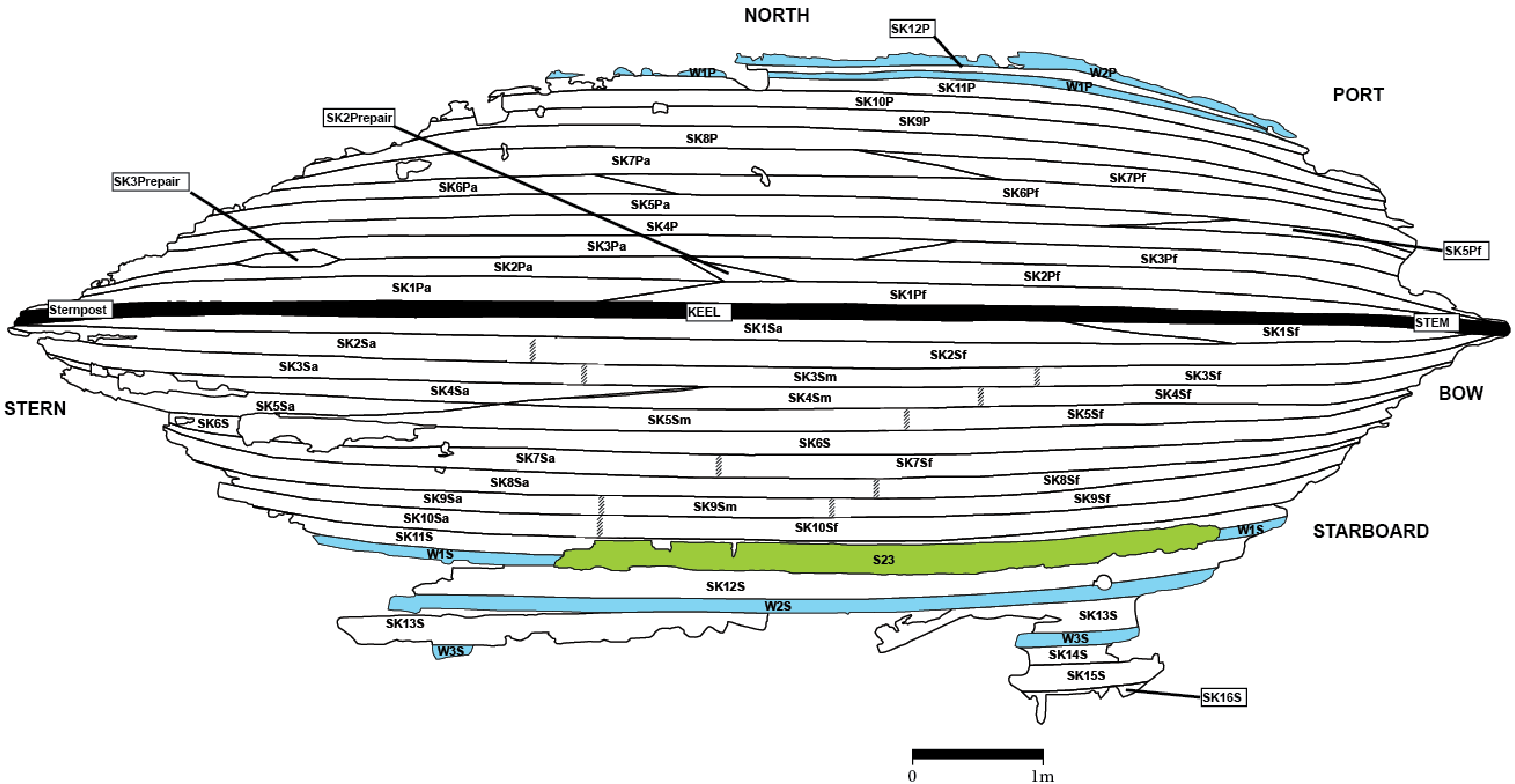


Figure 5-6. Hull Construction Plan. Stringer S23 in green, wales in light blue. Dotted lines indicate the existence of unlocated strake joints based on wood sample results

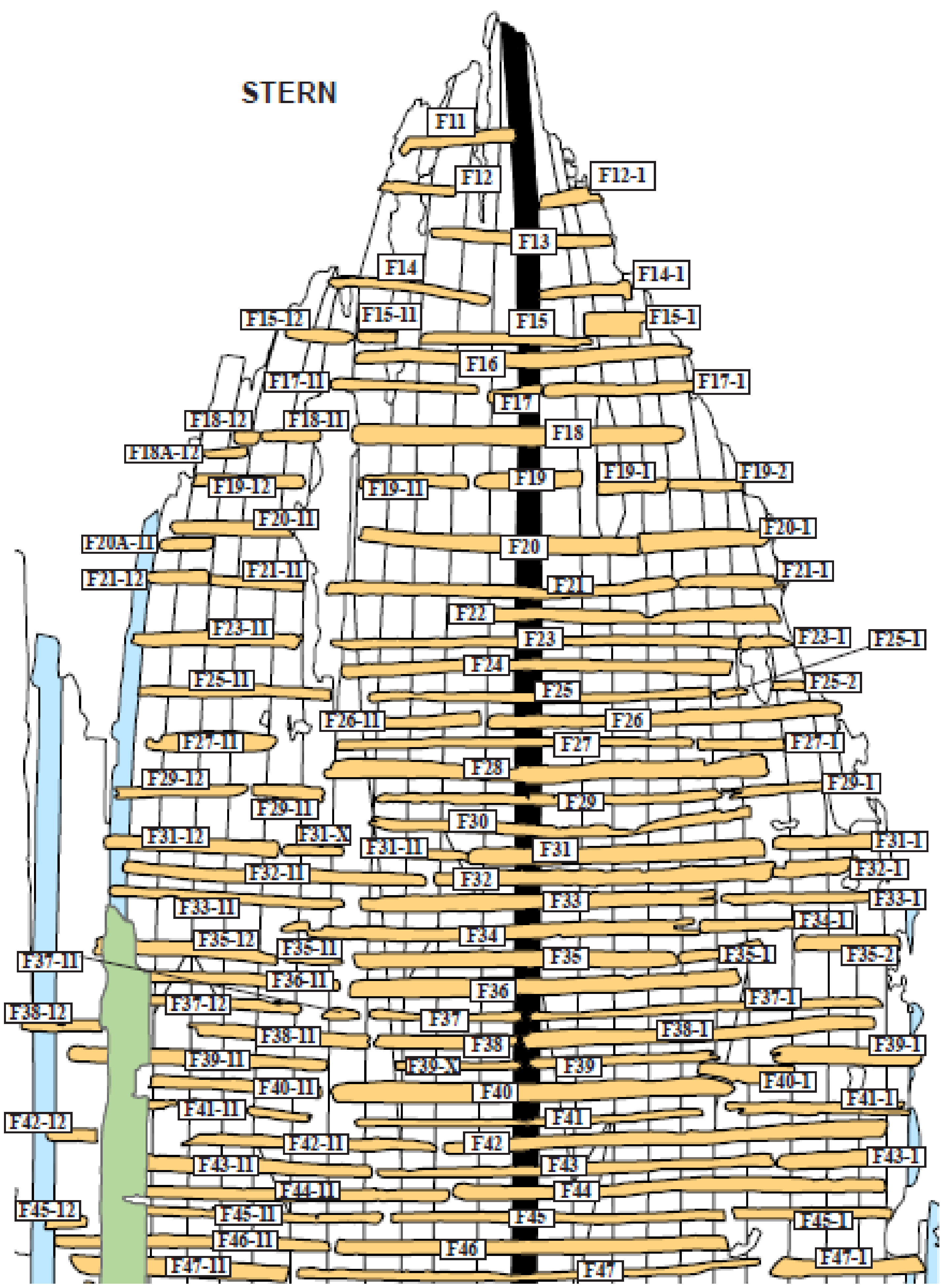


Figure 5.7. Framing Plan (Stern). Frames brown, stringer S23 green, wales light blue.

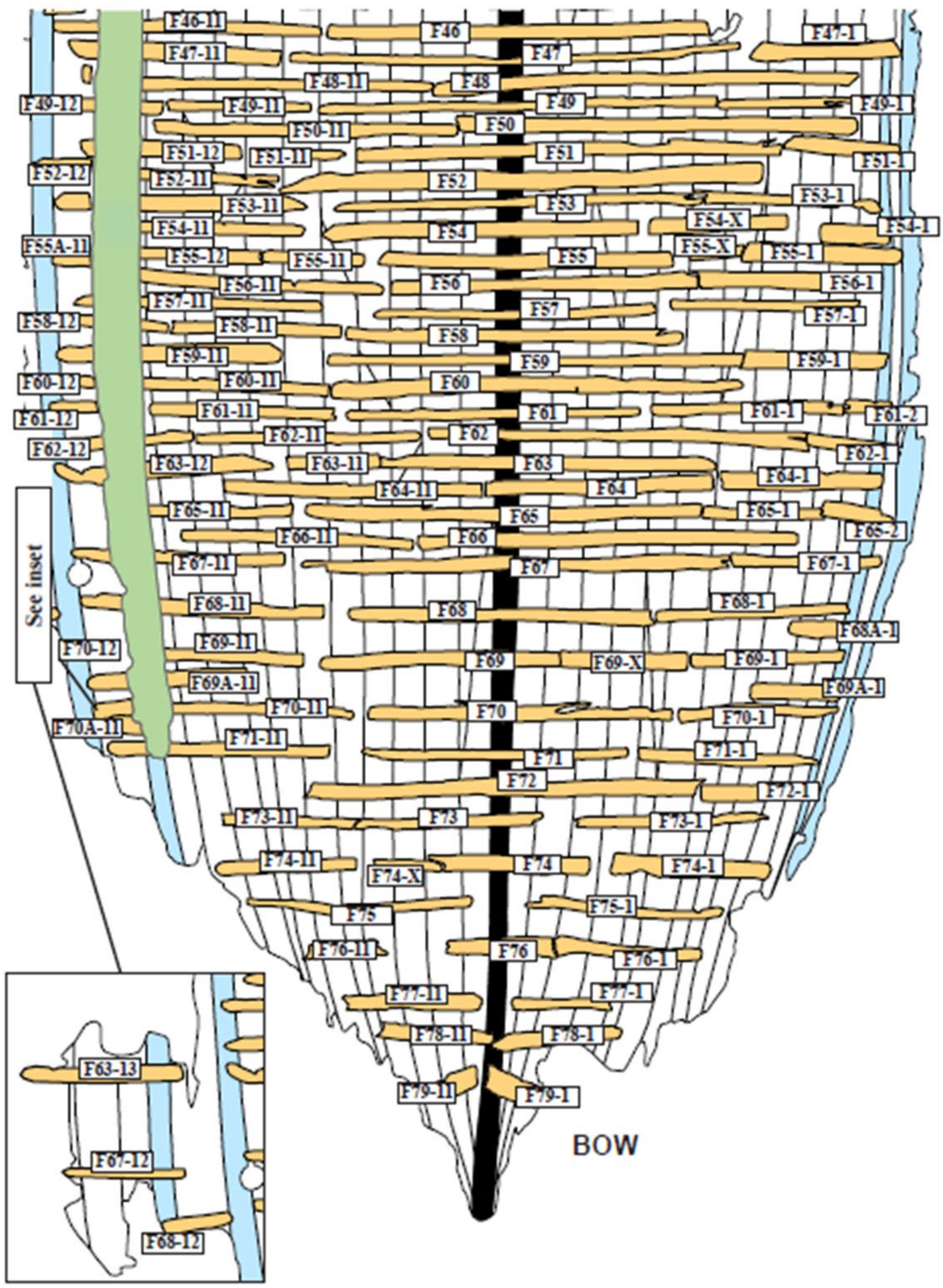


Figure 5.8. Framing Plan (Bow). Frames brown, stringer S23 green, wales light blue.

6. SHIP REMAINS AND HULL DESCRIPTION

6.1 Introduction

One challenge of a shipwreck analysis and reconstruction performed without full excavation is the inability to study in detail the actual construction techniques of the ship by careful disassembly of its components, coupled with the lack of capacity to undertake a comprehensive study of the hull exterior embedded into the sea bottom. This is the situation of the wreck at Trstenik, which in a three-week excavation had the interior surface of the ship recorded in detail by photographs, subsequently processed into a scaled photogrammetric model. While the temptation is to focus on the information missing in the analysis of the ship's construction and usage, and lament the ability to be omniscient regarding the pegging of every tenon in new construction and the repair of every damaged strake during the ship's operational life, it should be realized that a significant amount of information is afforded to us via coupling observations made during the excavation with subsequent computer modeling and analysis. As Sergei Gorshkov, Admiral of the Fleet of the Soviet Union during the Cold War, is often quoted, "better is the enemy of good enough."[255] Not every shipwreck can be fully excavated, preserved, and displayed in a museum setting. However, it is certainly appropriate to extract the maximum amount of information from a particular wreck site at economical cost, analyze the information, and make a determination in the future for the potential gain of supplementary information through additional campaigns of partial

[255] Polmar 1983, xii.

excavation, full excavation followed by *in situ* preservation, or even full excavation followed by recovery, conservation and subsequent display. As the cost of excavation and preservation continues to skyrocket, limited archaeological funds must be expended in a fiscally prudent fashion. The wreck at Trstenik exemplifies this process: excavate, extract information, then determine if additional field seasons could be useful from an archaeological standpoint, or if the cultural significance of the site warrants full excavation with subsequent public presentation of the ship remains.

The Trstenik keel is oriented in an east-west direction. To the south of the keel, the hull remains have been broken outward due to the weight of stones used to scuttle the ship; however, this increased the total extent of hull preserved under the weight of the stones. While the extent of remains to the north of the keel is more limited, the 'turn of the bilge' curvature is preserved in the strakes, visually defining the original ship form. The remains are well-preserved. While some of the frames do show evidence of age and decay, others are bright with visible wood grain, and do not appear almost 2000 years old based solely on their excellent visual condition.

The following sections, organized to provide insight into different hull components, do not follow an identical sub-heading structure, as different components require elaboration in varied areas. For example, the keel section is relatively straightforward and short, while the frame section has several design and fabrication issues to be explored based on the complex framing structure found on the Trstenik wreck.

6.2 Stem, Keel, and Sternpost

6.2.1 Introduction

The keel, the backbone of a shell-first built Roman ship, was the first piece assembled before building the ship's shell. On the Trstenik ship, the keel was composed of three pieces of wood, scarfed together to form one continuous spine, to which the garboard strake is attached. See Figure 6-1.

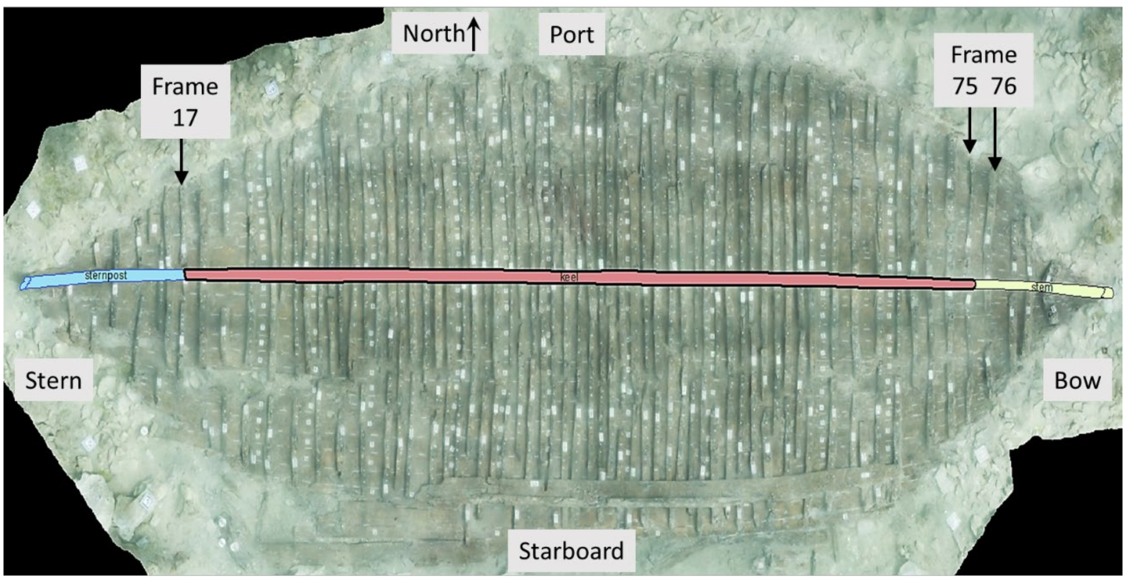


Figure 6-1. Stem, Keel and Sternpost. From left to right: sternpost (blue), keel (red), stem (yellow). The frames actually cross the keel and end posts; the keel components are shown here in their entirety for clarity.

The scarf between sternpost and keel was located directly underneath frame 17 and was not visible without removing floor F17. The scarf between keel and stem was located between frames 75 and 76, thus it was visible without removing frame components. As the ship was not disassembled during the excavation, the symmetry of and any changes in the cross-sectional shape of the stem, keel or sternpost could not be determined. Depth (or molded) dimensions were not available and width (or sided) measurements were based on the seams between the keel and the garboard strakes. With respect to the completeness of the keel assembly, there are two possibilities: either (a) the ship's entire stem and sternpost assemblies each consisted of a single piece of timber, or (b) there were additional pieces of timber which did not survive that were scarfed onto the ends of the existing pieces of the stem and sternpost to provide the required height above the keel for planking. Based on the length of the timber used for the keel (8.7 m) compared to the surviving lengths of the stem (1.7 m) and sternpost (1.8 m) sections, it is possible that the stem and sternpost were each composed of a single timber, but this is considered unlikely due to the pronounced curvature required for either post. There is no archaeological evidence to support either scenario/possibility. As the scarfs were not disassembled the details of the connection of stem and sternpost to the keel are not known. There is no visual evidence of any bolts or vertical support locking the two timbers together at either scarf location, although some sort of locking key could potentially have been installed horizontally. This lack of bolting a floor frame directly through the keel scarfs is consistent with the fact that the ship somewhat predates the "Western Roman Imperial" tradition, defined by Pomey et al. as a set of common characteristics appearing in the 2nd century CE.[256]

[256] Pomey et al. 2012, 237.

6.2.2 Stem, Keel and Sternpost Wood Sample Results

Tree species of the stem, keel and sternpost are shown in Table 6-1.

Timber	Common Tree name	Tree species	Number of Samples
Stem	Elm	*Ulmus campestris*	1
Keel	Beech	*Fagus sylvatica*	5
Sternpost	Ash	*Fraxinus excelsior*	2

Table 6-1. Stem, Keel and Sternpost Wood Sample Results.[257]

While ash and elm are represented in frame components (see Section 6.4.3), the only additional finding of beech (besides the keel) in the Trstenik ship was in one peg for a mortise-and-tenon joint. Because of the extended run of the keel, the inability to disassemble the ship with frames covering much of the interior surface of the keel, and pine pitch spread over the top of planking and the keel, obscuring some planking seams and scarfs, six different wood samples were taken of the keel to verify that it was not composed of two or more different wood species scarfed together. All six samples taken were of beech. Without disassembly of the ship and close examination of the keel it is possible that two or more pieces of beech were scarfed together to comprise the keel. However, the need for rigidity in the ship, particularly under the heavily constructed central cargo area, lends support to the view that the 8.7 m run of keel is composed of a single beech timber.

[257] I am extremely grateful to Nili Liphschitz of Tel Aviv University, Israel for her tireless efforts in wood species determination.

6.2.3 Stem-Keel Scarf and Circular Depression on Stem

Just forward of the stem-keel scarf, between frames 76 and 77, a 14.5 cm diameter circular depression appears directly on top of the stem (Figure 6-2).

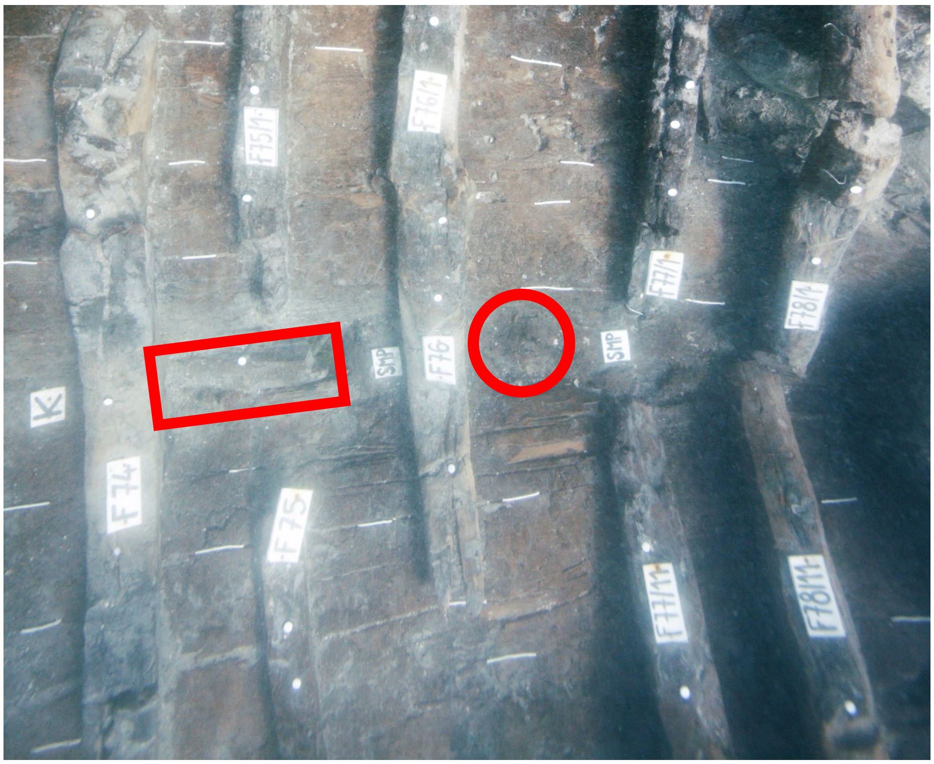


Figure 6-2. Circular Depression on Stem. Depression (circled in red) is just forward of floor F76 and the stem-keel scarf (red rectangle).

As shown in Figure 6-2, the scarf between the keel and stem is visible. The scarf is deformed from its original shape; both the keel and stem are depressed downward below the level of the garboard strakes.[258] Initial analysis hypothesized this circular depression was related to the stem-keel scarf deformation; however, that deformation is

[258] See Section 7.2 for a discussion of how this damage and deformation was corrected during reconstruction.

more likely to have been a result of the ship's having been loaded with rocks over an uneven bottom and the scarf giving way over time as the forward end of the ship collapsed down into the seabed. Because the ship was loaded with rock as it was scuttled, the circular depression is unlikely to have been inflicted after scuttling and must reflect a wear mark imposed onto the stem during the ship's operational life. There are no visible markings on the frame components of frames 76 or 77 (forward and aft of the circular depression) that might indicate a stanchion or a brace near the circular depression, nor are there any visible stanchion or brace markings on stringers S43 and S31 to port and starboard of this spot, respectively. Two hypothetical explanations for this circular mark are that it reflects a rub from either a small artemon mast or from a tow post, either of which would have been supported and braced by a structure installed above the surviving portion of the ship's hull. Supporting the mast theory is a poorly preserved coin found at frame 78 near the keel, not yet identified (Figure 6-3). However, as Carlson notes "it is difficult, and in some cases impossible, to distinguish between a coin which was intentionally deposited as a votive, and one that was simply lost."[259] Additionally, it seems unlikely that such a stress-concentrating attachment as a mast or a tow post would be allowed to nestle directly against the stem adjacent to the stem-keel scarf. Some sort of small mast step would have been appropriate to provide support for either a mast or a tow post. Finally, this location for a tow post is farther forward than is typically shown in ancient depictions of smaller Roman ships being towed. The exact cause of this circular depression remains unconfirmed.

[259] Carlson 2007, 321.

Figure 6-3. Unidentified Coin Found at Frame 78. This location is one frame forward of the circular indentation on the stem. Both sides of the coin are shown for clarity.

6.3 Strakes and Wales

6.3.1 Introduction

Study of the Trstenik ship's strakes and wales is challenging due to the nature of the single-season-long partial excavation in 2015. No strakes were removed to study the exterior of the hull, and the high frame density (Section 6.4) coupled with the interior of the hull planking being coated with pitch prevented detailed visual inspection of a large portion of each strake. However, some conclusions may be drawn from the visible scarfs, repair features, and wood identification results obtained.

As discussed in Section 4.3, the strake labeling done during the 2015 excavation season was identical to that of the 2012 partial excavation. The keel, which was oriented east-west, was labeled K. The first (garboard) strake to the north (port) of the keel was labeled SK1 and each sequential strake to the north was incremented up by one number (SK2, SK3, etc.). Likewise, the strakes to the south (starboard) began with SK10 and were incremented upwards to the south (SK11, SK12 etc.) This labeling scheme became problematic toward the end of the excavation, when it became apparent that more than 10 strakes survived on either side of the ship. Thus, the 10th strake to port (SK10) had the same name as the garboard strake to starboard (SK10). Although this labeling scheme was not corrected during the last days of the excavation due to photogrammetry time constraints, it was updated during site plan development by revising strake labeling to port (north) to SK1P, SK2P, etc., and likewise revising starboard (south) strake labeling to SK1S, SK2S, etc. This strake labeling was then expanded when a specific strake was composed of more than one piece, by adding a descriptor: a (aft), f (forward), or m (middle) to the scheme, e.g. SK4Sf. Two strake repairs were noted on the port side, on strakes SK2P and SK3P. These two inserted pieces were labeled SK2Prepair and SK3Prepair respectively.

Similarly, wales were labeled in 2015 to match their labeling in 2012: W1 and W2 to port, and W11 and W12 to starboard. For consistency, these were also renamed during site plan development, to W1P, W2P, W1S and W2S. During the last days of the excavation, a small section of hull was identified to starboard outside of the main area of the excavation. This included three new strake fragments (SK14S, SK15S and SK16S) and one new wale fragment (W3S). The ship's strake and wale patterns were symmetrical in the port and starboard hull remains: 11 strakes and then two wales separated by a single strake. The additional hull that survived to starboard was most likely mirrored on the port side. The entire strake spacing sequence for the Trstenik ship would be: 11 strakes, then wale 1/strake/wale 2/strake/wale 3, and finally two strakes, ending at strake SK15. A small fragment of wood survived outboard of SK15S, tentatively labeled SK16S. Its identification as a strake is tenuous due to minimal surviving remains and lack of a wood sample; it could potentially be the remains of a fourth wale. Additional excavation and sampling in this area is required. For reconstruction (Section 7) SK16S was treated as a strake, not a wale. See the strake plan in Figures 5-6 and 6-4.

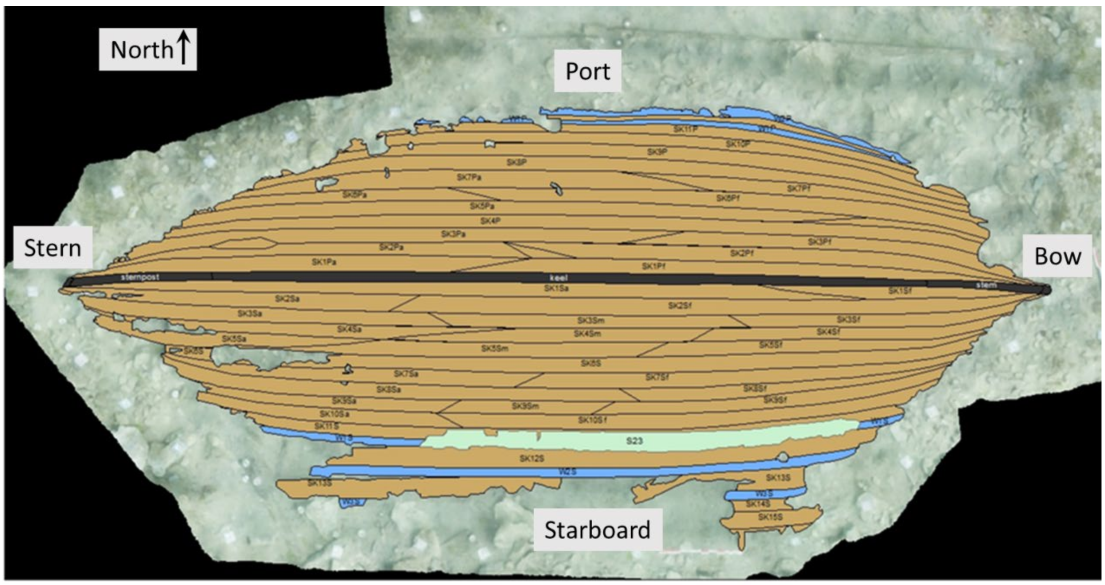


Figure 6-4. Strake Plan. Stringer S23 (green) was left in place during the excavation. Wales shown in blue. See Figure 5-6 for larger depiction.

The strake plan displays the damage to the starboard side caused by the rocks used to scuttle the ship, collapsing the hull outward, most notably along either side of SK5Sa. Strake widths vary, with a typical width of 16-18 cm, narrow sections as thin as 13 cm and the widest section at 23 cm. Strake thickness measured at the edges of the ship was 4-5 cm; however, these measurements were in areas of poor preservation, and should be confirmed by disassembly of uneroded planking in multiple zones of the ship. One important caveat must be discussed regarding the strake plan: the frames were not actually removed, but only deleted with the aid of computer tracing. Thus, the physical locations of some of the scarfs between the strake planks are not known. The 10 short scarfs shown in the starboard half of the plan (one each in strakes SK2S, SK4S, SK5S, SK7S, SK8S and SK10S, and two in strakes SK3S and SK9S) are all based on species identification results. Because different species of tree were identified along the same strake, a scarf must exist, but it was not located during the excavation, being obscured by pitch and closely spaced frames. Should the frames of the Trstenik ship be completely removed at some future date, the exact locations of these scarfs may be identified. Additionally, unidentified scarfs between planking in the same strake made of the same type of wood may also be identified; for example, the three samples along strake SK6S are identical, but it is certainly possible that a scarf exists somewhere along that strake.

While no strakes were pulled up to study the exterior or outboard side of the planking, there was no lead hull sheathing visible through the holes in the wooden hull, and no lead sheathing was found anywhere at the site. If lead sheathing had been used on the Trstenik ship, evidence must be detected either by finding remnants of sheathing after excavation or through analysis of tack patterns on the planking exterior following excavation and removal of the hull planking. At this stage, the use of lead sheathing on the Trstenik ship seems unlikely.

6.3.2 Strake Wood Sample Results

Sample results of strakes are shown in Table 6-2 and plotted in Figure 6-5.

Common Tree name	Tree species	Number of samples
Aleppo pine	*Pinus halepensis*	12
Black pine	*Pinus nigra*	13
Mediterranean cypress	*Cupressus sempervirens*	7
Scots pine	*Pinus sylvestris*	1
Stone pine	*Pinus pinea*	1
Total number of samples		34

Table 6-2. Strake Wood Sample Results.

The sample results and the strake map with wood types show that the Trstenik hull was largely built of three different coniferous tree species—Aleppo pine (*P. halpensis*), black pine (*P. nigra*), and Mediterranean cypress (*C. sempervirens*)—with one strake section each of Scots pine (*P. sylvestris*) and stone pine (*P. pinea*). No hardwoods were detected in the makeup of the hull planking. There is no apparent pattern associated with the organization of the wood chosen to comprise a particular strake. While a portion of the port side planking of the ship was not sampled, over 75% of the existing hull planking was sampled. It is therefore possible, but unlikely, that the overall makeup of the hull planking could vary to some small extent with additional analysis results.

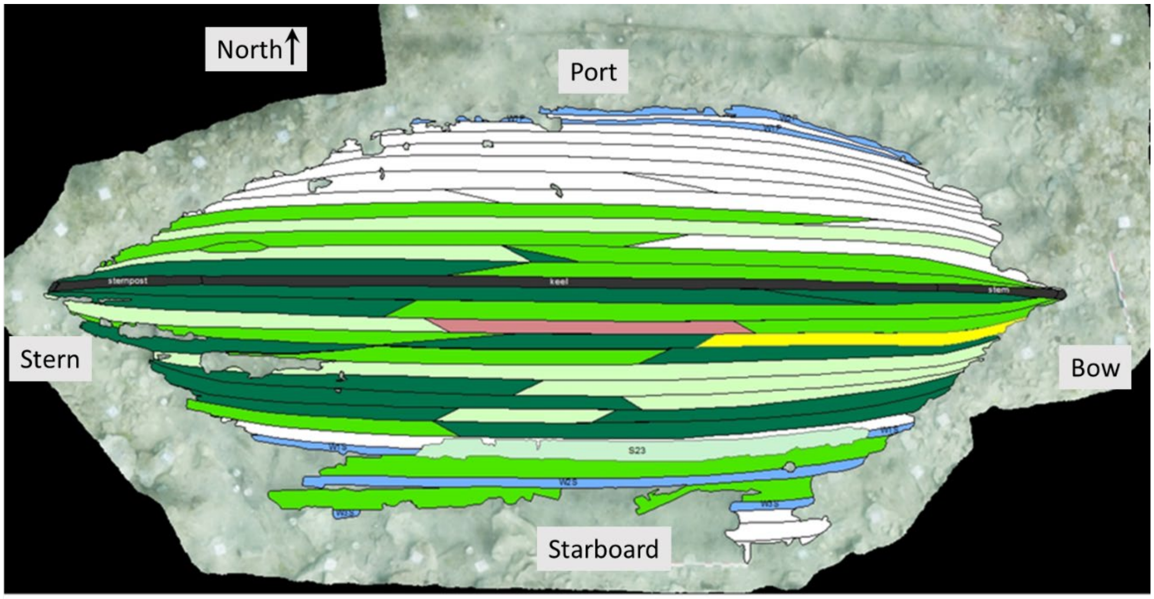


Figure 6-5. Strake Wood Species Map. Black pine is dark green, Aleppo pine is medium green, Mediterranean cypress is light green, Scots pine is pink, stone pine is yellow, unsampled areas are white. Stringer S23 (left installed), also black pine, is mint green to differentiate it from strake identification. The wales, all stone pine, are blue.

6.3.3 Strake Mortise Spacing

Without hull planking disassembly followed by measurement of the mortise spacing along the entire edge of multiple strakes, it is problematic to determine an average or standard spacing utilized by the builder when joining together strakes by cutting a mortise, inserting a tenon in the mortise, then pegging the tenon to lock the two strakes together. Several stretches of the photogrammetric model do highlight consecutive pegged spots along a strake; measurements of these show wide variation, with typical spacing between 19 and 30 cm. As discussed elsewhere, the coating of pitch over the planking coupled with the massive number of frames in the ship obscures many mortise-and-tenon joints. A reliable average spacing or any comment about mortise-and-tenon spacing variation between the frame-dense central section of the ship in comparison with the wider frame spacing of the bow and stern must be deferred until a future excavation of the wreck.

6.3.4 Scarf Orientation

A commonly observed pattern of scarf joinery for Roman mortise-and-tenon construction is that the builder began planking the hull by starting at either the bow or the stern of the ship to scarf the garboard strake onto the keel. As the builder worked the first section of the garboard strake onto the keel, the first diagonal scarf would be formed with the joint pointing in the direction of laid plank alongside the keel. The builder typically worked in the same direction on both sides of the keel for the garboard (first) strake, and then reversed to work in the opposite direction for the second strake (Figure 6-6).[260] This pattern is visible in the strake pattern of the Trstenik ship (Figure 6-4). The scarfs in the garboard strake on both the port and starboard sides (SK1P and SK1S) indicate the builder worked from the bow toward the stern. While no scarf was identified in SK2S or SK3S, the scarf in SK2P indicates the builder worked from the stern to the bow, and the scarf in SK3P indicates the builder worked from the bow to the stern. Additionally, no scarf was identified in SK4P, but the scarf in SK4S indicates the builder worked from stern to bow. Due to masking of scarves by dense framing and

[260] See Steffy 1985, 90-4 for a detailed analysis and discussion of scarf orientation on the Kyrenia ship.

pitch over the interior surface of the planks, disassembly of the ship is required for additional analysis of the direction of work.

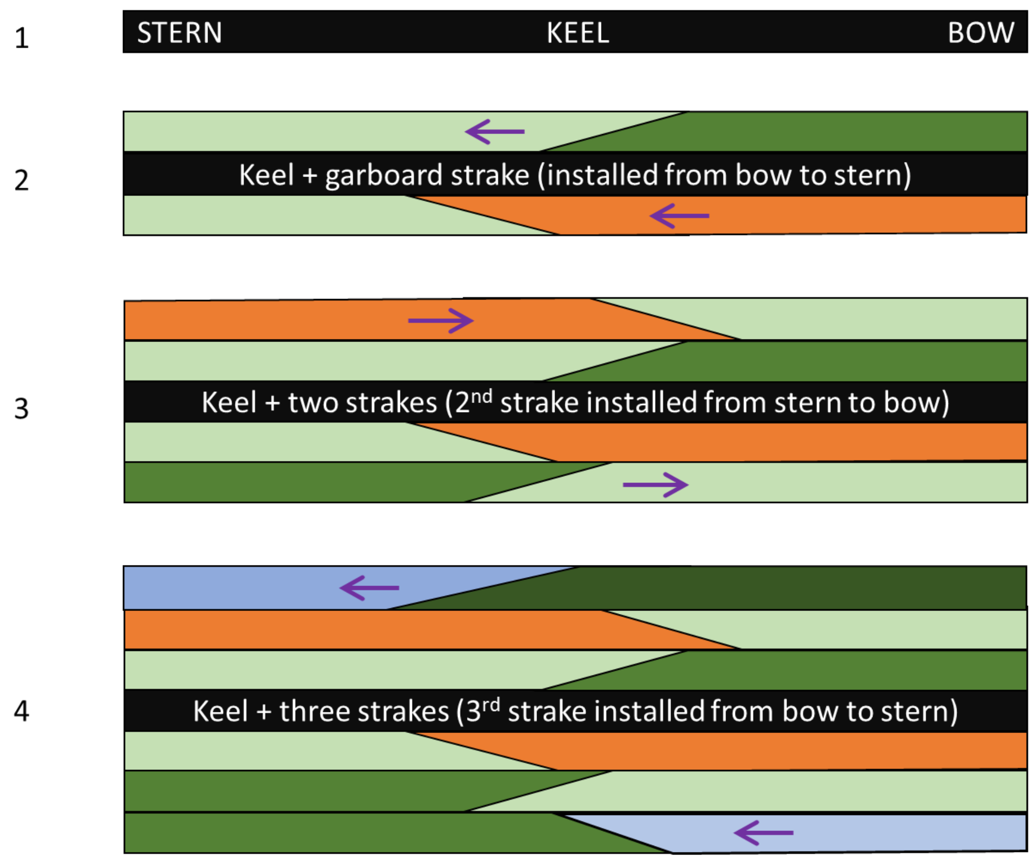


Figure 6-6. Scarf Orientation. The arrows indicate the direction of hull planking assembly by strake.

Relating wood sample analysis results to the postulated workflow of the builder, it is noteworthy that in addition to tree species not being consistent in a particular strake, wood selection was not symmetrical when comparing the wood chosen to build the same-numbered strake on the port and starboard sides. For example, the very first plank chosen to begin planking the starboard side (SK1Sf) was of black pine, while the first plank utilized on the port side (SK1Pf) was of Aleppo pine. To put it another way, in addition to wood selection being inconsistent from one strake to the next on a given side of the hull, there is no evident pattern when comparing the choices made on one side of the hull to the choices made in that same strake on the opposite side of the hull. The impression left is that workers walked to a laydown area and grabbed the next available piece of planking, regardless of species, and the selections made from that pile of lumber ended up roughly equal between the three majority tree species.

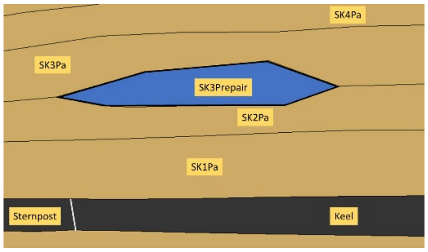
6.3.5 Wales

The Trstenik ship remains exhibit three visible wales to starboard and two to port, in varying degrees of completeness (see Figure 6-4, the wales are in light blue). The wale cross sections appear to be fairly regular and consistent between all five wales, measuring approximately 10 cm wide, and roughly 5 cm in thickness where measurements could be taken. Again, due to lack of disassembly of the ship, it is possible that these measurements are not consistent throughout the hull. The wales were all flush with the interior surface of the ship's planking, protruding past the hull planking on the ship's exterior. Each of the five surviving wales was sampled, and all five results were stone pine (*P. pinea*). This is a noteworthy result, as only one frame component (F26-11) and one strake plank (SK4Sf) were made of stone pine. Thus, this particular tree species was preferred for the long runs of wales, yet it was not a commonly used species elsewhere in the ship. As long runs of stone pine were preferentially selected for wale manufacture, clearly there was more value in keeping longer pieces of this species intact, rather than cutting to provide raw material for other, less critical locations. No scarfs were observed in any of the wales; although it is possible some were missed, it is more likely that the wales were a single continuous piece of timber to maximize the stiffness and strength provided to the hull.[261] As discussed in Section 6.3.1, strake S16S, a very degraded strake fragment, requires sampling. If the result is *Pinus pinea*, S16S should be redesignated as W4S, and the ship's reconstruction adjusted from three wales per side to four. Since there are two strakes between W3S and S16S, but only one strake separating all the other wales, it is unlikely that S16S is actually a wale, but without sample identification and *in situ* measurements of those fragmentary remains, that possibility cannot be ruled out.

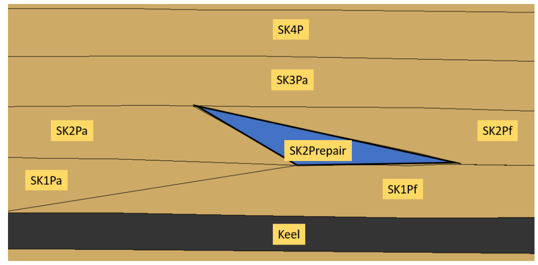
6.3.6 Hull Repairs

A comprehensive catalog of damage and subsequent repair to the ship's hull cannot be developed without complete disassembly of the hull to search for evidence of past repairs, including mortises in a strake that no longer line up with mortises in the adjacent strake, patches, evidence of scuffs, dents and other external hull damage, repair tool marks, repair tenons, and other indications of hull mending. However, two inserted graving pieces clearly testify that the Trstenik ship underwent significant repair during its operational life (Figures 6-7 a and b).[262]

[261] Steffy 1994, 281 notes wales are typically thicker than regular planking, with the purpose of girding and stiffening the hull.
[262] Steffy 1994, 291, Figure G-11a.



a. SK3Prepair.



b. SK2Prepair.

Figure 6-7. Hull Repairs.

Strake SK3Prepair is a graving piece located in the after port quarter of the ship (Figures 5-6 and 6-7a). This section of Aleppo pine, 85 cm long and 13 cm at its widest point, is inserted at the seam between strake SK2Pa (Mediterranean cypress) and strake SK3Pa (Aleppo pine) between frames 17 and 20. Strake SK3Prepair is pegged to all three frame components touching it (F18, F19-1 and F20).

Strake SK2Prepair is a triangular graving piece located in the central section of the ship on the port side, totally contained within the second strake (Figures 5-6 and 6-7b). This section of black pine separates strake SK2Pf, a long plank of Aleppo pine, from strake SK2Pa, a long plank of Mediterranean cypress. Thus, all three major tree species used in planking are represented in strake SK2P. This long narrow triangular piece is 1.1 m long, and 13 cm wide at its widest point. Strake SK2Prepair runs between frames 41 and 47 and is pegged to the three frame components that touch its widest part (F43, F44 and F45). While it is possible strake SK2Prepair could have been installed during initial construction of the ship in order to fill the gap between SK2f and SK2a, it would have been much simpler for the builder to have simply sawn a small length off of one of the two longer planks and scarfed them together without inserting such a small piece. Thus, SK2Prepair is most likely a graving piece installed as a repair.

Due to pitch and high frame density, the method of installation of these two graving pieces is unclear. It is possible that extended mortises were cut into the adjacent planks to allow the insertion and pegging of repair tenons to lock the graving pieces into place. It is also possible that the graving pieces were cut to fit the holes in the planking, then nailed into place from the outside, with no use of mortise-and-tenon joinery for the repairs. Excavation and subsequent examination of these hull repair components are required to determine the exact method of repair. Based on the two dissimilar locations of the repairs, it is unlikely that a single event caused damage to both strakes. Determination of the cause for these repairs (collision, decay, grounding, or some other mechanism) must await disassembly and close examination of the planking adjacent to these graving pieces, and may never be known with certainty even following a full excavation.

6.3.7 Hull Fastening Materials

While the ship was not disassembled, several 'floating' tenons and tenon pegs were collected from the site and submitted for wood species analysis. The results are presented in Table 6-3. While the quantity of these opportunistic samples is insufficient to draw conclusions, it is noteworthy that all four of the small (strake-to-strake) tenons collected were made of oak, while the single, larger (strake-to-wale) tenon was made of

Common Tree name	Tree species	Number of samples
Large tenon (strake to wale)		
Mediterranean cypress	*Cupressus sempervirens*	1
Tenon (strake to strake)		
Turkey oak	*Quercus cerris*	4
Sessile oak	*Quercus petraea*	2
Tenon peg		
Beech	*Fagus sylvatica*	1
Mediterranean cypress	*Cupressus sempervirens*	1
Sycamore	*Acer pseudoplatanus*	1
Unknown	Crushed broadleaf spp.	1

Table 6-3. Hull Fastening Material Wood Sample Results.

Mediterranean cypress. Lastly, each of the four tenon pegs sampled was made from a different tree species. Additional samples of these materials are required to better understand the selection of wood species for various types of joinery.

6.4 Frames

6.4.1 Introduction

The framing of the Trstenik ship is complex and reflects various aspects of design, intended usage, actual usage with repairs, and location where the ship was likely built. As an overall summary, the Trstenik ship is a flat-floored densely framed ship, and its framing pattern tentatively supports many potential usages of a strongly built flat-floored ship. Upon initial examination its frame structure appears somewhat random in the shape of the frames, wood selection and installation. However, closer investigation reveals method behind the seemingly unusual structure and illustrates purposeful choices made during construction that are still visible in the hull remains today.

As previously discussed in Section 4.3 the remains of the Trstenik ship stretch in an east-west direction. During the initial excavation season in 2012 the western half of the ship was uncovered and labeled. For the 2015 excavation the same frame numbering convention was retained for consistency. Thus, the western-most frame was designated frame 11 (leaving additional lower numbers unassigned should frames further to the west be discovered during excavation of unexplored seabed), and the number was incremented up sequentially for each frame crossing the keel. As most of the ship's frames were composed of floors with associated futtocks, the component of a frame either crossing or closest to the keel was labeled F#. Futtocks to port were labeled F#/1, then F#/2, etc. moving outboard from the keel; similarly, futtocks to starboard were labeled F#/01, F#/02 and so on. Of the frames that were uncovered for the first time in 2015, only the three forward-most frames were clearly made up of two half-frames (frames 77, 78 and 79). Thus, there is no frame component F77, F78 or F79. All of the other frames from 11 to 76 have a central floor F#.

Several unlabeled frame pieces were noted subsequent to photogrammetry during site plan development. These new pieces were added to the frame catalog by annotating "X" when a new frame component label was required, or by adding "A" when a piece of frame was found between two previously numbered frames (e.g. F31/X, F68A/1). In site plan and frame catalog development, the slash (/) in labeling was converted to a dash (-) for consistency and ease of spreadsheet manipulation. The framing plan with labels assigned to each portion of the frame is shown in Figures 5-7 and 5-8, and the details of each frame are provided in Appendix A. An overview of the frame number plan is shown in Figure 6-8.

In broad measure, the ship remains have a total of 69 frames, and a total of 214 frame components received numbers. Frame component size varies widely; for example, frame component F28 is 2.2 m long, while frame component F25-1 is 18 cm long. Frame component molded dimensions (heights) are typically 6-8 cm; frame component sided dimensions (widths) vary more widely, from 4 cm to 10 cm. The wider frames usually are of Aleppo or black pine, while the thinnest frame components are chestnut. However, wide variation was observed, even between frame

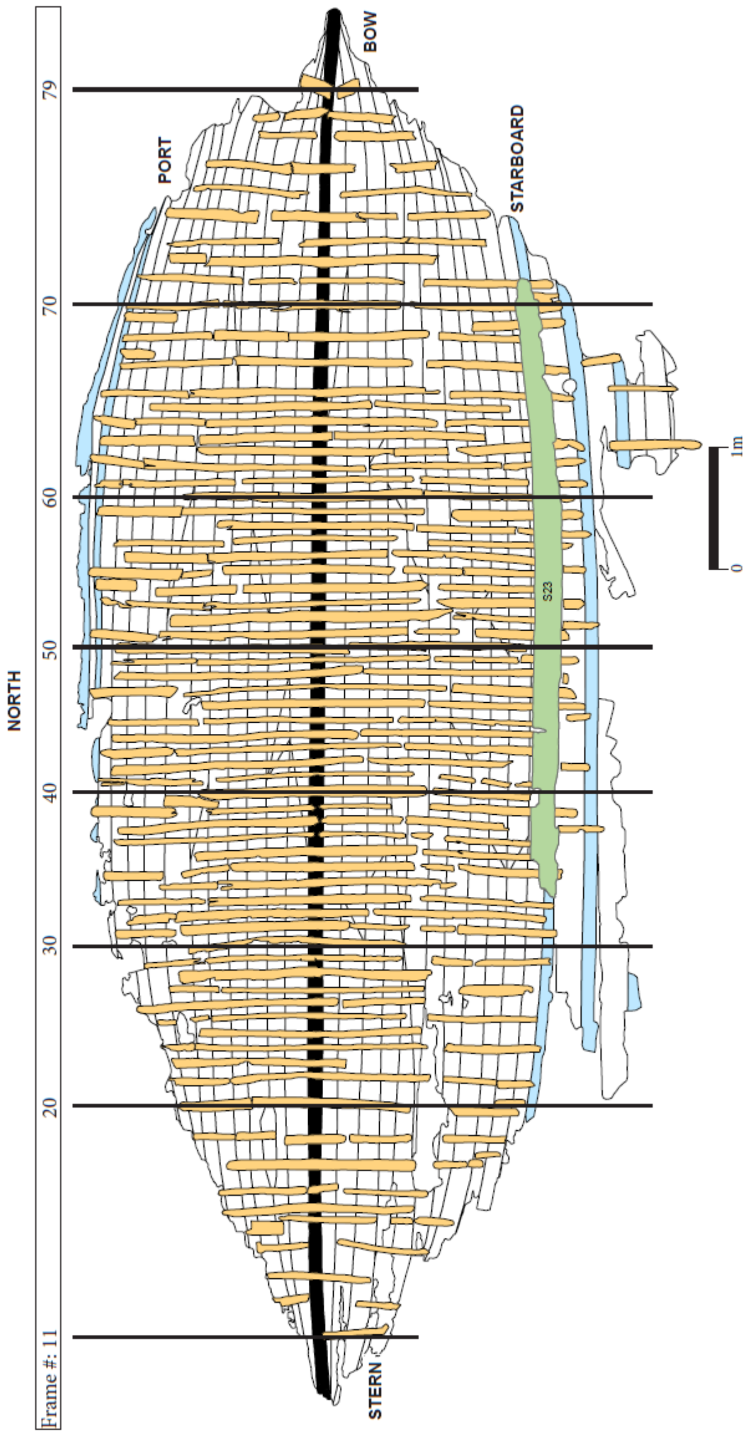


Figure 6-8. Frame Number Plan. Frames in brown, wales in blue, stringer S23 in green.

components made of the same species. These 214 frame components were all 'stand-alone' pieces of wood. In no case was a frame component scarfed or connected to an adjacent component. None of the frame components was bolted, treenailed, or otherwise attached to the keel. Adjacent frame components were most often installed with an obvious gap between them, but there were several examples of two frame components of different wood species installed with no discernable gap between the two components. For example, there is no gap between frame components F20 (sycamore) and F20-1 (Aleppo pine).

Each frame component was attached to the planking with treenails, likely all driven from outside-in due to the lack of marks on top of the frames. Actual determination of treenail driving direction would appropriately wait until after examination of the exterior of the hull during a future excavation. Without complete disassembly of the frame components from the planking, the use of short nails driven from the outside cannot be ruled out. No nails were observed driven through treenails. Nails were used during construction to attach the stringers to the tops of the frames. A total of 23 nails were recovered during the 2015 excavation (Table 4-1). The nails were not assayed but are likely iron based on wood staining and nail corrosion. However, there is no evidence nails were employed in frame component fastening. No large nail heads are visible on the tops of the frame components driven toward the planking, and no clenched nail ends are visible on the top of any frame component.

Four frame components (F15-11, F18-11, F19, and F25-2) do not appear in the orthophoto with stringers removed. These frame components had become detached from the hull and been raised to the surface prior to the photography for photogrammetry. However, the outlines of those four components were visible on the hull, so their shapes were drawn in on the frame plan (Figure 6-8). There are other apparent gaps in the framing pattern where a frame component likely existed, for example to starboard of frame components F17-11, F22, F24, F30 and F72, and to port of frame components F36, F46, F52, F58 and F60. Without hull staining, a visible treenail hole inside the stained area, and a detached frame component raised to the surface, no missing frame component was drawn over an open gap. Even allowing for the likelihood that small gaps contained now-missing frame components, over 90% of the framing of the surviving hull is represented in the frame pattern, allowing for solid conclusions to be drawn.

6.4.2 Frame Density

There are two distinct patterns of frame density visible in the Trstenik ship (Figure 6-9). The central section of the ship, defined on the basis of frame density, stretches from frame 21 to frame 67. Those 47 frames span a length of 5.9 m. Thus, the average center-to-center spacing between the 47 frames in this central section of hull is 12.8 cm. With the average sided dimension of frames approximately 6.5 cm, visually and computationally half of the central portion of the ship's hull is covered by frame components. Due to variable frame component widths, the gaps between frame components in this central section of the hull also vary. For example, the gap between the edges of frame components F31 and F32 is only 2.5 cm, while the gap between the edges of frame components F33 and F34 is 7 cm. In contrast, the stern of the ship, stretching 2.25 m between frames F11 and F21, has an average center-to-center spacing between those 11 frames of 22.5 cm. The bow of the ship, stretching 2.6 m between frames F67 and F79, has an average center-to-center spacing between those 13 frames of 21.7 cm. As the frame dimensions are the same, this wider spacing produces much wider gaps between frames forward and aft. For example, the gap between the edges of frame components F69 and F70 is 20 cm.

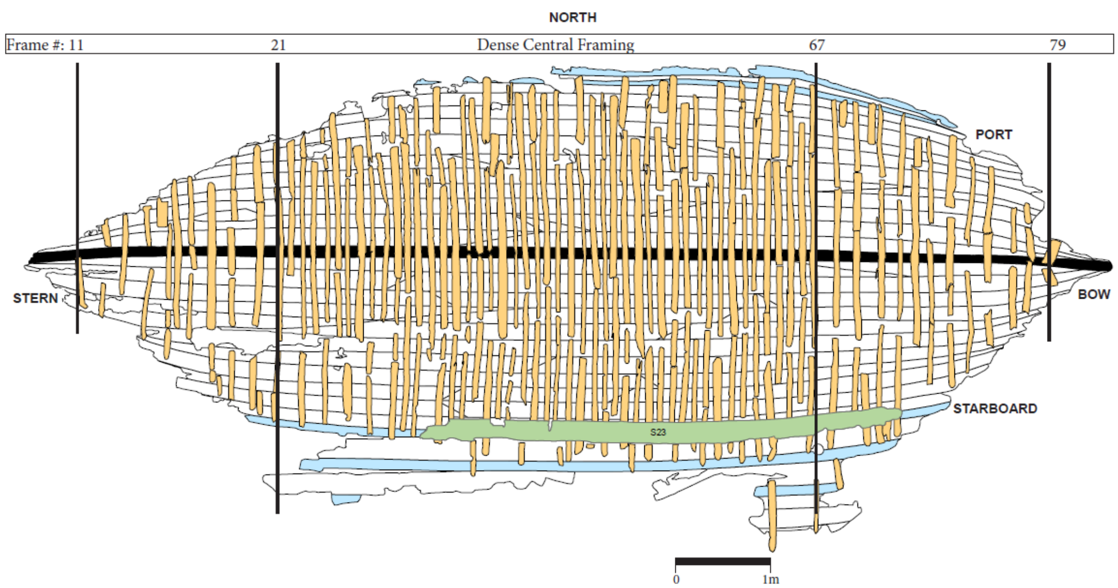


Figure 6-9. Framing Density. The framing in the central portion of the ship (between frames 21 and 67) is roughly twice as dense as the bow and the stern.

6.4.3 Frame Wood Sample Results

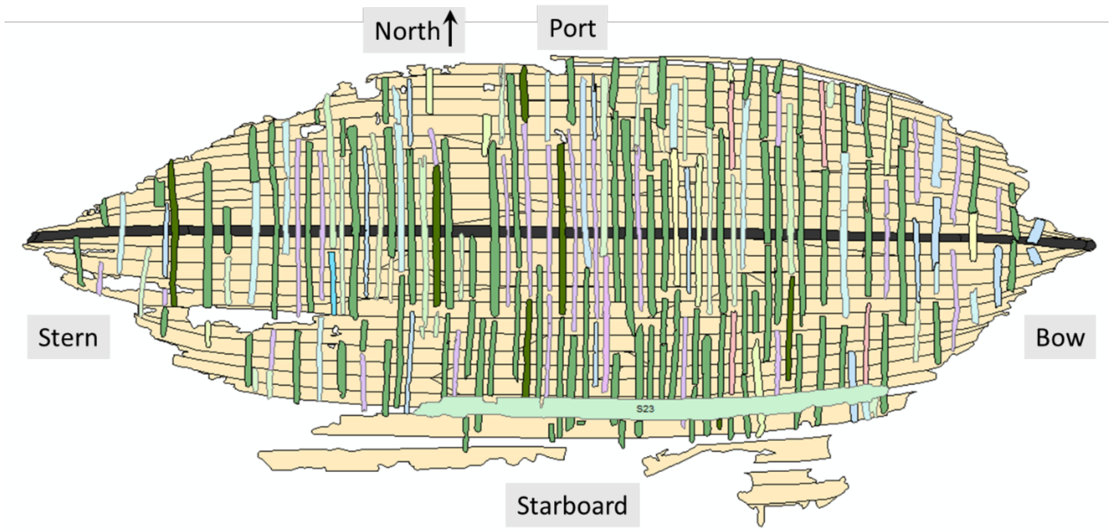
The selection of tree species used in frame components for the Trstenik ship was by no means homogeneous, consistent, or repetitive. Of the 214 frame components, 182 components were ultimately classified by tree species (Figure 6-10 A-F).[263] The wood sample results are summarized in Table 6-4.

Common Tree name	Tree species	Number of samples
Conifers (softwood)		
Aleppo pine	*Pinus halepensis*	84
Black pine	*Pinus nigra*	7
Mediterranean cypress	*Cupressus sempervirens*	7
Stone pine	*Pinus pinea*	1
Turkish pine	*Pinus brutia*	1
Total conifers		100
Deciduous (hardwood)		
Ash	*Fraxinus excelsior*	14
Birch	*Betula pendula-B. pubescens*	2
Broadleaf (crushed)	unidentified	4
Chestnut	*Castanea sativa*	23
Elm	*Ulmus campestris*	2
Oak (deformed)	unidentified	2
Oak (sessile)	*Quercus petraea*	6
Oak (Turkey)	*Quercus cerris*	14
Sycamore	*Acer pseudoplatanus*	14
Walnut	*Juglans regia*	1
Total deciduous		82
TOTAL frame samples		182

Table 6-4. Frame Wood Sample Results.

[263] See Liphschitz et al. 2018.

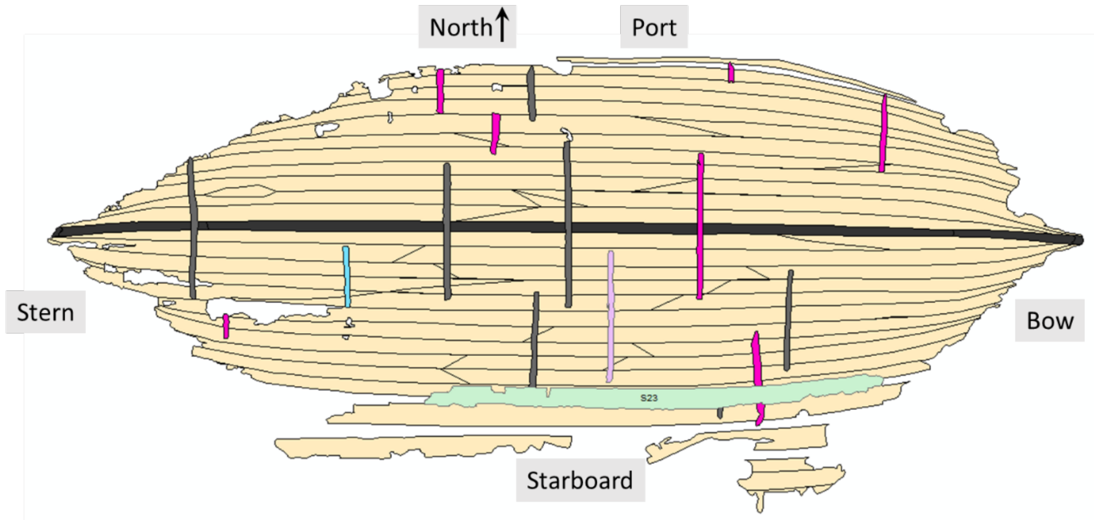
A



B

Figure 6-10. Frame Tree Species. A – All sampled frames displayed. B – Aleppo pine samples in green.

C



D

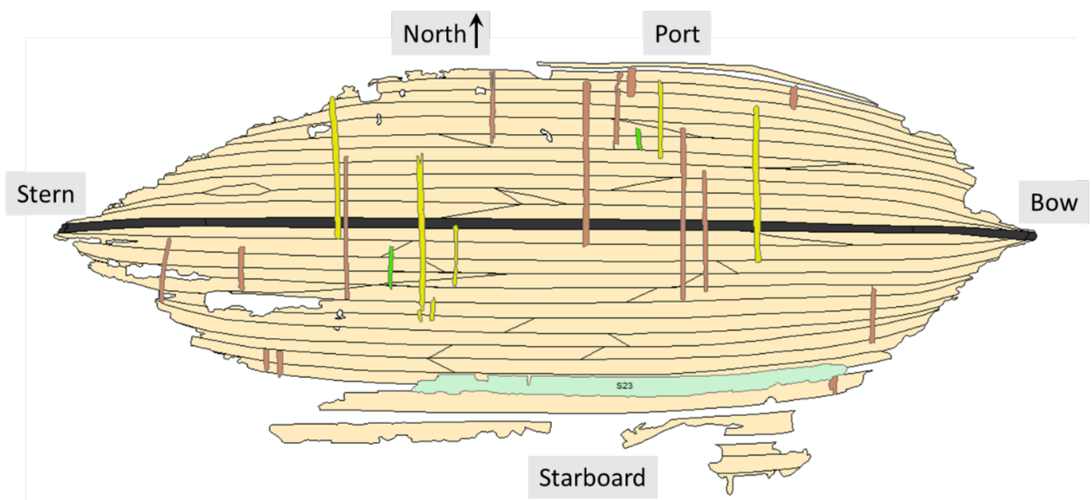
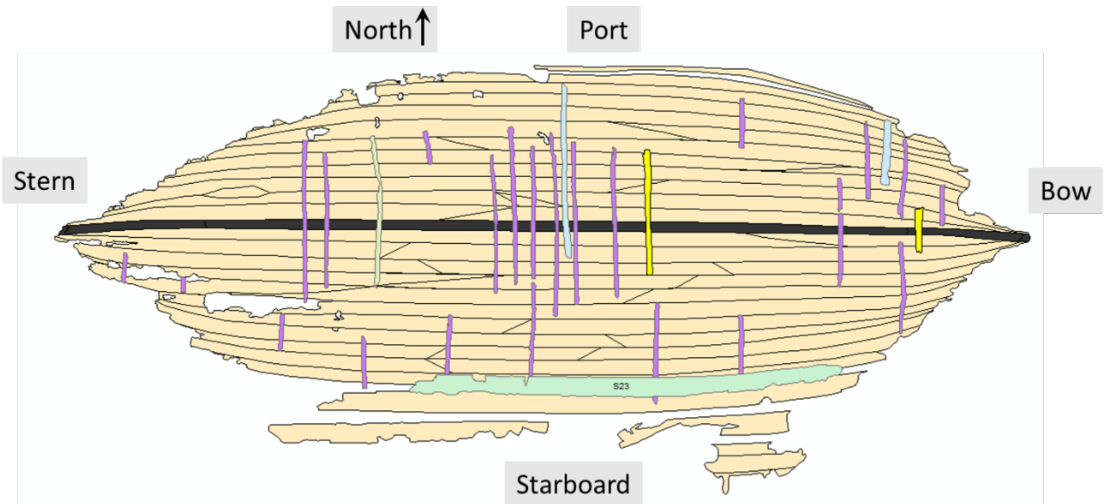


Figure 6-10 Continued. C – All conifers except Aleppo pine. Black pine in black, Mediterranean cypress in magenta, stone pine in blue, Turkish pine in pink. D – All oaks displayed. Turkey oak in brown, sessile oak in yellow, unidentified oak species in green.

E



F

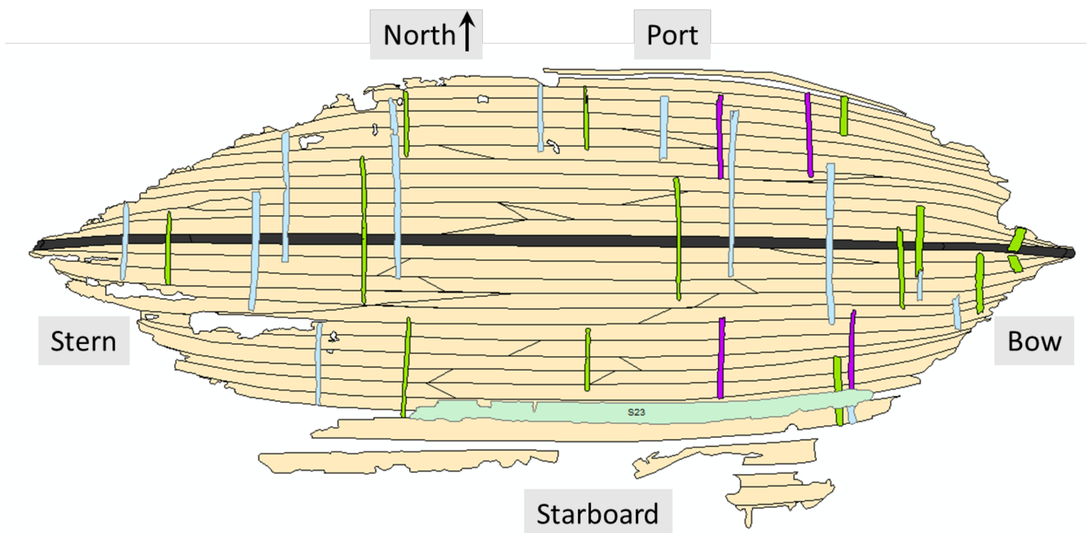


Figure 6-10 Continued. E – Chestnut in purple, elm in light blue, birch in yellow, walnut in green. F – Ash in green, sycamore in light blue, unidentified broadleaf in purple.

There was clearly no requirement for homogeneity in the installation of the frame components; it was much more common to have different wood species in adjacent frame components than it was to utilize the same tree species in a particular frame. Additionally, two adjacent frame components of the same species might have significantly different physical characteristics. For example, Figure 6-11 illustrates the difference in size between frame components F40 and F40-11, both made from Aleppo pine.

Figure 6-11. Frame Component Size Comparison. Components F40 (left, unlabeled) and F40-11 (right) are both made of Aleppo pine.

Two frame wood species preferences deserve specific mention. First, Aleppo pine was clearly the workhorse frame material selected when building the Trstenik ship, comprising 46% of the frame sample results. Of the sampled frame components, more were fashioned from Aleppo pine (84) than from all deciduous tree sources combined

(82). The Aleppo pine framing is shown in Figure 6-10b. Despite its common usage, no specific pattern was noted for its installation; examination from the perspective of forward vs aft, port vs starboard, more dense vs less dense framing regions, etc. did not discern a distinct builder's pattern.

However, a semblance of a preference, if not a pattern, does appear when studying the distribution of deciduous (hardwood) frames. Chestnut, the most prevalent hardwood, was identified in 23 frame component samples (Figure 6-10e). Of these 23 frame components, nine of them comprised the central portion of a floor crossing the keel. Thus, 39% of the chestnut frame components were central floor timbers, compared to only 26% of the Aleppo pine frame components. Additionally, of the nine chestnut frame components that cross the keel, all nine of them were of odd frame numbers (F23, F25, F41, F43, F45, F47, F49, F53 and F71). The probability of flipping a coin and having it come up 'tails' nine times in a row is 1/512, or 0.2%; thus, this pattern is unlikely to be random. Other hardwood species were examined for this pattern. An examination of the use of ash determined that five of the 14 ash frame components were central floors. Four of those five were odd frame numbers (F15, F29, F57 and F73), and one was even F74. A similar examination of the use of Turkey oak found four of the 14 frame components were central floors; three of them were odd frame numbers (F27, F59 and F61) and one was even F50. The use of other hardwoods on odd-numbered central floors was less defined. Two birch frame components were central floors, both even (F56 and F76). Only one central floor was made of elm, even F48. Of the six sycamore central floors, four were even (F20, F22, F32 and F62) and two were odd (F13 and F69).

Only one central floor was made of walnut, even F30. Of the four sessile oak central floors, three were even (F24, F34 and F66) and one was odd F37.

A summary of the material type selected for the central floor of the frames numbered 15 through 74, the run of 60 consecutive floors discussed in Section 6.4.4, is shown in Table 6-5.

Consecutive Floor Frames (frames 15-74)	number of frames	Hardwood	Softwood	Not sampled
Odd-numbered Frames (frames 15-73)	30	18	9	3
Even-numbered Frames (frames 16-74)	30	12	17	1
Total Frames (frames 15-74)	60	30	26	4

Table 6-5. Wood Types of Central Floor Frame Components.

While the builder did not appear to appreciably favor hardwood or softwood when selecting a piece of timber to use in a central floor, he did appear to modestly favor alternating the use of hardwood and softwood, due largely to the penchant to select chestnut, ash or Turkey oak for the central floor timber of odd-numbered frames. Again, it must be emphasized that this is less of a rigidly followed pattern, and more of a proclivity in material selection.

6.4.4 Floor Timbers

As shown in Figure 6-8, the Trstenik ship was fitted with consecutive floors virtually the entire length of the hull. At the stern, the aft-most two frames (frames 11 and 12) are clearly paired half-frames and frame 13 is a floor. Frame 14 is either paired half-frames with a very wide spacing between them, or frame 14 once had a small central floor timber installed between the two surviving components (futtocks) that is now missing. At the bow, the forward-most three frames (frames 77, 78 and 79) are clearly paired half-frames and frame 76 is a floor. Frame 75 is either paired half-frames with a very wide spacing between them, or frame 75 once had a small central floor timber installed between the two surviving components (futtocks) that is now missing. Thus, the after and forward framing patterns are identical, except there is one more pair of half-frames forward than aft. See Section 6.4.9 for a discussion of this difference.

The central frame structure from frame 15 all the way forward to frame 74, a span of 60 consecutive frames, consists of only floor timbers over the top of the keel—except for frames 37, 38, and 39. These three consecutive frames have small gaps over the top of the keel. During the excavation, divers taking measurements in this area of the hull recorded their opinion that each of these three frames had originally consisted of a single floor timber which had separated into two halves at the limber hole cut in the lower edge of the floor over the keel. Unfortunately, wood samples were not taken on both sides of each break in the three floors. However, visually the two halves of each floor are similar in size and appearance, and the width of the small sections missing over the keel is the same as that of limber holes measured in other floors. Figure 6-12 illustrates this area of the hull. Of note, forward of frames 37-39, frame component F40 is notched on its forward edge, and aft of frames 37-39, frame component F36 is notched on its after edge (Figure 6-12). Thus, this region is bracketed forward and aft by notches suggesting the location of a now-lost component. While no parts of a bilge pump or its mount were recovered during the excavation, a bilge pump or some other piece of ship's equipment installed longitudinally between F36 and F40 may explain the purpose of the notches on those frame components. This equipment would have blocked access to the

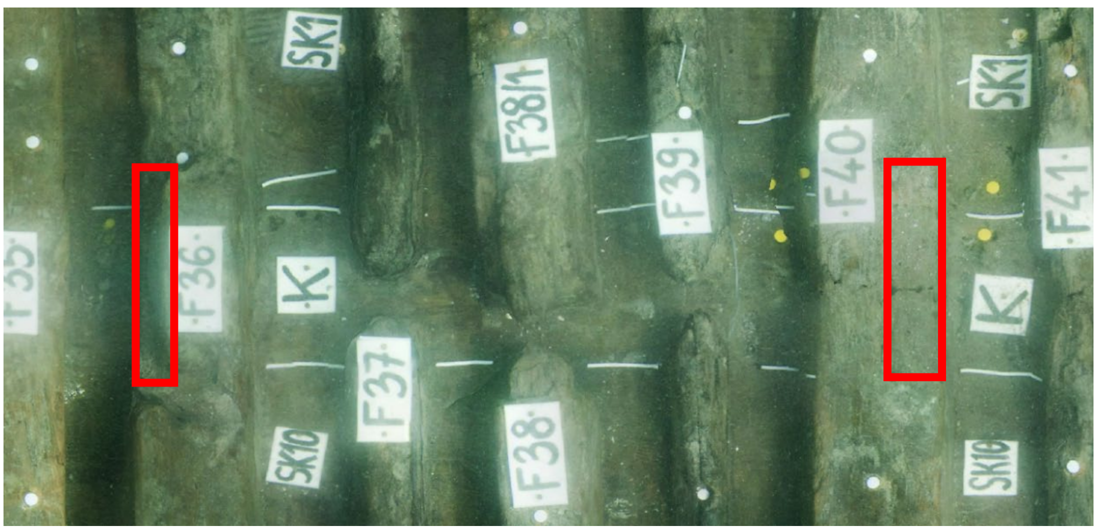


Figure 6-12. Possible Bilge Pump Location. Frames 37, 38, and 39 display a gap over the keel. These frames are evaluated as originally floors split in half over the keel at the limber holes. The notches on top of frame components F36 and F40 are highlighted in red. Bow to right.

central portions of F37, F38 and F39, including their limber holes. The gap in these floors is potentially consistent with the installation of a chain bilge pump which could have operated in this three-frame section just above the keel.[264] Additional measurements and study of the gaps in these three floors including verification of the alignment of the gaps is necessary to determine if a chain pump could have operated in this space. Based on the determination that these three frames originally consisted of a continuous floor timber over the keel, the Trstenik ship is seen to have 60 consecutive floor timbers, from frame 15 to frame 74. For additional discussion of the notched frames see Section 6.4.7.

6.4.5 Intermediate Timbers

During site plan development and frame component labeling, several short frame components were observed to have been inserted between full-length frames at the quarters of the of the ship. As discussed in Section 6.4.1 each component was designated with an 'A' to indicate that it was a frame component that did not belong to a full-length frame crossing the keel (Table 6-6). For example, frame component F18A-12 is between frames 18 and 19. Various terminology has been used to describe this type of frame component in the literature. For example, Steffy noted similar components in the Kyrenia shipwreck, which he called "intermediate timbers;" Steffy suggested that these intermediate timbers could have extended to the top of the hull, and also supported splashboards or other elements designed for topside protection.[265] In more recent wooden vessels, this type of framing can be termed "doubling up,"

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[264] See Carre and Jezego 1984, Beltrame and Gaddi 2005, 83-7, and Tiboni and Tusa 2016, 247-8 for discussions of various bilge pump designs and installations based on shipwreck excavations.
[265] Steffy 1985, 94 and Steffy 1994, 44, 51 and 273.

signifying two or more rows of overlapping futtocks.[266] McKee termed this type of framing "top timbers," and hypothesized that top timbers were placed where local stresses could result from waves, stays, oars or impact.[267] In the case of the Trstenik ship, such timbers will be termed "intermediate timbers."

Frame component	Location of Strakes	Common Tree name
F18A-12	SK9Sa, SK10Sa	Not sampled
F20A-11	SK10Sa, SK11S	Turkey oak
F68A-1	SK9P, SK10P, SK11P	Turkey oak
F69A-11	SK9Sf, SK10Sf, SK11S, SK12S	Ash
F69A-1	SK9P, SK10P, SK11P	Ash
F70A-11	SK11S, SK12S	Turkey oak

Table 6-6. Intermediate Timbers.

On the Trstenik ship, these intermediate timbers were installed at the forward and aft quarters in the same places where the orientation of the hull planking was undergoing two dimensional changes: 1) strakes began to transition from a perfectly flat orientation to a rounded one at the turn of the bilge, and 2) strakes began twisting from a flat horizontal position to eventually attain a vertical orientation at the stem or sternpost. These transitions, coupled with heavy cargo placed on the flat portion of the hold as well as dynamic stresses imparted on the hull during high seas, result in high-stress locations

266 Steffy 1994, 270, 293.
267 McKee 1983, 60.

on the hull. In the Trstenik ship, these high-stress areas occur just forward and aft of the locations where the frame density decreases by 50% (see Section 6.4.2), between frames 18-20 aft and between frames 68-70 forward. Figure 6-13 shows the location of the six installed intermediate timbers. While no intermediate timbers were found in the aft port quarter, hull symmetry would suggest that intermediate timbers were originally installed in that location as with the existing intermediate timbers shown in Figure 6-13, but they did not survive in the wreckage. Table 6-6 shows that the surviving aft starboard intermediate timbers were fastened to strakes SK9S through SK12S, while the site plan indicates that the port strakes associated with frames 18-20 did not survive outboard of strake SK8P. It is noteworthy that although less than half of the ship's frame components were made of hardwoods, all five sampled intermediate timbers were made of hardwoods. It appears as though the strongest woods were selected to reinforce the weakest points of the hull. It is also possible that these locations were reinforced by intermediate timbers to support the employment of ship's equipment, such as steering oars, anchors, or mooring cleats.

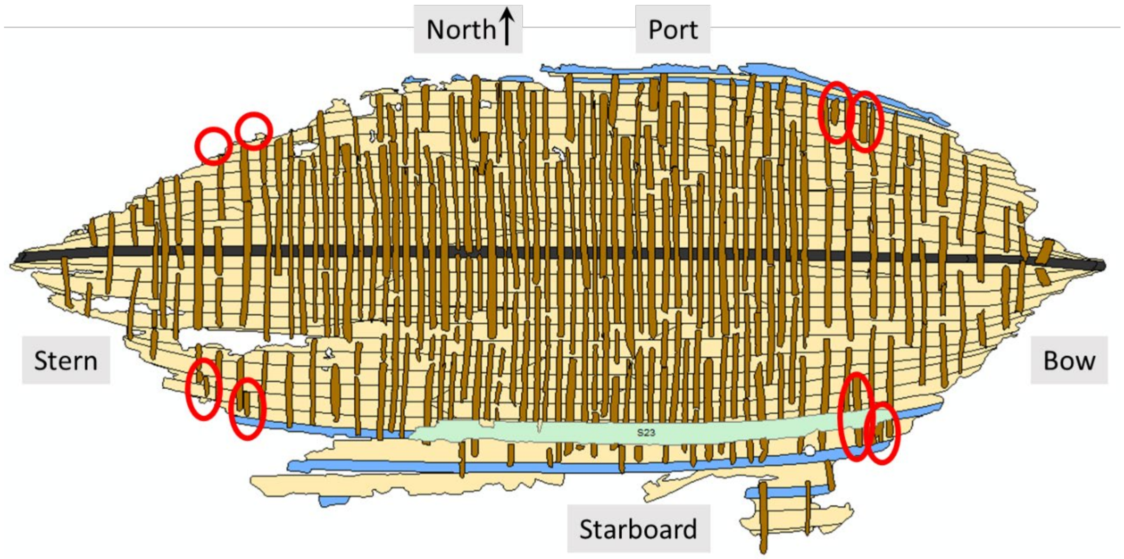


Figure 6-13. Intermediate Timbers. The six surviving intermediate timbers were inserted between full frames at the bow and stern quarters. No aft port intermediate timbers survived; the circled locations are postulated based on the symmetry with three other locations in the hull.

6.4.6 Limber Holes

As would be expected for a flat-floored ship, the frames of the Trstenik ship were each provided with a central limber hole. Many different shapes and patterns of limber holes have been noted on Roman shipwrecks. The Trstenik ship has perhaps the simplest pattern: a single cut in the bottom of each floor timber directly over the keel, in the shape of a semicircular arc. As discussed by Steffy, the likely assembly sequence was that the shipwright marked the desired location for the limber hole as each frame was being fitted to the planking, and then cut the limber holes just before the frames were permanently fastened to the hull planking.[268] For a typical central floor timber, the limber hole measured 4-6 cm in width at the keel and also 4-6 cm above the keel at its highest point. See Figure 6-14. Near the bow and the stern, the holes are slightly more irregular in size.

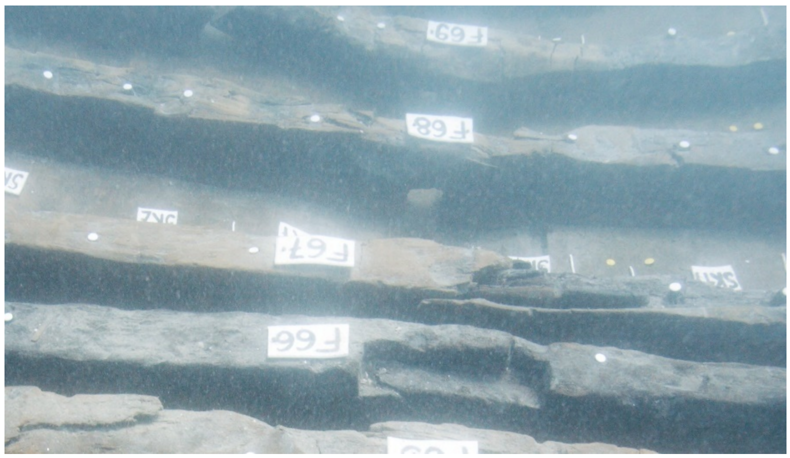


Figure 6-14. Limber Hole and Frame Notch. Limber hole visible at frame 68. Aft-facing notch visible at frame 66.

Frame 17 is the exception to the rule that every floor had a limber hole over the keel. F17, a very small central floor timber (28 cm long), is located directly over the scarf between the keel and the sternpost (Figure 6-15). Diver examination suggests that frame components F17 and F17-1 were once a single piece of wood which separated just to port of the keel due to the lack of a limber hole. Future sampling of these two frame components is required to confirm this hypothesis.

[268] Steffy 1998, 165-6.

6.4.7 Frame Notches

Of the 69 frames, 11 have some form of notching on the top edge of the frame, directly over the keel. Of the 11 notched frames, frames 59 and 61 are double-notched

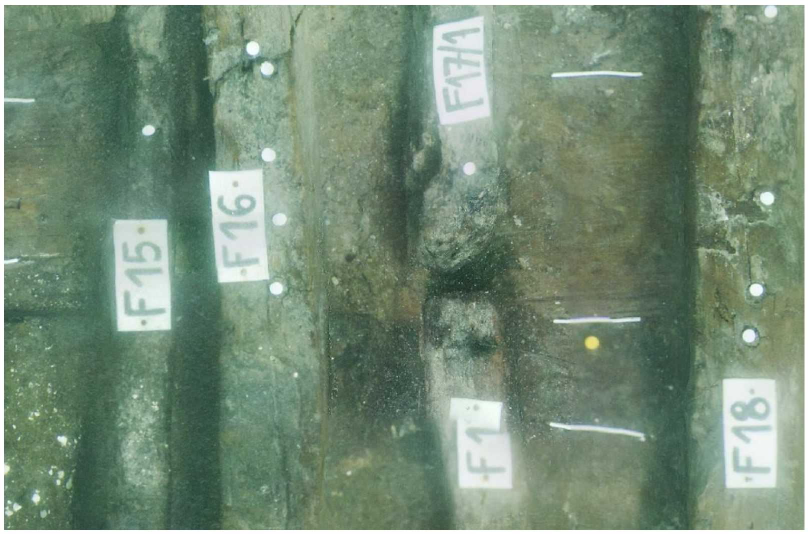


Figure 6-15. Frame Components F17 and F17-1. These two frame components are likely halves of the same floor timber, which separated due to lack of a limber hole.

and made of turkey oak. See Figure 6-14 for an example of a notch on F66. Table 6-7 summarizes these notch locations and their measurements. Figure 6-16 graphically illustrates the location of the notched frames in the hull. Based on study of contemporaneous shipwrecks (Section 7.1) these notches could have supported a mast step of various length. Unfortunately, the mast step of the Trstenik ship was removed prior to scuttling the ship, thus any discussion of mast-step length or the purpose of specific notch designs and locations must be based on mast steps preserved on contemporaneous shipwrecks (Section 7.1). Estimated mast-step length and location for the Trstenik ship based on analysis of similar shipwrecks is discussed in Section 6.5.3.

	Notch Dimensions on Frames (cm)				
Frame component	length (athwartships)	width (fwd & aft)	depth	location over keel	
Aft facing notches					
F66 (sessile oak)	17.6	3.2	2.4	directly over keel	
F55 (Aleppo pine)	16.9	3.5	3.3	slightly off to starboard	
F52 (Aleppo pine)	20.4	4.2	2.5	directly over keel	
F46 (black pine)	17.3	2.6	2.7	slightly off to starboard	
F45 (chestnut)	14	1.2	1.1	slightly off to port	
F36 (Aleppo pine)	15.7	1.7	2.1	directly over keel	Note 1
F28 (Aleppo pine)	14.6	5.1/3.7	2.7	very slightly off to port	Note 2
Forward facing notches					
F60 (Aleppo pine)	14.4	3.5	1.2	Slightly off to starboard	
F40 (Aleppo pine)	14.1	4.1	1.9	directly over keel	Note 1
Double notches					
F61 fwd (Turkey oak)	22.6	2.2	2.6	directly over keel	Note 3
F61 aft (Turkey oak)	22.4	2	2.8	directly over keel	Note 4
F59 fwd (Turkey oak)	21.4	1.8	2.7	directly over keel	
F59 aft (Turkey oak)	21.7	2.3	2.6	directly over keel	

Table 6-7. Notch Dimensions on Frames.

Note 1: See Section 6.4.4 and Figure 6-12 for a discussion of the three floor timbers located between notched frame components F36 and F40.

Note 2: Two width measurements; the port side of the notch has an additional indention (based on appearance, most likely a split in the wood and not an intentional notch alteration).

Note 3: Angled (triangular) notch; the maximum width measurement is to port; the notch tapers to zero to starboard.

Note 4: Angled (triangular) notch; the maximum width measurement to starboard; the notch tapers to zero to port.

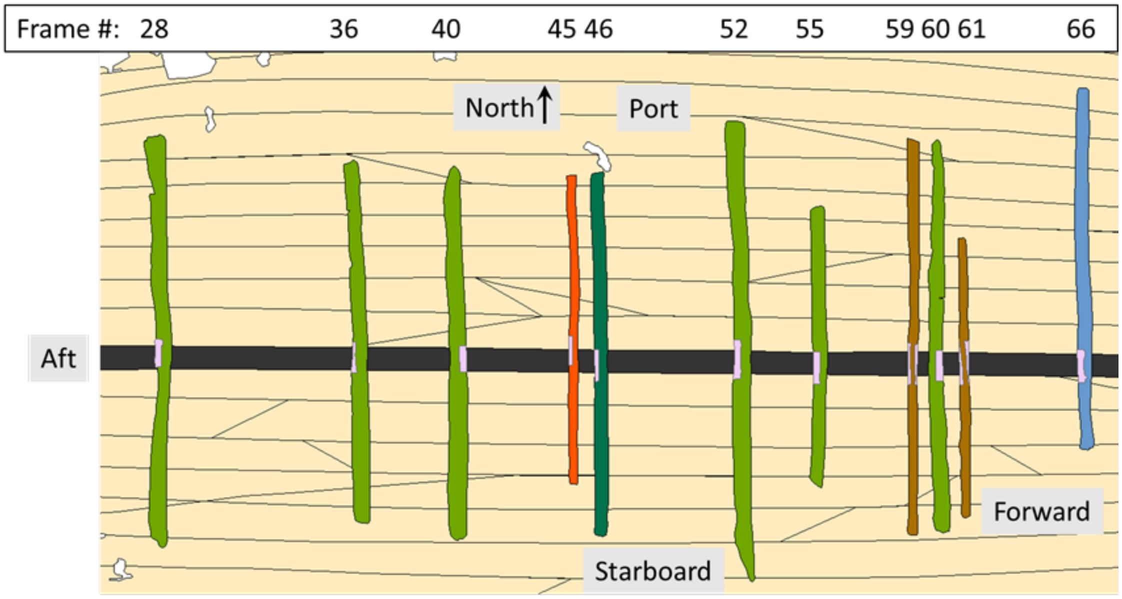


Figure 6-16. Notched Frames. All notches over the keel, shown in pink. Aleppo pine in light green, black pine in dark green, Turkey oak in brown, chestnut in orange, sessile oak in blue.

6.4.8 Frame Treenails

As mentioned in Section 6.4.1, the frames were fastened to the strakes of the ship's hull by treenails, likely all driven from outside-in due to the lack of toolmarks on the interior tops of the frames. The use of iron nails driven from the outside in cannot be ruled out without disassembly, although no clenched nail ends were located on the tops of the frames. The treenail spacing varies between frame components; the majority of frame components were attached to each strake by one treenail, but some instances of two treenails connecting a strake to a particular frame component were noted. In rare cases a frame component crossed a strake without being treenailed to it. A typical value for frame treenail spacing is 8-12 cm; some treenails were within 1 cm of each other, while a gap as large as 23 cm can also be observed. A total of 1,200 white thumbtacks were used to mark the locations of treenails during the excavation. Even allowing for some being dropped or replaced, this is a large quantity. With 60 floors in the central area of the ship, one treenail per strake across each of the 22 strakes in place below the first wale would require 1,320 treenails.

As mentioned earlier, four frame components broke away from the ship and were removed to shore before the ship remains were photographed for photogrammetry. Additionally, sections of other frames loosened as treenails separated between the hull planking and frame components. This allowed some treenails to be removed from the ship for sampling. A total of 27 treenails, corresponding to less than 2% of all treenails, were removed from the wreck and sampled for tree species identification. Results are displayed in Table 6-8.

Common Tree name	Tree species	Number of samples
Sycamore	*Acer pseudoplatanus*	19
Mediterranean cypress	*Cupressus sempervirens*	2
Turkey oak	*Quercus cerris*	2
Alder	*Alnus* sp.	1
Black pine	*Pinus nigra*	1
Olive	*Olea europaea*	1
Sessile oak	*Quercus petraea*	1
TOTAL		27

Table 6-8. Treenail Wood Sample Results. Locations as shown in Appendix A.

Based on the limited sampling of treenails, it appears that the builder preferred sycamore for fashioning treenails. This preference, however, is not seen in the sampled tenon pegs (Table 6-3), but that sample size consisted of only four pegs. Additional samples are required to identify any potential preference for peg material. Of note, two new tree species, alder and olive, appear as treenails, which were not used in any frame, stringer, or strake construction in the hull.

6.4.9 Canted Frame

As discussed in Section 6.4.4, the central portion of the Trstenik ship consists of flat floor timbers crossing the keel, while the forward-most three frames (frames 77-79) and the aft-most two frames (frames 11 and 12) are composed of paired half-frames. As a ship's bow and stern narrow and become more vertical, paired half-frames are often installed to conform to the shape of the hull. While the aft-most frames are not particularly well preserved or of remarkable shape, the forward-most frames are in somewhat better condition, and the shape and structure of frame 79, the forward-most frame in the ship, is unique among the surviving frames (Figure 6-17).

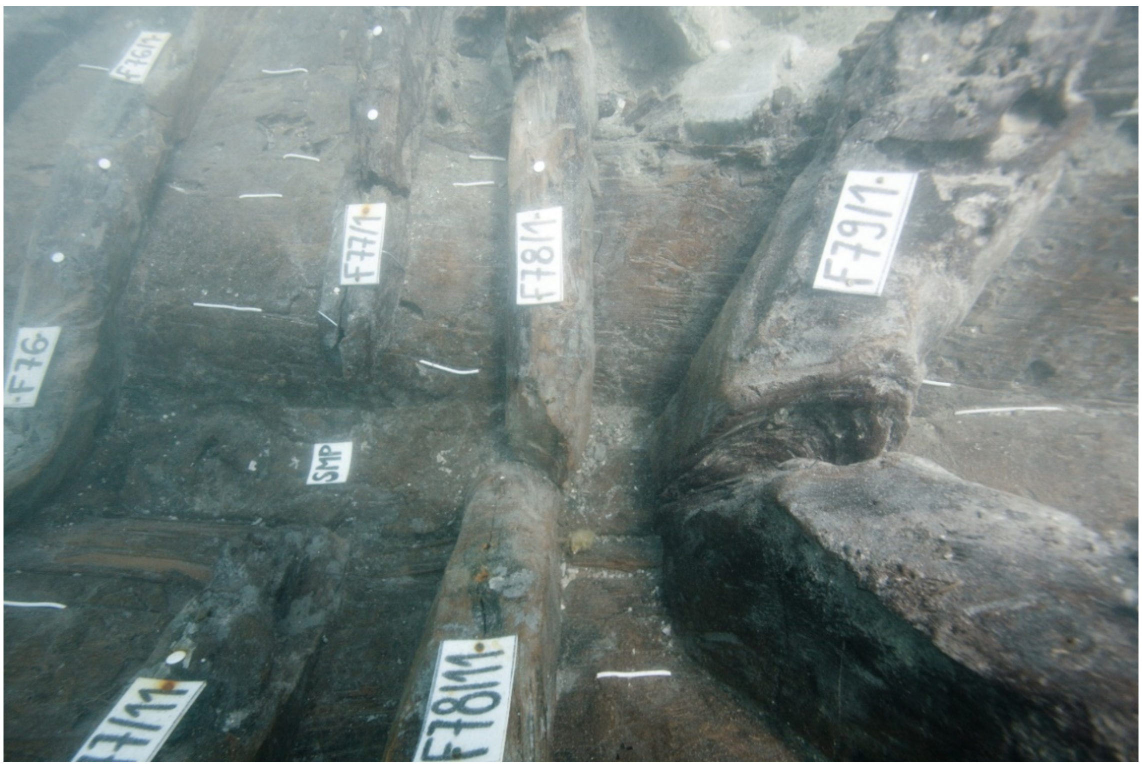


Figure 6-17. Frame 79. Composed of two half-frames, this forward-most frame displays forward cant.

The paired half-frames of frame 79 (F79-1 and F79-11) are made of ash. Based on grain patterns, these two pieces were most likely cut from the same timber, or they resulted from a single piece of wood, originally shaped into a "V" to exactly fit the frame location, snapping in half as the ship collapsed outward due to the weight of rock.

Measuring over 12 cm at the widest point, both the height and width of these frame components are the largest found on the Trstenik ship. Additionally, a cant is clearly visible in Figure 6-17, showing that the frame components were intentionally shaped to rake forward, different from all other frames.

As shown in both Steffy and McKee, a cant frame is mounted obliquely from the keel rather than perpendicularly; this allows for denser frame distribution around the incurving bow and stern sections of a ship.[269] While the forward-most frame on the Trstenik ship, frame 79, is clearly canted, frame 11, the aft-most frame, more closely resembles the design and installation of frame 78. An additional similarity is that frame components F11, F78-1, and F78-11 were all made of Aleppo pine. Based on hypothesized forward and aft symmetry of the hull, wood species results and the poorer preservation at the stern of the ship, it is reasonable to infer that a frame made of hardwood, similar in design to frame 79, was originally installed aft of frame 11, but did not survive to the present day. This is supported by slight staining visible just aft of frame component F11 on poorly preserved strake SK3a. This stain measures 11 cm in width, very similar to the large widths of frame components F79-1 and F79-11.

[269] Steffy 1994, 180, 268, 294; McKee 1983, 62.

6.5 Stringers

6.5.1 Introduction

After the structural shell of the Trstenik ship was completed and frames were attached to the shell to add strength and support, multiple lengths of planking were nailed longitudinally across the tops of frames. This internal planking, termed stringers here but also known as ceiling or ceiling planking, protected the hull from direct contact with cargo, and also likely provided attachment points for the fastening of ship's equipment such as deck-beam support stanchions or a bilge pump. While these stringers may have incidentally provided some longitudinal stiffening to the hull, their primary purpose was as internal support structure. Although any useful attached ship's equipment would have been removed prior to filling the ship with rocks and scuttling it alongside a sea wall, the stringer pattern and construction materials add insight into ship usage, and some markings and evidence survive, not obliterated by the weight of rocks piled on top of the stringers for 2,000 years. The stringer pattern found in 2015 is shown in Figure 6-18.

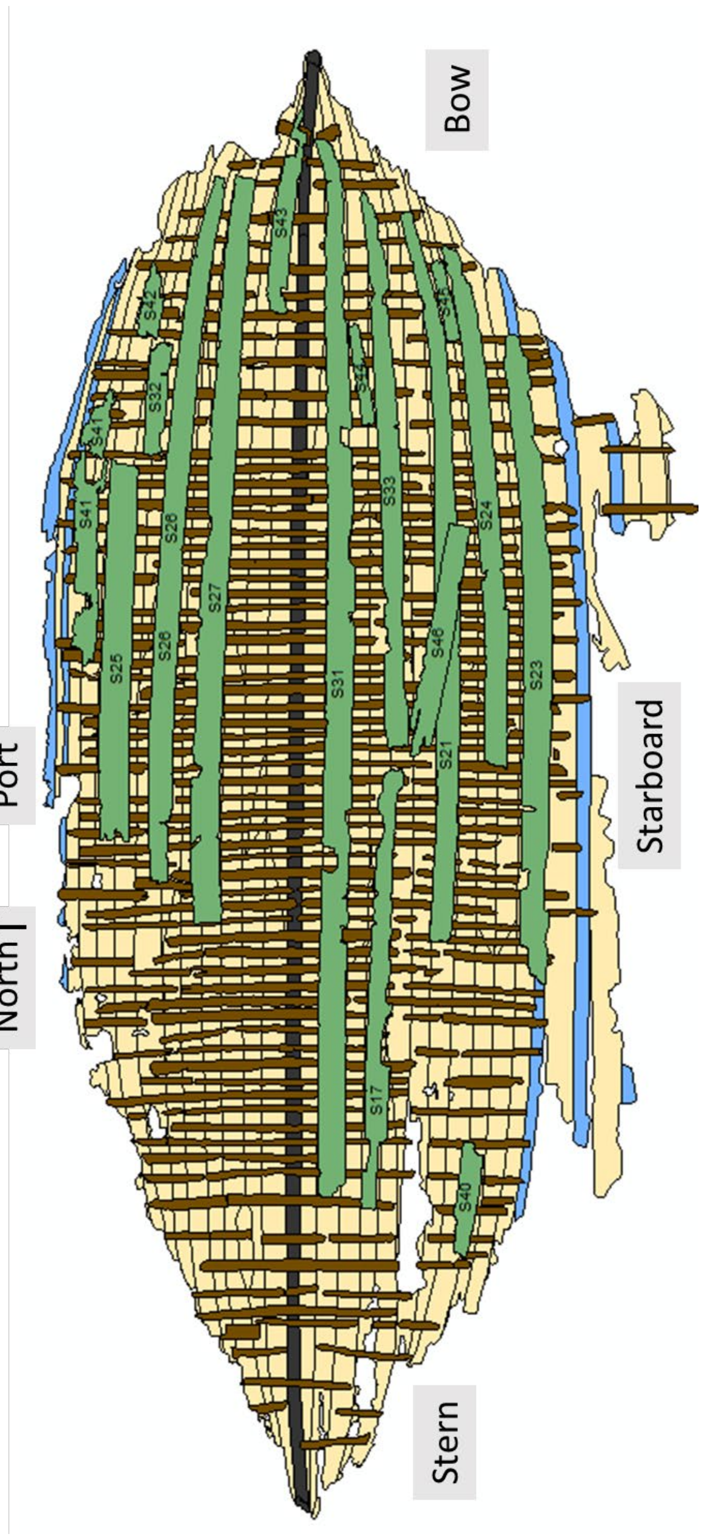


Figure 6-18. 2015 Trstenik Stringer Pattern. Stringers shown in green.

In the 2012 excavation, which uncovered the west (aft) portion of the ship, attached longitudinal timbers were labeled IP (inner planking), then numbered sequentially. Thus, the smallest numbers started near the stern of the ship and incremented higher as the excavation worked forward, in no particular order. The 2015 excavation continued with the numerical sequence to harmonize with drawings from the 2012 excavation, but changed the IP label to S (stringer), which is the term utilized here. The exception to this pattern is stringer S40, which is located in the after portion of the hull. Prior to photographing the ship for photogrammetry with stringers installed, this short stringer was noted to be unlabeled and given the next sequential number (S40). Based on the 2012 drawings of the hull, S40 was subsequently recognized to be a part of IP19, most of which broke loose during the 2015 excavation and was raised as "floating wood" with its 2015 label (S19) still attached. This is also confirmed by the wood analysis results. Retrieved stringer S19 and *in situ* stringer S40 were both determined to be made of black pine, supporting the conclusion that S19 and S40 were two pieces of the same timber.

The stringers were attached to frames with both treenails and nails. Based on rust stains on the stringers, some of the nails must have been made of wrought iron. However, as no metallic sampling has been undertaken, it cannot be stated conclusively that some nails were not of copper or some other alloy. Figure 6-18 illustrates the symmetry of the stringers across port and starboard, which is consistent on either side of the keel with the exception of a length of stringer clearly missing just to port of the keel, a long extension aft from stringer S43 at the bow. Based on review of the photogrammetry orthophotos, there are markings that could be nail holes on the top surface of many central frames where an extension of S43 could have been installed. Nail holes at these positions would support the theory that a long stringer was installed during the ship's operational life and removed prior to scuttling. However, no *in situ* observations were specifically made of these markings, and deformations of the top surfaces of some of these frames caused by the weight of the rocks loaded directly on top of them could resemble nail holes. Therefore, the length of such a stringer or the actual number of pieces it consisted of cannot be accurately determined without additional excavation and analysis. In addition to the symmetry hypothesis of a single long, missing stringer to port of the keel, three stringers have the appearance of being loose and scattered into the bottom of the ship, rather than carefully placed and then attached: short, thin S44 and S45 toward the bow, and longer S46, which is actually on top of stringer S21. In fact, S44 and S45 were attached by nails to framing; only S46 was loose and unattached. S46 was apparently pulled up, then abandoned rather than being removed from the ship prior to scuttling by filling with rocks.

As mentioned above, the excavation in 2012 exposed the after portion of the hull to approximately frame 47 (Figure 6-19). Due to time constraints combined with the newness of the technology, photogrammetry was not performed during that partial excavation. Three years later, several of the stringers uncovered in the earlier excavation had cracked, deteriorated, and become detached from the frames. These stringers were removed to land during the 2015 excavation as unprovenienced 'floating wood'. Without photogrammetric documentation, the stringer pattern in the after part of the hull

Figure 6-19. 2012 Excavation. The western half of the ship was cleared of stones. Photograph taken from the north, looking south.

can only be inferred from several hand drawings from the 2012 excavation. Also, due to time constraints during the 2015 excavation, the shipwreck with the remaining stringers still installed *in situ* was photographed for subsequent photogrammetry (Section 5.2), then the stringers (with the exception of S23—see Section 6.5.4) were removed to facilitate access to the internal structure of the ship. At the completion of the excavation the removed stringers were labeled, bundled, and reburied with the ship.

6.5.2 Stringer Wood Sample Results

Results of wood analysis of stringers that were in place during photogrammetric documentation are shown in Table 6-9 and plotted in Figure 6-20.

Common Tree name	Tree species	Number of samples
Aleppo pine	*Pinus halepensis*	9
Black pine	*Pinus nigra*	5
Mediterranean cypress	*Cupressus sempervirens*	2
Total number of samples		16

Table 6-9. Installed Stringer Wood Sample Results. Only the results of *in situ* stringers installed during photogrammetric documentation are listed.

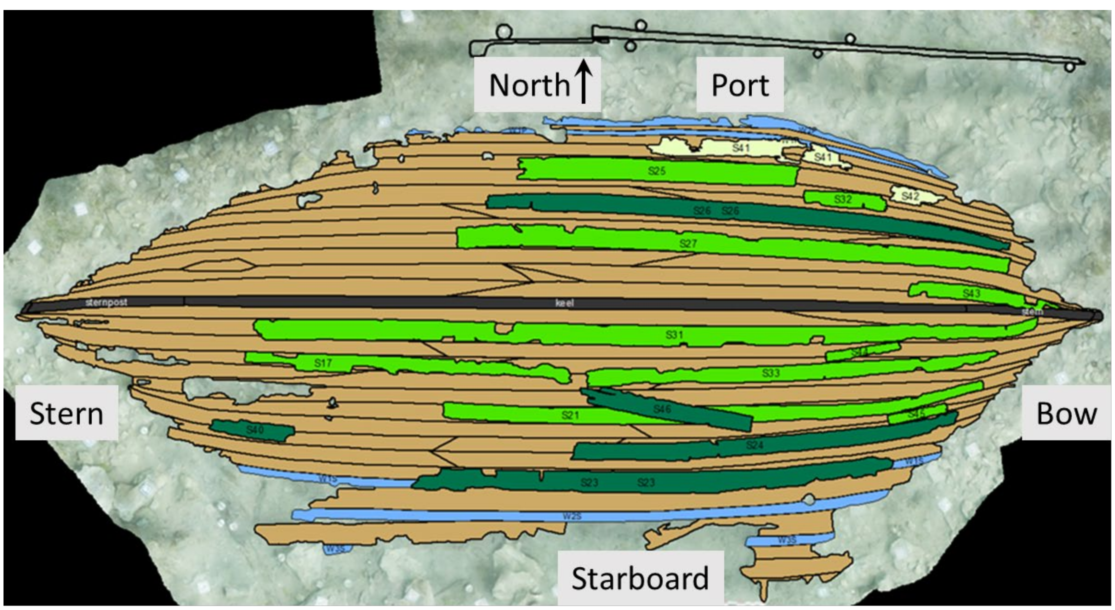


Figure 6-20. Installed Stringer Wood Species Map. Black pine in dark green, Aleppo pine in light green, Mediterranean cypress in yellow.

As discussed earlier, some stringers broke loose during excavation and were removed from the ship as unprovenienced 'floating wood' before photogrammetric documentation. These removed stringers were sampled. Adding the identification results of these removed stringers to the installed stringer results generates total stringer wood sample results (Table 6-10).

Common Tree name	Tree species	Number of samples
Aleppo pine	*Pinus halepensis*	14
Black pine	*Pinus nigra*	9
Mediterranean cypress	*Cupressus sempervirens*	4
Total number of samples		27

Table 6-10. Total Stringer Wood Sample Results.

These stringer wood identification results share several characteristics with that of the strake sample results (Section 6.3.2). First, the three tree species identified in the stringers of the Trstenik ship are the same three species used in the majority of the strakes. Aleppo pine, black pine and Mediterranean cypress are all conifers, and would have been the preferred choices for both planking and stringers due to their relative ease of shaping, rapid growth, and abundance. Second, the relative propensity of wood choice is approximately the same for both strake and stringer. The results leave the perception that a single planking source supplied lumber for both strakes and stringers, with Aleppo pine and black pine availability from that yard exceeding Mediterranean cypress availability by a factor of 2:1 (Table 6-11).

Based solely on sample results, the one unattached stringer, S46, was most likely originally a part of stringer S24. Both stringers are made of the same wood (black pine) and both stringer widths are 18-20 cm. However, there is not a perfect join between S46 and S24, so this must remain a likely, but unconfirmed, theory.

Common Tree name	Tree species	Number of samples		
		Strake	Stringer	Total
Aleppo pine	*Pinus halepensis*	12	14	26
Black pine	*Pinus nigra*	13	9	22
Mediterranean cypress	*Cupressus sempervirens*	7	4	11
Scots pine	*Pinus sylvestris*	1	0	1
Stone pine	*Pinus pinea*	1	0	1
Total number of samples		34	27	61

Table 6-11. Strake and Stringer Wood Sample Results. Table is a summation of strake wood sample results (Table 6-2) and total stringer wood sample results (Table 6-10).

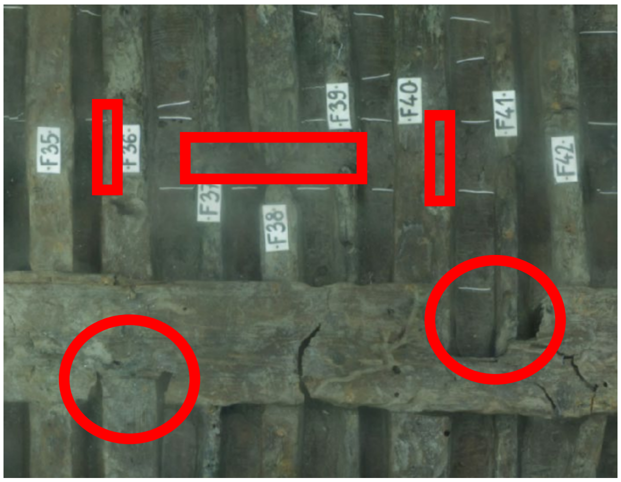
6.5.3 Stringer Locations and Notches for the Mast Step

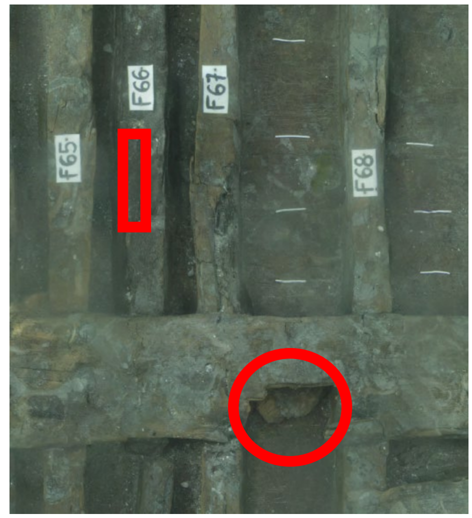
An important point to note is that there were no stringers discovered that were attached directly over the keel. This would suggest that the Trstenik ship originally had a long mast step, ultimately removed from the ship for repurposing prior to filling the ship with rocks and scuttling. Had the mast step been short, it would make sense from a cargo hold utilization perspective to have installed a small stringer directly above the keel over the floor frames, either forward or aft of the mast step, to facilitate cargo handling when loading or unloading the ship and to provide footing for walking belowdecks when the ship was unloaded. While conceivable, it is unlikely that the mast step was a small piece of timber that could have been moved forward or aft to adjust mast position or to support cargo load placement. Based on the lack of a stringer over the keel, coupled with the large number of notches over the central floor timbers, the Trstenik mast step may have been more similar to the mast step of the Napoli A shipwreck (found in Naples, Italy, and dated to the 1st century CE), which extended over 27 floors, rather than the mast step of the Ladispoli A shipwreck (found off the coast of Ladispoli, Italy, and dated to the 1st century CE) , which crossed eight floors, or the mast step of the Baie de l'Amitié shipwreck (found off the coast of Agde, France, and dated to the 1st century CE), which was installed over six floors.[270]

Continuing the theme of stringers providing information about the missing mast step, the long stringer S31 that would have been placed just to starboard of the mast step has three small sections taken out of it: one oriented away from the keel at frame 36, one pointing toward the keel at frame 40, and one facing away from the keel at frame 67 (Figure 6-21). While not perfectly regular, these removed sections appear to have been cut out of stringer S31 during the operational life of the ship. The edges are too angular to have resulted from decay. As discussed in Section 6.4.4, three central floor frames (F37, F38 and F39) had central gaps bisecting the floor timbers at the limber holes over the keel (Figure 6-12). Stringer S31 shows two missing sections adjacent to these three

[270] See Section 7.1.4 for a detailed discussion of the floors of these three ships, including references.

gaps, roughly aligned with the two notched floors F36 and F40 (Figure 6-21a). If the hypothesis of a bilge pump at this location is correct, brackets to support the pump





a. Stringer S31 adjacent to frames 36 and 40. b. Stringer S31 adjacent to frame 66.

Figure 6-21. Stringer S31 Missing Portions. Figure 6-21a shows missing stringer sections adjacent to notched floors F36 and F40, which bracket the three central floor timber gaps of F37, F38, and F39. Figure 6-21b shows a missing stringer section near the frame notch in F66, the forward-most notched frame on the ship.

could have been fitted into these missing sections in stringer S31 for attachment. Additionally, if the notch on F40 supported a bilge pump, frame 41 would be the aft-most extent of the mast step. Similarly, Figure 6-21b shows a missing section from stringer S31 at frame 67, adjacent to F66, the forward-most notched frame. If this section from S31 also defined the location of some sort of mount for equipment that was removed before scuttling the ship, the maximum extent of the missing mast step would have been from frame 41 to frame 67, a total of 27 frames, which is identical to the number of frames covered by the Napoli A ship's mast step. The distance between frame 41 and frame 67 at the keel is 3.35 m, almost 1/3 of the total length of the Trstenik ship. This is actually shorter than the Napoli A's mast step, which spanned 27 frames over a length of 5.32 m, almost half of the total length of the Napoli A ship (12 m), which, incidentally, is the same length as the Trstenik ship.[271]

With respect to the actual location of a mast, two indicators could potentially pinpoint the location of the heel of the mast on the Trstenik ship mast step. First, the double notches on frames 59 and 61 are unique among the 11 notched floor frames. These two frames, both fashioned from Turkey oak, are located 1/3 (33%) of the total distance from the bow of the ship, similar to the location of the mast on the L'Anse des Laurons 2 shipwreck (found near Martigues, France, and dated to the 3rd century CE), which was placed 3/8 (37.5%) of the total distance from the bow of the ship.[272] Secondly, there are two very regular cutouts on stringer S31 just to starboard of the keel, adjacent to the two double-notched floors (Figure 6-22). If the Trstenik ship utilized some sort of rudimentary mast partner to support the mast near the heel or had a vertical stanchion athwartships of the mast, the holes cut in stringer S31 are in the appropriate location. The stringer cutouts adjacent to two double-notched floors at the appropriate fore-and-aft location for a mast heel are the most convincing tangible evidence on the Trstenik ship for the potential location of the heel of the mast on the missing, long mast

[271] Giampala et al. 2005, 67-9.
[272] Gassend et al. 1984, 104.

step. Figure 6-23 integrates the information provided by stringer cutouts to postulate a hypothetical mast step and mast heel location.

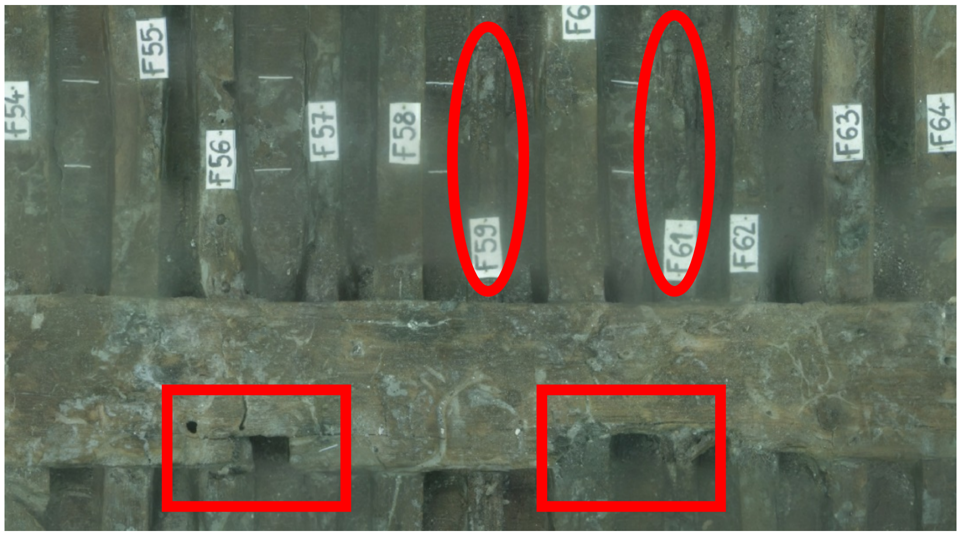


Figure 6-22. Possible Location of Mast Heel. Circles highlight the two double-notched floors (F59 and F61). The squares highlight the regular cuts in stringer S31 adjacent to the double-notched frames.

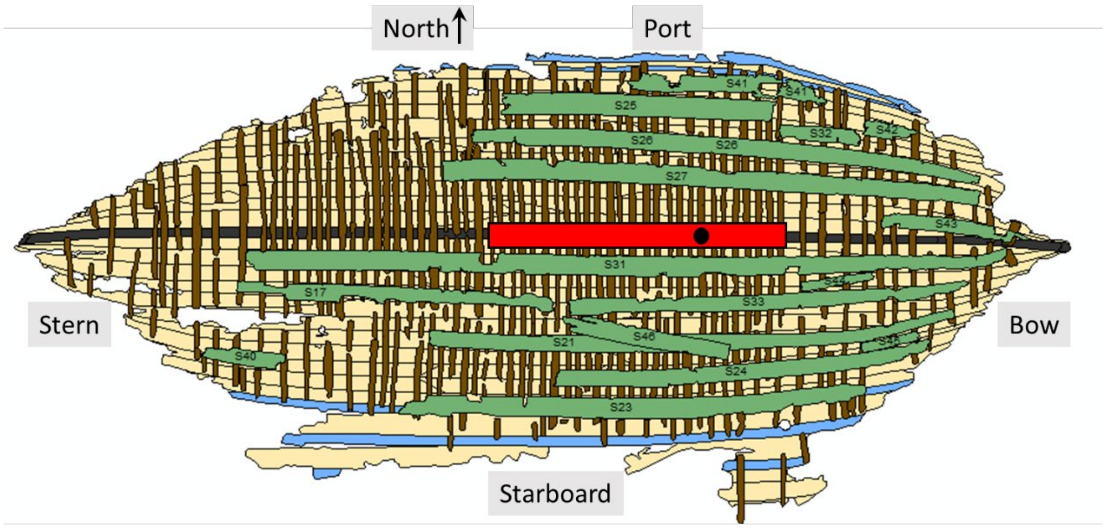


Figure 6-23. Hypothetical Mast Step and Mast Heel Location. The extent of the mast step is based on evidence from stringer S31 and locations of notches on floor timbers. The mast heel is placed between double-notched frame floor components F59 and F61.

6.5.4 Stringer S23

Among the stringers, S23 is significantly different in design and purpose. While the other surviving stringers are simple flat boards, stringer S23 has additional wood attached to it, the purpose of which is not clear. It is possible that stringer S41, installed symmetrically to S23 on the port side, was originally of the same construction as S23. However, the poor preservation of S41 prevents certainty of this conclusion. Based on the significance of S23 in the ship, it was not removed to examine the underlying framing. Instead, S23 was left *in situ* to allow for a detailed study during some future excavation.

Stringer S23, sampled once, proved to be of black pine. Further analysis indicates that this stringer consists of several wood pieces treenailed together, which may not all be of black pine. Additional samples from the attached wooden 'ledges' are required to clarify its construction. Figure 6-24 shows a closeup of wood attached to S23. The purpose of the rectangular cut-out with wood insert at frame component F47-11, under the after of the two wood ledges attached to S23 (Figure 6-24b and 6-25), is not clear. The wood ledge was attached directly over the rectangular cut-out, and the cut-out was directly over frame component F47-11. A sample taken from the wood insert filling the rectangular cut-out proved to be Mediterranean cypress, a different wood than that of the main portion of the stringer. It is possible that this plugged cut-out indicates S23 was repurposed from a previous use, with the hole patched when the wood was installed on the Trstenik ship. Or, this cut with insert may merely reflect a repair to S23.

a. S23 at frame 61, looking aft.

b. S23 at frame 47, looking aft.

Figure 6-24. Detail Views of Stringer S23. Figure 6-24a shows attached wood ledge at frame component F61-12, looking aft. Figure 6-24b shows attached wood ledge at frame component F47-11, looking aft. Note the rectangular cut-out of S23 under this attached wood, filled in with an insert.

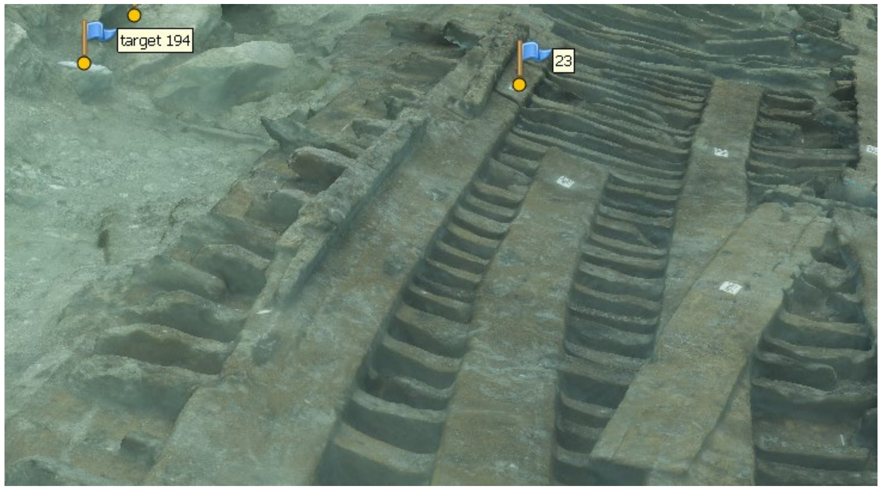


Figure 6-25. Photogrammetry Showing Stringer S23. This view from the PhotoScan 3-D model shows the two separate wooden ledges attached to the stringer.

The two ledge-like attachments treenailed to the upper edge of S23 are not perfectly aligned with each other (Figure 6-25). Based on their appearance, one potential purpose could have been service as some sort of support or track for a sliding access to the ship's hold. Before the starboard side of the Trstenik ship broke outwards after scuttling, S23 was positioned vertically at the same height above the keel as the lowest of the ship's three wales. This is reflected in S23's location directly over the top of wale W1S in the ship's hull remains (Figure 6-18). Based on being attached to S23 only by treenails, it is not likely that the wooden ledges could have supported significant weight, particularly when the ship was underway. Additional study of this component and its function is warranted.

6.6 Radiocarbon Dating

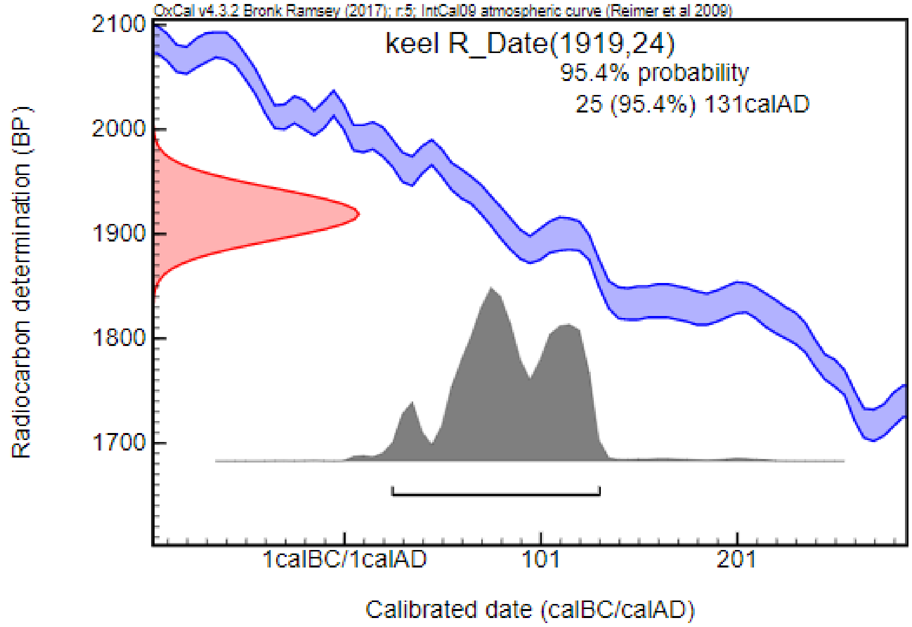
Radiocarbon analysis was performed on two wood samples from the ship. One sample was taken from the keel (subsequently identified as beech), and the second from a small branch with bark still attached (subsequently identified as sycamore), found wedged between stringer S21 and frame component F48-11, in the center of the ship on the starboard side, likely dunnage. These two samples were selected as most likely to be the oldest and newest pieces available on the ship, in an attempt to fully bracket the potential date range of the hull. The radiocarbon results are provided in Table 6-12 and Figure 6-26.[273]

[273] Analyses performed by the University of Georgia Center for Applied Isotope Studies.

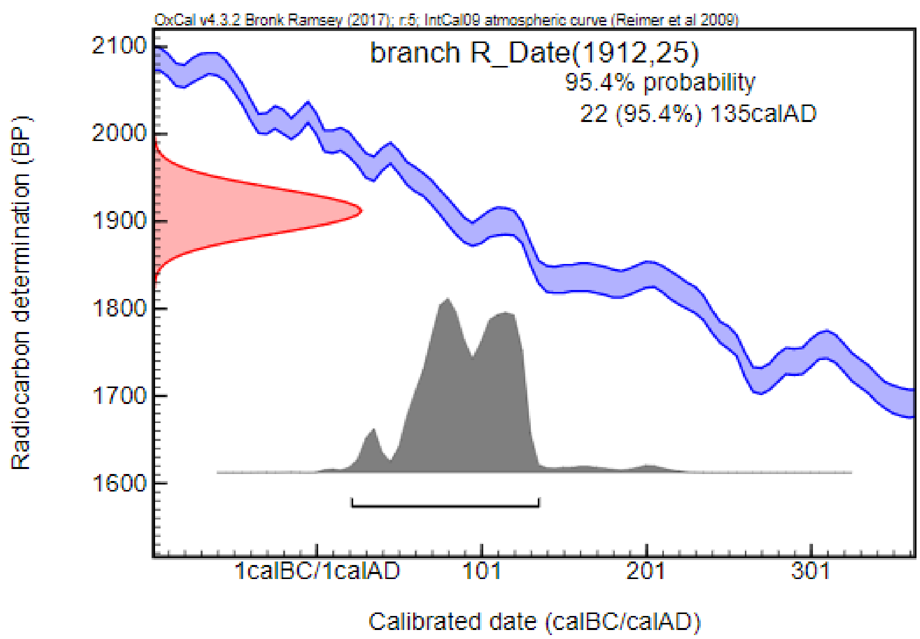
Sample	Material	UGAMS #	pmC ± 1σ		$\delta^{13}C$ corrected Radiocarbon age (YBP)		$\delta^{13}C$
keel	beech	22819	78.69	± 0.24	1919	± 24	-25.7
branch	sycamore	22818	78.76	± 0.25	1912	± 25	-25.7

Sample	Material	UGAMS #	1σ (68.2%) range (CE) From	To	relative area	2σ (95.4%) range (CE) From	To	relative area
keel	beech	22819	60	90	0.589	26	42	0.068
			100	123	0.411	47	130	0.932
branch	sycamore	22818	68	92	0.48	24	134	1.0
			98	125	0.52			

Table 6-12. Radiocarbon Analysis and Stable Isotope Ratio $\delta^{13}C$ Results. Uncalibrated dates given in radiocarbon years before 1950 (YBP) using a ^{14}C half-life of 5568 years. Calendar calibrations made using Calib v.6.1.0 with calibration data set intcal09.14c.



a. Keel.



b. Branch.

Figure 6-26. OxCal Radiocarbon Calibration Graphs. Graphs generated by inputting the radiocarbon analysis results into the OxCal program, version 4.3.

The two date ranges provided by radiocarbon dating are overlapping and consistent. There is no "old wood problem" apparent in the keel dating, which could have resulted from the keel being shaped from the heartwood of a large tree, or by the keel having been cut, aged and seasoned for a length of time before being used, either of which could have resulted in a significantly older date than the branch. No date separation or an estimated life span for the ship is apparent from comparison of the two samples. Additional radiocarbon analysis coupled with dendrochronological or tree ring analysis are required to narrow down the Trstenik ship's construction and operational life beyond mid-1st to early-2nd century CE.

6.7 Tree Species Analysis

Table 6-13 summarizes the different tree species identified in the Trstenik ship's hull. After analyzing over 300 wood samples from the ship, a total of six softwoods (conifers) and 11 hardwoods (deciduous trees) were identified. Guibal and Pomey make this comment about tree species diversity in ancient ship construction:

> A small number of species identified on a same hull means homogeneity and often quality; on the other hand, a high number of species may reflect as well structure complexity, timber supplying problems or repairs without jeopardizing the structure homogeneity. Besides that, species diversity…means actual structure heterogeneity and probably a lesser construction care resulting from timber shortage. Moreover it can be said that homogeneity of axial elements and planking contrasts with the heterogeneity of frames. Less care seems to prevail in frame construction of which the function appears quite secondary when compared to strakes for which much more carefulness is allocated…it does not make much sense in assessing geographical location to the shipyard where the ship was built unless homogeneous taxonomy of the hull and a restricted geographical distribution area for species identified occur together.[274]

[274] Guibal and Pomey 2003, 38, 41.

Tree	Species
Conifers (softwood)	
Aleppo pine	*Pinus halepensis*
Black pine	*Pinus nigra*
Mediterranean cypress	*Cupressus sempervirens*
Scots pine	*Pinus silvestris*
Stone pine	*Pinus pinea*
Turkish pine	*Pinus brutia*
Deciduous (hardwood)	
Alder	*Alnus* sp.
Ash	*Fraxinus excelsior*
Beech	*Fagus sylvatica*
Birch	*Betula pendula-B. pubescens*
Chestnut	*Castanea sativa*
Elm	*Ulmus campestris*
Olive	*Olea europaea*
Sessile oak	*Quercus petraea*
Sycamore	*Acer pseudoplatanus*
Turkey oak	*Quercus cerris*
Walnut	*Juglans regia*

Table 6-13. Tree Species Identified in the Trstenik Ship's Hull Remains.

The wood sourced to form the strakes of the Trstenik hull is neither homogeneous (largely Aleppo pine, black pine, and Mediterranean cypress, with one sample each of Scots pine and stone pine) nor restricted in geographical area. Thus, geographical identification of the construction location based on hull planking is not feasible. Russell Meiggs notes:

> The mountain chain behind the east coast of the Adriatic and the mountains behind them were rich sources of timber, which later helped to maintain the fleets of Venice. Salona was the best port on this coast. There happens to survive an inscription of a timber merchant, *negotiator materiarius* in the district, and we know that the territory was well wooded. It would be surprising if Salona was not concerned with timber export.[275]

A port with large timber export would certainly have a large variety of tree species passing through, potentially available for local use.

Several points should be considered while reviewing the types of wood used to build the Trstenik ship:

1) Aleppo pine is the most common material used in the ship. Almost 50% of the frames were of Aleppo pine. Aleppo pine and black pine were used roughly in equal proportion for both strakes and stringers, with a significant contribution from Mediterranean cypress, suggesting wood from all three of these tree species must have been readily available.

2) The keel, the largest single timber in the ship, is made of beech. Beech is found in only one other sample, a peg. Beech was either a rare, uncommon tree, or it was not locally available, and the timber for the ship's keel was obtained from elsewhere.

3) The most common hardwood used in frames is chestnut. Chestnut must have been readily available for use in building the ship.

[275] Meiggs 1982, 355.

4) Treenails are mostly made of sycamore, which also appears in framing 14 times, tied for the third-highest frequency of wood species used in frames. Sycamore wood must have been locally available and common.
5) One possible ship origin indicator is the identification of a single sample of Turkish pine (*Pinus brutia*), used to fashion frame component F50-11. That tree is not found in Dalmatia today (see Figure 6-27), and its identification could indicate ship assembly in a construction yard to the east, in Greece or Turkey.[276] However, the modern distribution of a tree species may not accurately reflect its ancient distribution.[277] Additionally, basing the construction location of the entire ship on one sample result out of hundreds is problematic. The sample could be identified incorrectly, this frame component could have been installed as a repair made years after the original construction, and it is also possible this frame component could have been repurposed from another ship. More data is required before making such a bold claim.
6) In addition to Turkish pine, four other tree species were detected only in a single sample: walnut, alder, olive, and Scots pine. These trees may not have been commonly available where the ship was constructed.

[276] Coode and Cullen 1965, 73-5.
[277] Ferreira Dominguez 2019.

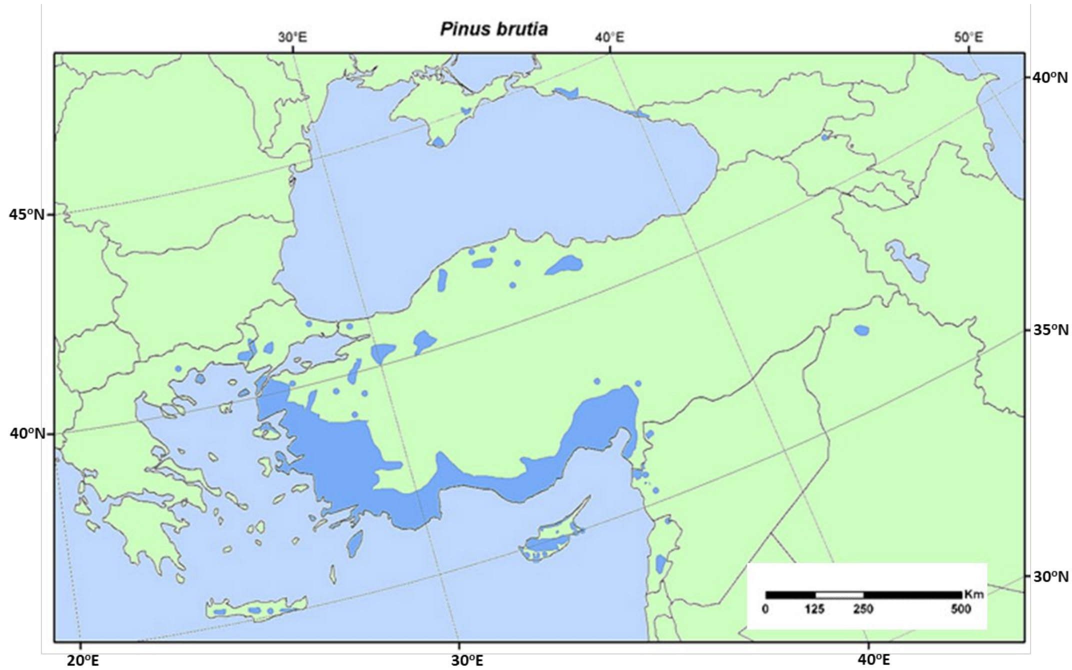


Figure 6-27. Modern Distribution of Turkish Pine (*Pinus brutia*). Distribution in dark blue.[278]

6.8 Summary of Hull Remains

The Trstenik hull remains demonstrate a shell-first-built hull constructed in the Roman pegged mortise-and-tenon fashion, with multiple consecutive flat-floored frames and a centrally-dense framing pattern, suitable for transport of heavy loads in relatively shallow coastal waters. Despite a wide variety of typical Mediterranean wood species used in its construction, there is no clear ability to narrow down its origin to a specific locale, as the most common tree species used in its construction were widely available throughout the Mediterranean basin. Based on radiocarbon dating, the ship was constructed between the middle of the 1st century CE and the early 2nd century CE, and

[278] Euforgen 2009.

its hull repairs indicate that it was well-used before its scuttling alongside a seawall 3 km from Salona, the Roman capital of the province of Dalmatia. While the lack of additional remains (mast step, rigging materials, decking, etc.) removes some certainty regarding the exact construction and layout of the ship, its hull shape is well-preserved against the seawall, and the maximum extent of preservation demonstrates the ship had at least three wales and 16 strakes. Thus, the hull shape can be reconstructed with a high degree of certainty, and computer modeling of the hull should generate a reasonable estimate of the ship's displacement under sail based on its draft.

7. SHIP RECONSTRUCTION

7.1 Compendium of Similar Ships

7.1.1 Introduction

Reconstruction of a ship studied with photogrammetric documentation, but not excavated completely, has to rely on other sources of information to fill in the blanks and extrapolate hypothetical, but reasonable and defensible choices to complete the reconstruction. The Trstenik ship benefits greatly from fairly complete hull remains up to the first wale on either side of the keel, and a site formation process against a rigid vertical wooden surface that preserved the shape of the bilge on the port side. However, like most ancient wrecks the caprail, the extremities of the hull at the bow and stern, and the upper works were not preserved. Additionally, since the Trstenik ship was scuttled, many large reusable parts of the ship, including the mast and the mast step, as well as any smaller, portable components and equipment such as rigging, oars, bilge pump, cargo, and personal possessions of the sailors were removed in antiquity. While there is no guarantee any of these items would have survived intact to the present day, certainly the amount of material left on the ship before it was filled with rocks and scuttled was minimized before the ship was repurposed to strengthen a sea wall.

To support hypothetical extension of the hull of the Trstenik ship beyond the observed wooden remains, it is appropriate to examine previously well-documented Roman-era wrecks and identify common features that reinforce the assumptions that must be made to complete the ship's reconstruction. After reviewing the corpus of publications for ship excavations and reconstructions, and focusing on reconstructions based on the thorough study of shipwrecks with significant percentage of hull survival, three main factors were considered to filter the number of ships examined for reconstruction purposes: 1) date, 2) size, and 3) construction tradition. The first factor was the estimated date of a wreck. The Trstenik shipwreck was radiocarbon dated to between the mid-1st and early-2nd centuries CE (Section 6.6). Thus, emphasis was placed on choosing wrecks dated between the 1st century BCE and the 2nd century CE in order to bracket the Trstenik remains in time. Wrecks from this time period were also filtered by the size of the wreck; with the 11 m of Trstenik remains indicating a ship of approximately 12-16 m in length, any contemporaneous wrecks estimated to be greater than 25 m in length were excluded from the comparison. Lastly, with the Trstenik ship constructed using the typical Roman pegged mortise-and-tenon construction technique of that era, ships built in different construction traditions, such as Liburnian sewn or laced boats, were excluded from the comparison.

After application of the three factors mentioned above (date, size, and construction tradition), three other factors were then considered to override the date criterion and include in the study a specific ship reconstruction if appropriate. First, any Roman-era ship reconstruction of appropriate size that was sufficiently extensive to develop a set of ship's lines was considered for addition to the compendium of similar ships, even if the date of the ship was outside the 1st century BCE to the 2nd century CE. The significant amount of work required to develop ship's lines warrants consideration of that ship's hypothetical reconstruction in the development of a Trstenik ship reconstruction. Additionally, two uncommon construction features seen in the Trstenik ship were also noted in other Roman ships. Including such ships in the study might facilitate the reconstruction process. The Trstenik ship was a flat-floored, barge-like craft, with multiple consecutive flat-floored frames, in contrast to the early Imperial Roman framing pattern of floors with futtocks alternating with paired half-frames. Therefore, other Roman-era ships with evidence of multiple consecutive flat-floored frames were added to the comparison list. Lastly, the Trstenik ship has two fairly complete wales on either side, with evidence of a third wale preserved in one small portion of the hull. Thus, some otherwise-excluded Roman ship reconstructions displaying multiple wales were added to the comparison list.

Several sources contributed significantly to the development of this compendium. First, in a seminal 2012 article Pomey, Kahanov and Rieth explored the corpus of ancient ship remains to propose a transition sequence between "shell-first" and "skeleton-first"' construction of ancient ships.[279] Their transition chronology began with the 2nd century CE "Western Roman Imperial" type, ships that were conceived and built shell-first, with flat frames, rounded turn of the bilge, and tight-fitting mortise-and-tenon joints, all characteristics shared by the ship at Trstenik. However, other characteristics they ascribed to the Western Roman Imperial type, including overlapping half-frames, floor timbers bolted to the keel, and a long mast-step or keelson set on two sister keelsons were characteristics either not present or not observed on the Trstenik ship.[280]

[279] Pomey et al. 2012.
[280] Pomey et al. 2012, 237, 306.

As some of the characteristics do match and the time frame is within 100 years, several ships included in their analysis as representative examples of the Western Roman Imperial tradition were added to the comparison list. Second, Kevin Melia-Teevan undertook a detailed study of the evolution of ancient framing patterns from the 5th century BCE to the 9th century CE, including an extensive compilation of shipwrecks sorted by century to support his conclusions. His work was an excellent source of data for the Trstenik reconstruction.[281] Lastly, the compendium of ships maintained by the Texas A&M Ship Lab provided a wide-ranging library to consult for reference material.[282]

After studying the available references and collating the features of the specific ships, a total of 20 ships were selected for study and reconstruction of the Trstenik ship reconstruction (Appendix B). The breakdown of applicable areas of interest is as follows:

Date: 13 examples (Section 7.1.3)

Ship's lines: 6 examples (Section 7.1.4)

Multiple consecutive flat-floored frames: 8 examples (Section 7.1.5)

Multiple wales: 7 examples (Section 7.1.6)

Of note, only two ship reconstructions of the 13 contemporaneous examples selected included ship's lines, and only three among them were fitted with multiple wales. In

[281] Melia-Teevan 2016.
[282] Castro et al. 2018.

contrast, six of the eight ships with multiple consecutive flat-floored frames are contemporaneous with the Trstenik wreck.

It is appropriate to introduce the relevance of these 20 ships to the Trstenik shipwreck reconstruction. First, due to the disassembly, removal, and detailed measurements of many of these wrecks taken on land, there is significantly more information available for some of them than can be gleaned from the photogrammetric documentation of the Trstenik wreck. Second, as most of these ships have benefited from extensive study over years or even decades, it is apt and efficient to capitalize on the parallels between these ships and the remains of the Trstenik shipwreck.

7.1.2 Contemporaneous Imperial Roman-Style (Mortise-and-Tenon) Constructed Ships

The earliest archaeological evidence of pegged mortise-and-tenon joinery is found in the construction of early Dynastic coffin lids discovered at Tarkhan, Egypt, dated to the very beginning of the third millennium BCE.[283] The unique conditions found in Egyptian tombs allowed 5000-year-old wood to survive to the present day for archaeological study. Due to the sparse archeological record, the number of years required to spread this technology out of Egypt and into the ancient world cannot be ascertained. However, tables found in a tomb in Jericho, dated to the 17th or 16th century BCE, were also assembled with mortise-and-tenon joinery.[284]

The earliest archaeological evidence of mortise-and-tenon ship construction found to date is the Bronze-Age Uluburun shipwreck, dated to approximately 1320

[283] Ward 2000, 32.
[284] Simpson 2010, 62.

BCE.[285] This construction technique is a shell-first assembly, cutting a mortise into the edges of two adjoining planks, then inserting a wooden tenon into each mortise and pegging it on either side of the seam to lock the two planks together. Connecting planks together in this manner formed a shell to define the shape of the hull, rather than constructing a skeleton of frames to pre-define the ship's shape, then waterproofing the skeletal structure with planking. The Uluburun shipwreck and the Cape Gelidonya shipwreck (approximately 1200 BCE) both exhibit the shell-first style of construction, although the smaller Cape Gelidonya vessel had smaller mortise-and-tenon joints.[286] Similar to the later technology of using double-clenched nails, pegged mortise-and-tenon joints provide positive fastening on both sides of a planking seam and do not require reinforcement. Additionally, tightly fitted tenons within their mortises provide a significant resistance to shear force.[287] This construction technique was also used in the Kyrenia shipwreck, a 4th century BCE ship found off the coast of Cyprus and studied extensively,[288] then replicated to full-scale three separate times.

The changing depth and spacing of mortise-and-tenon joints over time was discussed by Steffy as shipbuilding evolved into the Roman Imperial era:

> Most of the strength of Bronze Age watercraft was vested in their shells of outer planking. Planking was thick, sometimes carved to shape, and its seams were reinforced with mortise-and-tenon joints that were locked with pegs, at least by the late Bronze Age. Frames and other structures were relatively weak and undeveloped…the Kyrenia ship's…planking shell was still the primary structure, and its major features were its strong system of edge joinery and the expeditious

[285] Pulak 2003, 28. For a full discussion of Uluburun hull remains see Pulak 2002.
[286] Pulak 1998, 210-13.
[287] McGrail 2008, 618.
[288] Steffy 1985.

> use of hull shapes for added strength. This was a much more efficient planking shell than that of the Bronze Age vessels, because it was lighter, stronger, and better fastened….Throughout the remainder of the Roman period there were improvements in design and structure, and hulls probably became increasingly structurally efficient. But much of this added efficiency was vested in innovations and additions to the overall structure, not to the systems of edge joinery…the strength of mortise-and-tenon joint systems was being replaced with better framing, keelsons, ceiling, and deck structure…But in spite of all the excavations now published for the classical and early medieval periods in the Mediterranean, we still do not know exactly how shipbuilders arrived at designs for larger hulls…we can be sure, however, that mortise-and-tenon joints played a major role in this transition.[289]

While the exact study of mortise depth and spacing, and tenon shape, size, and material must be postponed until the Trstenik ship is fully excavated and studied, it is clear that the ship was built shell-first using pegged mortise-and-tenon construction. Thus, all the ships that appear in Appendix B were built in the same way.

7.1.3 Reconstructions with Generated Sets of Ship's Lines

It is not a trivial exercise to develop a set of ship's lines from the remains of a ship. Deriving a set of lines requires extensive recording and analysis of the ship's remains, either on paper, on a computer, or both, followed by educated extrapolation of the remains to complete missing portions and present a reasonable hull shape and reconstruction.

Of the six examples of Roman-era mortise-and-tenon constructed ships with reconstructed ship's lines (Appendix B), the four closest to the Trstenik ship in time are the Chrétienne C, Cavalière, Saint-Gervais 3, and La Bourse shipwrecks, published

[289] Steffy 1994, 83-4.

between 1975 and 1990. In all four cases wreck information was transformed manually into a hypothetical set of ship's lines. While it is informative to study the lines of each of these four ships, there is no 'perfect match' among them with the remains found at Trstenik.

The Chrétienne C wreck was discovered in 1953 near Cannes, France, at a depth of 35 m and excavated from 1970 to 1973.[290] The ship, built in the 2nd century BCE, about 200 years earlier than the Trstenik ship, is reconstructed with a hull that has a wineglass-shaped cross section. Its frame spacing of 46 cm for the 20 surviving frames or partial frames is significantly more wide than those of the Trstenik ship. While the published information is insufficient to develop a reliable set of ship's lines for the Chrétienne C wreck, the photographs of the wreck, the drawings of the frames, and the deadrise angle of the garboard strake with the keel all appear to indicate a significantly flatter bilge than the ship's lines presented in its publication.[291]

Of the ships with line drawings, the Cavalière wreck is the most similar to the Trstenik wreck in both era and size.[292] The wreck was discovered in 1972 at a depth of 43 m at the entrance to the Bay of Cavalière, just east of Le Lavandou, France. It was excavated from 1974 through 1977. While its line drawings were generated as a mathematical attempt to determine the ship's displacement rather than to communicate the shape of the hull, these ship's lines are valuable for comparison to the Trstenik ship's reconstructed lines (Figure 7-12).

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[290] Joncheray 1975a.
[291] Joncheray 1975a, 76-7.
[292] Charlin et al. 1978.

The Saint-Gervais 3 wreck was discovered in 1978 near Saint-Gervais, France, and was excavated from 1983 through 1986.[293] Like the Chrétienne C wreck, the drawings of the frames in the publication appear flatter than the rounded hull portrayed in the lines drawing.[294] Additionally, the ship's lines were artistically drawn to show the Saint-Gervais 3 wreck as a ponto-style ship, with a sharply vertical and concave stem.[295] The evidence for this choice is not obvious in the wreck photographs or keel and frame drawings. Thus, the Saint-Gervais 3 wreck is of limited usefulness in the Trstenik wreck reconstruction.

Lastly, the La Bourse shipwreck from Marseille has a set of ship's lines developed from its remains, which were found during land excavations in the 1970s to construct a history museum.[296] The ship's conserved remains are now prominently featured on display in the Musée d'Histoire de Marseille. However, the La Bourse framing pattern, with frames bolted to the keel, and its dating to the late 2nd or early 3rd century CE place it firmly in the Western Roman Imperial tradition of ship construction discussed in Section 7.1.1. Its more massive construction to support its large size of 23 m (reconstructed) make its line drawings of limited utility for the analysis of the Trstenik shipwreck.

Two other ships selected for the compendium have line drawings developed in their reconstructions. While these two ships are not contemporaneous with the Trstenik

[293] Liou et al. 1990.
[294] Liou et al. 1990, 262-3. There is an obvious mismatch between the flat, transverse section of figure 136 compared to the wineglass-shaped body plans of figures 135 and 137.
[295] Liou et al. 1990, 223.
[296] Gassend 1982.

ship, their lines were generated more recently, and the techniques used for these line drawings are worthy of consideration.

The Fiumicino 1 ship was discovered in 1959 in Rome's Claudian harbor during land excavations in preparation for building the Leonardo da Vinci airport. The ship was preserved, reconstructed, studied, and placed on display. The hull remains have recently been extensively measured, modeled, and reevaluated.[297] The ship, dated to the 4th or 5th century CE, is currently envisioned as a *navis caudicaria*, a harbor service vessel, either sailed or towable. These craft were used to unload large ships arriving at Portus, Rome's Imperial harbor, and to transport cargo up the Tiber River to Rome. Unfortunately, there is no surviving archaeological field documentation of the Fiumicino 1 ship, either *in situ* or during its excavation.[298] However, extensive measurements of the preserved hull were combined with photographs taken during the original excavation to develop transverse section measurements, and in an iterative process the original dimensions of the vessel were reconstructed. Ultimately the decisions made were confirmed and enhanced by measuring illustrations and reliefs of similar ships, comparing dimensional ratios, developing a set of ship's lines, and finally building a model of the ship to verify its dimensions.[299]

Lastly, the Dramont E shipwreck, a 5th-century CE shipwreck discovered in 1965 at a depth of 42 m near Cape Dramont, France, was excavated exhaustively over eight

[297] Boetto 2000, 2001, 2003 and 2008 track the reevaluation of the Fiumicino 1 ship.
[298] Boetto 2000, 99.
[299] Boetto 2003, 67-8.

seasons between 1981 and 1991.[300] The comprehensive publication of the excavation did not include a set of ship's lines. However, 20 years later the meticulous recording of the remains provided sufficient data to reconstruct the hull, while the upper sides, superstructure, and rigging were hypothesized based on iconographic evidence and comparable archaeological remains.[301] The three-dimensional computer model developed was sufficiently detailed to allow computer hydrostatic testing of the ship as well as estimation of the ship's cargo capacity, displacement, center of gravity and center of buoyancy, demonstrating the seaworthiness of the hypothetical vessel.[302]

7.1.4 Ships Exhibiting Multiple Consecutive Flat-Floored Frames

The compendium of similar ships (Appendix B) includes eight ships with multiple consecutive flat-floored frames. This construction pattern differs from the Western Roman Imperial style (Section 7.1.1), which exhibits floors with futtocks alternating with paired half-frame combinations. Six of the eight multiple consecutive flat-floored ship examples are contemporaneous with the Trstenik wreck.

Of the two multiple consecutive flat-floored ships in the compendium not of similar time frame, the Chrétienne C wreck is the older, dated to the 2nd century BCE.[303] As discussed in Section 7.1.3, the 1970s-era excavation and publication of the Chrétienne C shipwreck occurred early in the field of nautical archaeology, and hence its reconstruction is somewhat lacking in documentation and precision. However, the

[300] Santamaria 1995.
[301] Poveda 2008, 2012.
[302] Poveda 2012, 332-6.
[303] Joncheray 1975a.

documentation does show two series of six consecutive floors that cross the keel without being attached to it, and if the frame component missing between these two series of six consecutive floor timbers was a central floor timber (which is unclear from the documentation), there would have been at least 13 consecutive flat floors in this ship.[304] Due to its earlier date, many other construction characteristics of the Chrétienne C ship, such as trapezoidal tenon shape, S-curved planking scarfs, and a significantly larger floor spacing, do not match those of the Trstenik ship. Regardless, the Chrétienne C shipwreck does demonstrate that ships with multiple consecutive flat floors were constructed during the Republican era.

The other non-contemporaneous ship with multiple consecutive floors, which postdates the Trstenik ship, is the Dramont F wreck of the 4th century CE.[305] Found near Cap Dramont, France, and excavated at a depth of 58 m in two seasons in the early 1970s, too little of the hull survived to make a useful plan, so the publications concentrate on the amphoras and other artifacts recovered. The sole sketch of the hull and framing indicates at least three consecutive floors, with the floors bolted to the keel in Western Roman Imperial fashion.[306] The Dramont F wreck is evaluated as a 10-13 m long and 4-5 m wide ship of crude construction, with irregular ceiling planking running parallel to the keel and nailed to the frames, and carrying a cargo of 120 amphoras filled with pine resin.[307] While the length of the Dramont F wreck is approximately similar to

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[304] Joncheray 1975a, 48.
[305] Joncheray 1975b, 1977.
[306] Joncheray 1975b, 126.
[307] Joncheray 1977, 5-7.

the Trstenik wreck, its breadth measurement is significantly narrower than that of the Trstenik hull. Moreover, the frame spacing of Dramont F is much wider than the spacing observed on the Trstenik ship, indicating a ship designed to carry a lighter, less massive cargo than the Trstenik ship.

For the purpose of this study, six contemporaneous shipwrecks with consecutive floor frames have been considered to add information to the reconstruction of the Trstenik ship. Two of these ships were *dolia* carriers, two others carried heavy cargo, and the final two add perspective to the configuration of the mast step, which is missing from the Trstenik ship.

Dolia carriers may be seen as tankers of the ancient world.[308] These ships were unique to the end of the Roman Republic and the beginning of the Roman Empire, and were specifically built to carry *dolia*, massive ceramic containers for bulk liquids such as wine or olive oil, or for loose bulk material such as grain. Given their short historical time span, it is possible that design issues with the ships that carried these heavy jars resulted in poor seaworthiness, thus rapid obsolescence.[309] In all likelihood, wine transported in these large containers would have been decanted upon ship arrival inport into either amphoras or casks for further distribution.[310] While at least 16 examples of *dolia*-carrier shipwrecks are known,[311] the two *dolia* ships that add reconstruction information to the Trstenik ship are the La Giraglia and Ladispoli A wrecks.

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[308] For the most comprehensive single source of *dolia* ship information, see *Archaeonautica* 15 (2008), which includes several articles and a comprehensive bibliography.
[309] Marlier and Sibella 2002, 161.
[310] Tchernia 2016, 108-9.
[311] See Cibecchini et al. 2013, 31 for a map of 14 *dolia* wrecks, concentrated along the coast of France, northern Italy and Corsica in the Tyrrhenian Sea. Additionally, Marlier and Sibella 2002, n. 2 reports a

The La Giraglia shipwreck was discovered in 1993 near the islet of La Giraglia, at the northern tip of Corsica. The site was surveyed and excavated over four campaigns in the late 1990s.[312] This ship, with estimated dimensions of 20 m long by 7 m width, carried at least eight *dolia*, all of which were broken, and is estimated to have also carried about 200 amphoras of several types. While the keel and most of the hull did not survive, and what did survive was in a poor state of preservation, there was evidence of 13 planking strakes connected by pegged mortise-and-tenon joinery, as well as 26 frames that had been treenailed to the hull planking. Although the keel did not survive, it is likely that these frames include multiple floors, although this cannot be proven. The relatively close frame spacing of 13-22 cm was required to support the massive *dolia*, with estimated capacities calculated in excess of 2,500 liters.[313]

The Ladispoli A wreck was excavated over three seasons from 1983 to 1985 off the west coast of Italy near Ladispoli, about 40 km northwest of Rome.[314] Five undamaged *dolia* of two different types were recovered from the wreck, along with fragments of other broken *dolia*, the weight of which contributed to the protection and survival of the hull remains. While the preservation of the frame floors crossing the keel was not complete, the documentation of the surviving hull and keel area, coupled with

dolia wreck at Cala di Conca in southern Corsica, and Radić Rossi 2006a, 55 reports a *dolia* wreck near Supetar Island off Cavtat, Croatia. See Heslin 2011 for additional *dolia* and fragments found at underwater sites, which possibly indicate wrecks but are not yet confirmed. For some of the underwater *dolia* sites, it is not possible to discern if the ship was a '*dolia* wreck,' or merely a regular ship transporting new *dolia*.

312 Marlier and Sibella 2002; Marlier and Sciallano 2008.

313 Marlier and Sciallano 2008, 121.

314 Carre 1993.

markings where non-surviving frames had been positioned, indicates 26 consecutive floor timbers crossed the keel over a length of less than 7 m.[315]

Lastly, a detailed model of a hypothetically reconstructed, generic *dolia* carrier was developed based on data from multiple *dolia* shipwreck excavations.[316] Although this model cannot be considered a primary source, the model design and decision processes were documented extensively, providing additional insight into the construction and development of a ship with multiple consecutive flat-floored frames. This hypothetical model incorporated some of the observed features noted in *dolia* shipwrecks that lacked sufficient hull remains to undertake a stand-alone reconstruction.[317] A recent reevaluation of that model estimated that a *dolia* ship would have been built around the *dolia*, with smaller *doliola* wedged in gaps to take up space and make the load more rigid and seaworthy. The ship's deck beams would be installed next to fully lock the *dolia* in place. This construction theory suggests vertical bulwarks for a *dolia* ship and proposes a shared location for the constructing shipyard and the *dolia* kiln site.[318]

Unfortunately, none of the *dolia* ship excavation publications discusses any mounting or support system found underneath the large containers. The reevaluation of the hypothetical model proposes no such structure, leaving the area underneath the *dolia* conspicuously empty.[319] No specific deck or frame structure that could have supported

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[315] Carre 1993, 13.
[316] Carre and Roman 2008.
[317] Additional *dolia* wrecks utilized in model development include Ouest Giraglia 2 (Cibecchini et al. 2013), Grand Ribaud D (Hesnard 1988), and Diano Marina (Pallares 1987, 1991).
[318] Roman 2018.
[319] Roman 2018, 235, figure 3.

dolia was excavated in the remains at the Trstenik wreck, nor were there any markings on stringers or frames that could be interpreted as evidence of the weight of a *dolium* pressing upon the Trstenik hull for an extended period of time.

Two ships contemporaneous with the Trstenik wreck that exhibit multiple consecutive flat-floored frames are known to have been heavy cargo carriers, thanks to the materials recovered from the wrecks. The Sud-Lavezzi 2 wreck was discovered at a depth of 42 m in 1978 near the small islet of Lavezzi in the notorious Straits of Bonifacio between Corsica and Sardinia, known for its shifting, variable currents and treacherous shoals. The shipwreck was excavated in three campaigns between 1979 and 1981.[320] Although the site had been looted of some of its amphoras before the excavation began, over 200 amphoras of various types were recovered. Additionally, a significant amount of copper and lead ingots survived to be excavated. Their loading low in the ship preserved their original arrangement in the ship's hold. The rectangular lead ingots were loaded longitudinally to straddle the floor frames, followed by amphoras arranged over the ingots. This kept the center of gravity of the ship low and, fortuitously, hid the ingots from looters 2,000 years later. The lead ingots were concentrated towards midships in approximately nine rows laid athwartships, while disc-shaped copper ingots, also placed on top of closely set frames, were loaded forward and aft of the lead.[321] A total of 95 lead ingots and 237 copper ingots were recovered from the wreck. The close spacing of the frames facilitated the transport of over 10 tons of

[320] Liou and Domergue 1990.
[321] Liou and Domergue 1990, 50, 53-7.

metal ingots in addition to hundreds of amphoras. While the hull was not studied in detail, photographs show an irregular framing pattern with at least three consecutive flat floor timbers crossing the keel. A repeating frame pattern consisting of three flat floors followed by two paired half-frames is postulated, but not clearly documented in either site photographs or frame drawings.[322] Regardless, the frame pattern and close spacing of the Sud-Lavezzi 2 ship facilitated the lading and transport of particularly dense and heavy cargo.

Another ship with a heavy cargo supported by multiple consecutive flat floor timbers was the Lardier 4 shipwreck, discovered 100 m south of Cape Lardier, the southernmost tip of La Croix-Valmer, France, between Marseille and Nice, and excavated in four seasons between 1995 and 1999.[323] This ship was a tile carrier found at a depth of 22 m, laden with a cargo of approximately 400 roof *tegulae* arranged in nine rows laid athwartships, stacked in two levels, with a total tile cargo weight of approximately six tons. Despite the weight of the cargo pressing down on the hull, the sandy bottom resulted in poor hull preservation. However, photographs and a drawing show at least three consecutive flat-floored frames preserved underneath the tiles, with a fairly narrow average spacing of 27 cm. Thus, hulls constructed with multiple consecutive flat-floored frames were recognized to provide superior strength when carrying large, dense and heavy cargoes of various types. This information adds additional possibilities to the potential original use of the Trstenik ship.

[322] Liou and Domergue 1990, 121.
[323] Joncheray and Joncheray 2004b.

With the mast step missing from the Trstenik wreck, it is useful to examine data that could add information to that aspect of the reconstruction. One ship previously discussed, the Ladispoli A *dolia* carrier, and another ship with multiple consecutive flat-floored frames, the Baie de l'Amitié wreck, share another characteristic of the Trstenik ship: angled notches cut on either side of a floor timber, over the keel. The Ladispoli A wreck had enough planking and keel preserved to indicate at least 26 regularly spaced successive flat-floored frames in a keel length of 7 m. This is a frame spacing of 27 cm, corresponding more closely to the Trstenik ship's frame spacing at the bow and stern of 22 cm rather than the dense midships spacing of only 13 cm (Section 6.4.2). While some of the Ladispoli A frames did not survive over the top of the keel, their presence is hypothesized based on staining left on the keel and adjacent planking. The site plan indicates six floors were notched at an angle on both the forward and aft edges of the floor timbers in frames 11, 13, 15, 17, 19 and 21.[324] This notching is similar to the notches found on F61 of the Trstenik ship (Section 6.4.7). The remains of the Ladispoli A mast step extended from double-notched frame 11 to unnotched frame 18, with the hole for the mast directly over unnotched frame 12.[325] Thus, the surviving extent of the Ladispoli A mast step began and ended at a floor frame, resting on a total of eight frames (four of them double-notched) at a total length of 1.6 m.[326] It is surmised that the original mast step may have extended over all six of the double-notched floors, a length

[324] Carre 1993, 13.
[325] Carre 1993, 18.
[326] Carre 1993, 19.

of 2.5 m. This length corresponds well with the hypothetical length of the Trstenik ship's mast step, calculated to be 3.35 m (Section 6.5.3).

The poorly preserved Baie de l'Amitié wreck was first located in 1961 in 3 m of water approximately 150 m off the coast near Agde, France, about 150 km west of Marseille. The location of the wreck was subsequently lost, unsuccessfully searched for in the 1980s, and ultimately rediscovered in 1997.[327] The small section of remains, 7.75 m long by 3.2 m wide, included a portion of keel, five strakes to one side and nine strakes to the opposite side of the keel, and portions of 22 frames spread over 5.8 m of hull. This is an average frame spacing of 27 cm, the same value calculated for the Ladispoli A ship. Unfortunately, the mast step did not survive. As there was not sufficient hull survival to determine the bow and stern of the wreck in the field, the 22 frames were numbered from the surviving end of the hull toward the center of the ship. Frames 3, 5, 7, and 9 through 13 are all flat floor timbers. With respect to notches in the frames, frame 3 has a square notch on the side of the frame facing amidships, and frames 5, 7, 9, 11, 12, and 13 all have angled notches on both the forward and aft edges of the frames.[328] While not identical, this notching pattern is similar to that observed on the Ladispoli A wreck. If this configuration matches that of the Ladispoli A wreck, where the mast step was evaluated to extend over all of the angled, double-notched floor timbers, the Baie de l'Amitié remains would correspond to the bow of the ship, the mast step would have stretched from frame 5 to frame 13, for a total length of 2 m, and the

[327] Wicha 2002, Jézégou 2003.
[328] Wicha 2002, 44.

heel of the mast would have been located over unnotched frame 6. Every unique piece of the Baie de l'Amitié shipwreck was sampled to determine tree species. The keel, all hull planking, and 10 of the 22 frames were made of oak. Although nine different tree species were identified in the ship, the only conifer identified was Aleppo pine, used to fashion frames 15 and 21, both aft of the postulated location of the mast step. All of the frames under the postulated mast step were made from hardwood tree species. Of the seven notched frames, frame 3 was made from beech, frame 5 from sycamore, and frames 7, 9, 11, 12, and 13 were all fashioned from oak.

The final example of a ship with multiple consecutive flat-floored frames to be considered for reconstructing the Trstenik ship is Napoli A, a contemporary ship of approximately the same size. The Napoli A ship was discovered in 2003 along with two other ships in the ancient port of Roman Neapolis, just inland of the modern harbor of Naples, during excavations near Piazza Municipio to expand the Metropolitana subway. The ship has been excavated and is currently undergoing conservation. Photographs and preliminary studies indicate that the Western Roman Imperial frame pattern of alternating floor timbers with paired half-frames occurs in the bow and stern, while the central part of the hull is composed mainly of flat-floored frames, including the frames under the mast step.[329] A plan of the Napoli A hull remains indicates a ceiling planking very similar to that of the Trstenik ship. However, the Napoli A hull is less flat bottomed than the Trstenik ship.[330] In contrast to the mast steps of the Ladispoli A and

[329] Giampala et al. 2005.
[330] Giampala et al. 2005, 64-5.

the Baie de l'Amitié ships discussed above, the Napoli A mast step is significantly more robust, with a total length of 5.32 m spanning 27 frames. This is an average frame spacing of 20.5 cm under the mast step. While the notch pattern of the frames under the Napoli A mast step is not provided in the publication, the site plan appears to indicate some of the frames are notched. Two other features of note on the Napoli A ship are the space thought to accommodate a bilge pump, and two different-sized wales, which will be compared to the Trstenik ship's wales in the next section. While full information is not available for this shipwreck, additional studies once the conservation and reconstruction of Napoli A are completed may add insight to the Trstenik ship analysis.

7.1.5 Ships Exhibiting Multiple Wales

At the Trstenik site, clear remains of two wales were observed, as well as traces of a third wale which was discovered on the starboard side during the final day of the excavation (Section 6.3.5). These wales were preserved mostly at the middle of the ship, with no evidence of how they were affixed to the stem or sternpost. Additionally, there were no surviving remains of any material that could be interpreted as a caprail or the uppermost sides of the hull. To fill this void during reconstruction, seven shipwrecks with multiple wales were examined as comparanda for the Trstenik ship. Three of the ships are contemporaneous with the Trstenik ship. Two of the three contemporaneous ships have been introduced in previous sections: the Napoli A ship (Section 7.1.4 due to its multiple consecutive floors) and the Saint-Gervais 3 ship (Section 7.1.3 due to its ship's lines).

As mentioned earlier, the Napoli A ship is still undergoing conservation and has not been fully published. However, publication photographs of the ship during excavation clearly show two wales. While measurements and drawings are not provided, the discussion indicates that the wales had undergone some repairs in which repair pieces were nailed and pegged onto the existing wales.[331]

The Saint-Gervais 3 ship's body plan does show two wales. However, they do not appear on the sheer plan, which is creatively drawn as a ponto-type ship. Additionally, the two wales are not shown in consistent locations between the body plan and the displacement calculation diagram.[332] Lastly, a review of the Saint-Gervais 3 publication and its site plans and photographs did not locate any evidence or discussion of a second wale. Thus, it appears that the display of two wales in the Saint-Gervais 3 reconstruction is based on artistic license, and there is no archaeological information to be incorporated into the remains of the Trstenik ship.

The third contemporaneous ship displaying multiple wales is the Dramont I wreck, discovered in 1991 west of Ile d'Or near Cape Dramont, France, and excavated in 1992 and 1993.[333] The ship was carrying three enormous blocks of marble which together weighed 23 tons. In a somewhat uncommon outcome of the site formation process, there were no hull remains found under the marble blocks, yet a section of hull was discovered about 10 m from the marble blocks, and a small section of keel survived separately from the hull remains. Manual drawings (unfortunately without a scale) of

[331] Giampala et al. 2005, 68-9.
[332] Liou et al. 1990, 262-3.
[333] Joncheray and Joncheray 1997.

the wooden hull remains show two robust wales approximately three times as thick and, unusually, twice as wide as the planking. This would seem to indicate that the shipbuilder expected a heavy, dense cargo to be carried and therefore strengthened the ship with particularly robust wales. Despite this construction detail it may be that his design was not adequate for the massive load of marble. While the Dramont I wale design is not reflective of that built into the Trstenik ship, it may confirm that wales were understood to provide stiffness and support for heavy loads. The Dramont I robust wale design in support of marble transport may be extrapolated to potential cargoes carried by the relatively small Trstenik ship with three closely-spaced wales.

Four other shell-first, mortise-and-tenon-built ships, all dating after the Trstenik ship but reconstructed with multiple wales, were identified to assist with interpretation of the Trstenik ship's wales and caprail. As previously discussed in the above section on ship's lines (7.1.3), the La Bourse shipwreck is a large 3rd-century CE ship excavated and on display in Marseille. The ship is built in the Western Roman Imperial style, with a framing system of floors alternating with paired, asymmetrical half-frames. Eight of the floor timbers are bolted to the keel. The site plan of the wreck shows one wale on the starboard side, and in its reconstruction the author postulates two wales, separated by three hull strakes.[334] A model built from the reconstruction drawings illustrates an artistic choice for the bulwark planking and caprail, where an additional strake is inserted above the second wale and the sides completed with a final plank and caprail.[335]

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[334] Gassend 1982, 31-2, 36.
[335] Gassend 1982, 22.

The spacing between wales of the La Bourse model is wider than the single strake observed in the Trstenik remains. Moreover, the La Bourse reconstruction appears to place the lower of the two wales at or perhaps just below the waterline, as evidenced in its line drawings.[336]

The L'Anse des Laurons 2 wreck, discovered in 1978 about 30 km west of Marseille, just south of the city of Martigues in only 2.5 m of water, was excavated in multiple campaigns from 1979 to 1983.[337] It was a well-preserved wreck, with an uncommon amount of surviving deck planking, bulwarks, and rigging, built in the late 2nd or early 3rd century CE. The ship's two wales are separated by a single strake, like those of the Trstenik ship. The L'Anse des Laurons 2 wreck is 13.3 m long and fitted with 55 frames, features that are fairly good matches to the Trstenik wreck. The surviving bulwarks show multiple similarities with the Trstenik ship, including identical wale spacing. Most importantly, the outstanding reconstruction and analysis of the L'Anse des Laurons 2 shipwreck make it an excellent example to consider during evaluation of the Trstenik reconstruction.

The Pointe de la Luque B shipwreck was discovered in 1970 just to the northwest of Pomegues Island near Marseille, France, at a depth of 30-37 m, and excavated over several seasons between 1971 and 1974.[338] This 4th-century CE wreck was not well preserved overall, with a surviving hull section measuring only 8 m long by 5 m wide. However, a small section of one side of the hull has survived which exhibits three wales,

[336] Gassend 1982, 47-8.
[337] Gassend et al. 1984.
[338] Clerc and Negrel 1973, Liou 1973, 1975.

each separated by one strake, similar to the wale arrangement seen on the Trstenik ship.[339] Thus, the reconstructed cross sections of the Pointe de la Luque B wreck comprise a noteworthy comparison to the Trstenik ship's cross sections.

Finally, the last ship to be considered for wale reconstruction purposes is the 5th-century CE Dramont E wreck, discovered in 1965 and previously discussed in the section on ship's lines (7.1.3). A review of the original excavation information shows that the actual archaeological remains consisted of one complete wale and a vestige of a second wale, separated by a single strake, surviving on the starboard side of the ship.[340] This ship was subsequently reconstructed and modeled digitally as a ship with three wales, each separated by one strake, based on the well-preserved remains of the L'Anse des Laurons 2 wreck discussed above.[341] As such, this reconstruction may be examined for applicability, but the L'Anse des Laurons 2 remains should be prioritized as a primary source ahead of the derivative Dramont E reconstruction.

7.1.6 Other Contemporary Shipwrecks

In addition to the ships and selection criteria discussed above, four other excavations of contemporaneous ships were considered in the Trstenik ship reconstruction.

Two of the four shipwrecks, the Barthélemy B and the Calanque de l'Âne shipwrecks, were tile carriers dated to the 1st century CE. The Barthélemy B shipwreck was discovered 400 m off the coast of Calanque de Saint Barthélemy, France, at a depth

[339] Liou 1975, 580.
[340] Santamaria 1995, 156-7.
[341] Poveda 2012, 333.

of 39 m and excavated over three seasons between 1994 and 1996.[342] While the extent of hull preservation was poor, details of the keel and garboard joinery were recovered during the excavation which may prove useful in comparison to a future excavation of the Trstenik ship. The Calanque de l'Âne shipwreck was found only a few meters south of the coast of Île Pomègues near Marseille, France. Discovered in 1956, it was excavated over multiple seasons in the 1980s and 1990s.[343] The Calanque de l'Âne ship was very robust, with a massive mast step atop two lateral keelsons. Both the Barthélemy B and the Calanque de l'Âne shipwrecks preserved the loading arrangement of their tile cargoes. As the Trstenik ship was scuttled, an examination of how these two heavy cargoes were arranged potentially adds information not available from the Trstenik ship's remains.

The final two shipwrecks are the Balise de Rabiou shipwreck and the Grado shipwreck. The Balise de Rabiou shipwreck is dated to the 1st century CE. The wreck was located in 1989 at a depth of 30 m approximately 1 km from the coast near Saint Tropez, France, and excavated over multiple seasons from 2003 to 2006.[344] Similar to the Trstenik ship, the curvature of the port side of the Balise de Rabiou hull was conserved against the sea bottom. The Grado shipwreck was found in 1986 at the extreme northern extent of the Adriatic Sea, 10 km off the coast of Grado, Italy, at a depth of 15m.[345] It was excavated over multiple seasons between 1987 and 1999 and

[342] Joncheray and Joncheray 2004a.
[343] Ximénès and Moerman 1994 and 1998.
[344] Joncheray and Joncheray 2009.
[345] Beltrame and Gaddi 2005 and 2007.

has been dated to the middle of the 2nd century CE based on its cargo of 600 amphoras. The remains of the Grado ship were particularly well documented. Additionally, its wreckage preserved artifacts not commonly found in early Imperial wrecks, including the bilge pump, a waterway conserved in partial ship's decking, and a large quantity of rigging elements. The Balise de Rabiou and the Grado wrecks complete the compendium of 20 ships considered in conjunction with Trstenik ship reconstruction.

7.1.7 Summary

Date, size, and construction technique provided a starting point to build a compendium of previously excavated ships against which to compare to the wreck found at Trstenik. The list was expanded to include additional wrecks with a developed set of hull lines, multiple consecutive flat-floored frames, or multiple wales. While many wrecks fit several categories of comparison, no shipwreck was a perfect match to all of the characteristics of the Trstenik ship. However, the excellent pre-existing data from decades of study of ancient Mediterranean ships certainly adds confidence to the choices made during Trstenik ship reconstruction.

7.2 Reconstruction of the Trstenik Ship's Hull using the Rhinoceros 3-D Digital Modeling Program

The Trstenik ship's hull remains were uncovered and cleaned of debris, then documented by digital photography (Section 4). These data were used to develop a 3-D model in the Agisoft PhotoScan software program (Section 5.3). Based on this accurate model of the wreckage and analysis of similar ships (Section 7.1), a 3-D model of the hull of the Trstenik ship was reconstructed. This model was used to estimate the Trstenik ship's displacement.

This process was performed with the Rhinoceros 3-D digital modeling program.[346] Rhinoceros mathematically models curves and surfaces using a process known as non-uniform rational basis spline (NURBS). This is a more powerful 3-D modeling process than the polygon mesh process employed by the Agisoft PhotoScan program. NURBS produces mathematical representations of curves and creates 3-D surfaces displayed on a 2-D computer screen. These curves and surfaces can then be manipulated in a variety of ways to support precise creation of shapes and volumes.

Digital photographs were taken on two different days to support Agisoft PhotoScan 3-D model development. The first recording was performed with stringers installed, and the second, several days later, was conducted with stringers removed in order to better record the ship's framing pattern. To begin the Rhinoceros modeling process, the Agisoft PhotoScan 3-D model developed after stringer removal (orthophoto in Figure 5-4) was imported into the Rhinoceros program (Figure 7-1).

[346] My sincere thanks to Jose Casaban for his invaluable assistance during this modeling process.

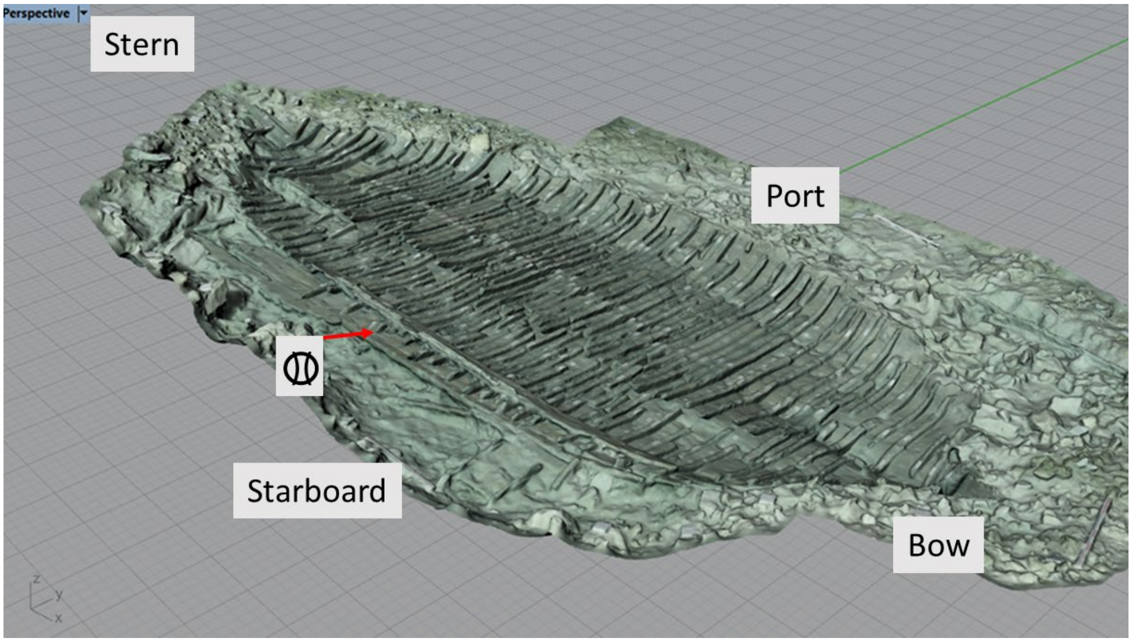


Figure 7-1. 3-D Model Imported into Rhinoceros. Symbol indicates ship's midships (frame 46).

After importation, multiple cross sections were sliced through the ship's remains (Figure 7-2), and then each cross section was updated with the location of the seams between adjacent strakes (Figure 7-3).

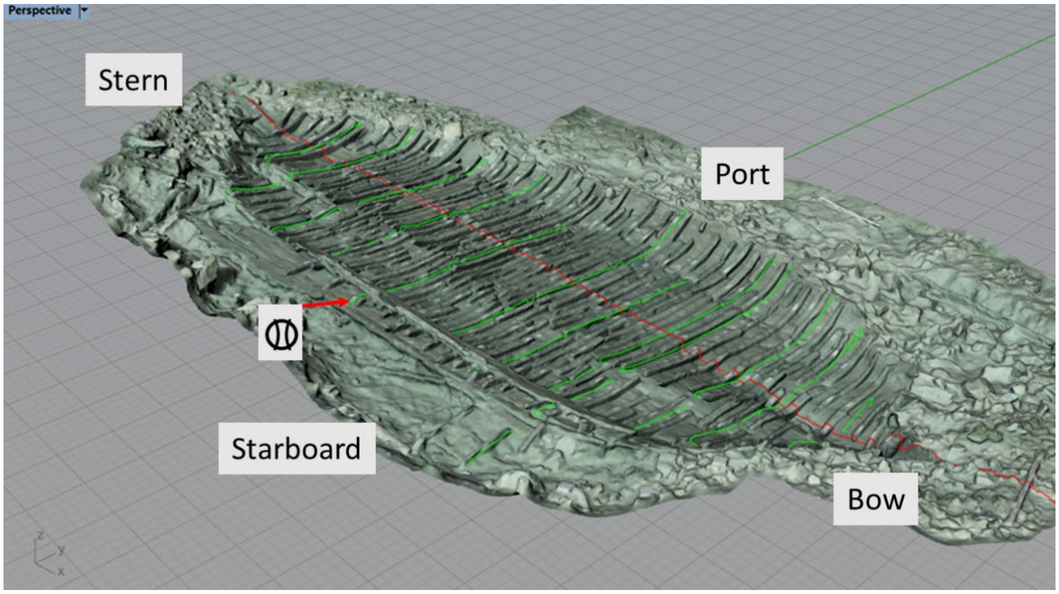


Figure 7-2. Cross Sections Taken on the Trstenik Remains. A section was taken at midships (symbol), with five additional sections aft and eight sections forward. Two of the additional sections were taken forward to provide coverage over the small fragment of wreckage preserving the third wale, to cover that fragment twice.

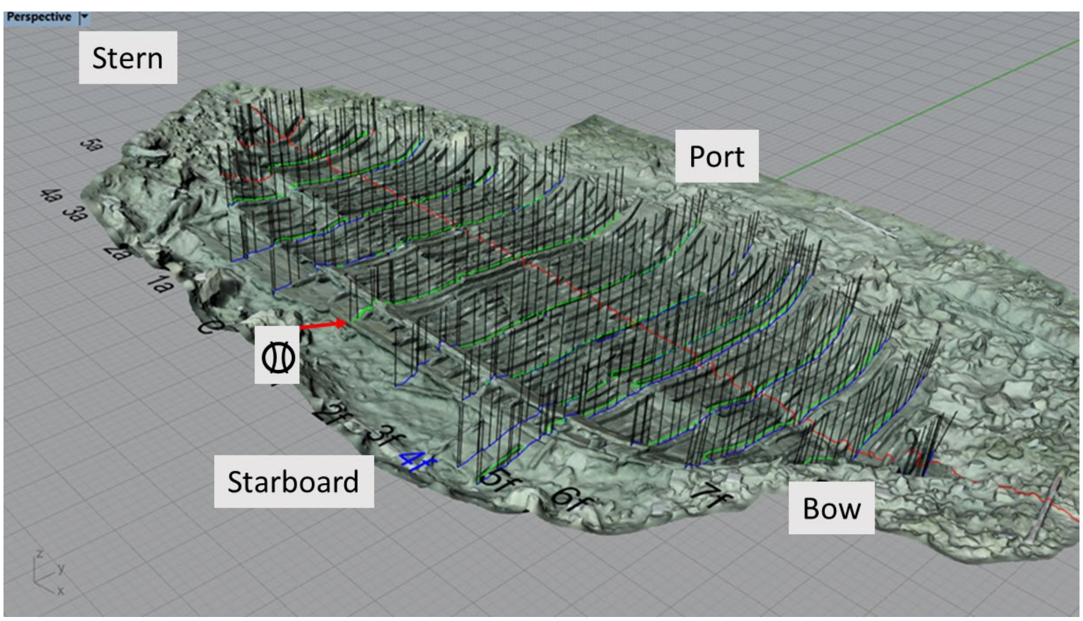


Figure 7-3. Seams between Strakes. Every seam was highlighted on each cross section.

After highlighting the location of each plank seam for all 14 hull cross sections, the cross-section lines were vertically expanded based on an assumed thickness for each hull component. Strakes were drawn based on an estimated plank thickness of 2.5 cm, wales based on a thickness of 4 cm, and the keel based on a thickness of 10 cm. Further excavation and disassembly are required to verify these estimates. Figure 7-4 displays the resulting 2-D image for cross section 3a (the third cross section aft of the midship cross section).

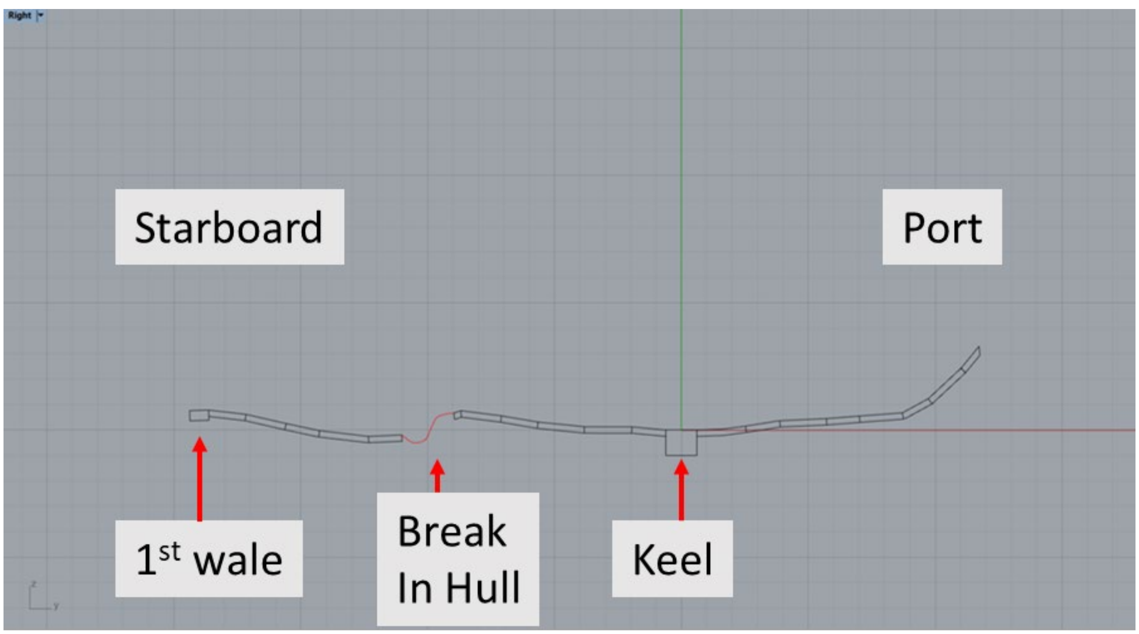


Figure 7-4. 2-D Drawing of Cross Section 3a. Looking aft. The preserved curvature of the bilge is visible to port. A break in the hull and the first (closest to the keel) wale are visible to starboard.

After tracing the cross sections, for each section, the starboard side was copied, rotated, and mirrored onto the port (sea wall) side. Figure 7-5 illustrates this process for cross section 3a.

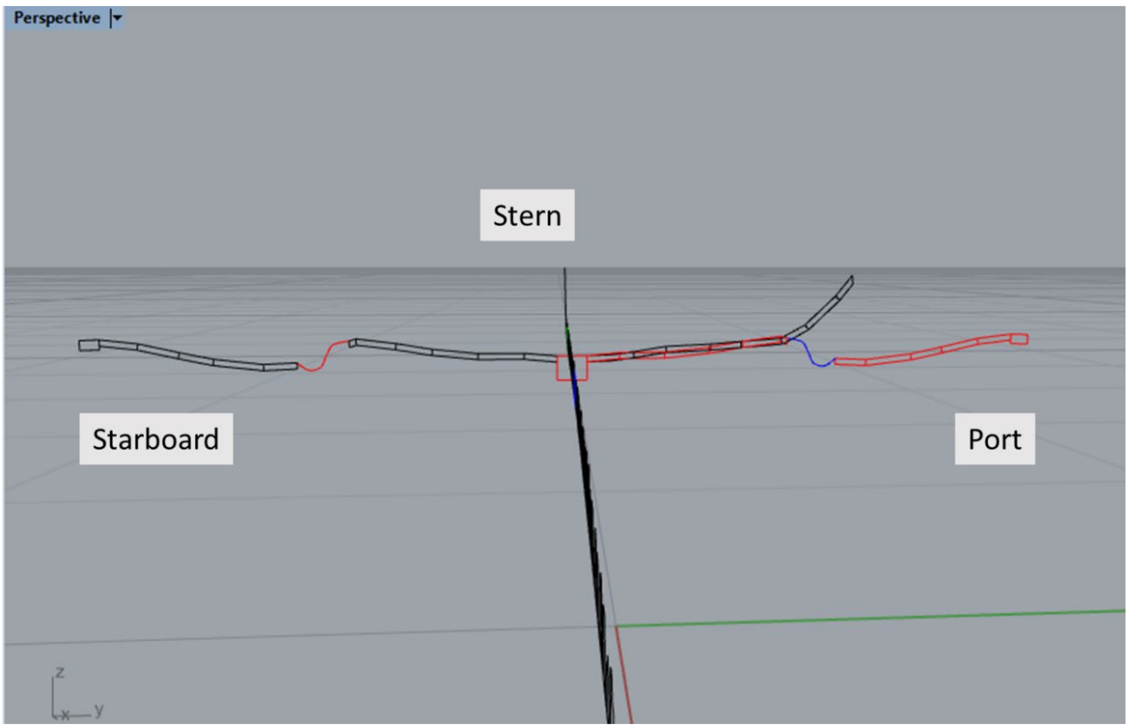


Figure 7-5. Cross Section 3a with Starboard Planking Copied and Mirrored to Port. The copy of the starboard side is shown in red.

Using the seams between the strakes as reference marks, the mirrored starboard side was adjusted vertically to conform to the curvature of the hull on the port side, which had been preserved by the sea wall (Figure 7-6).

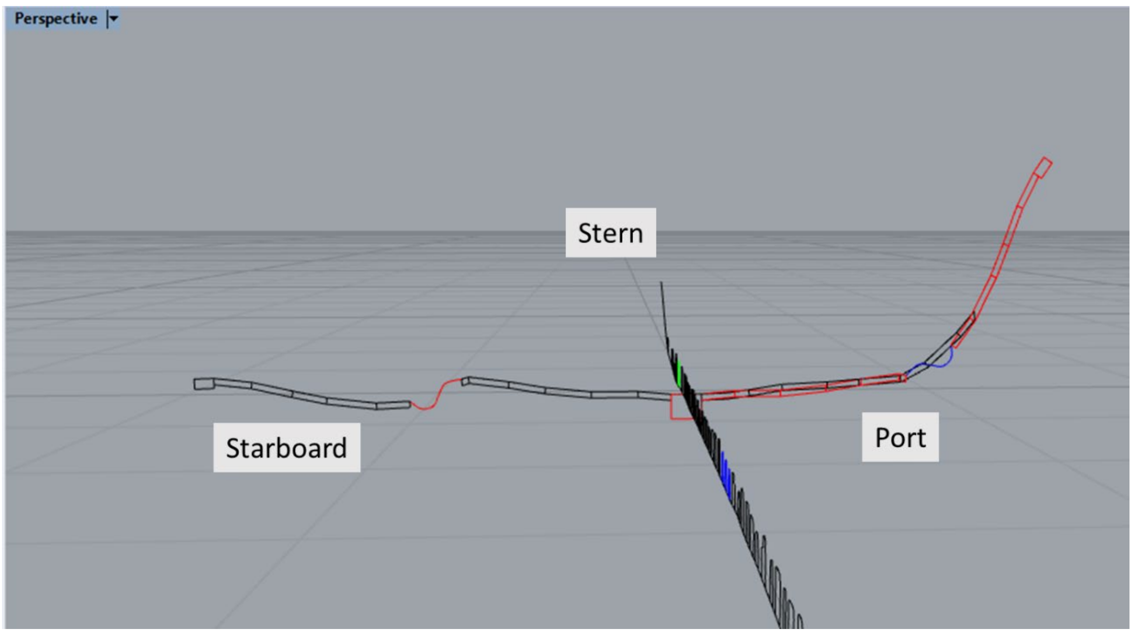


Figure 7-6. Defining Seam Locations. The mirrored starboard side (red) and the curvature of the port side were combined to extrapolate the extent of the starboard side remains onto the port side curvature.

Finally, the port and starboard sides were faired together and smoothed to define an internal cross section of the hull, including the locations of plank seams for every strake in each cross section. At that point the plank drawings and section data were deleted, allowing the hull points to be joined to form the lower portion of a body line (Figure 7-7).

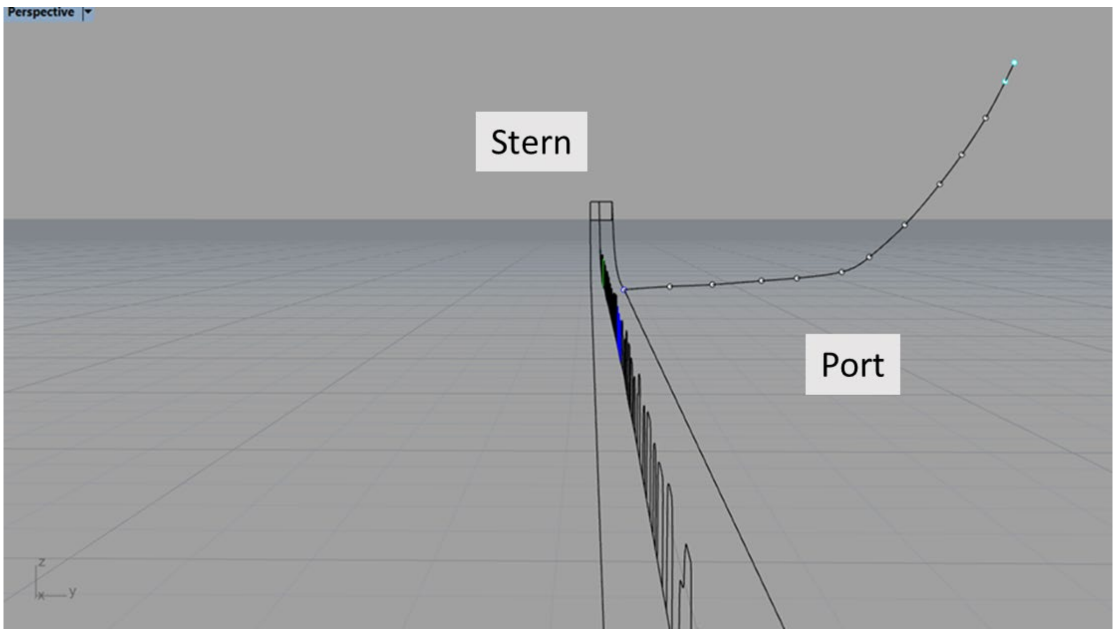


Figure 7-7. Body Line Segment Constructed at Cross Section 3a. The light blue dots are the seams for the first (lowest) wale.

Ultimately, each cross section resulted in its own set of hull points, which could then be connected to form the lower portion of a body line. Figure 7-8 shows all 14 body line segments generated by this process.

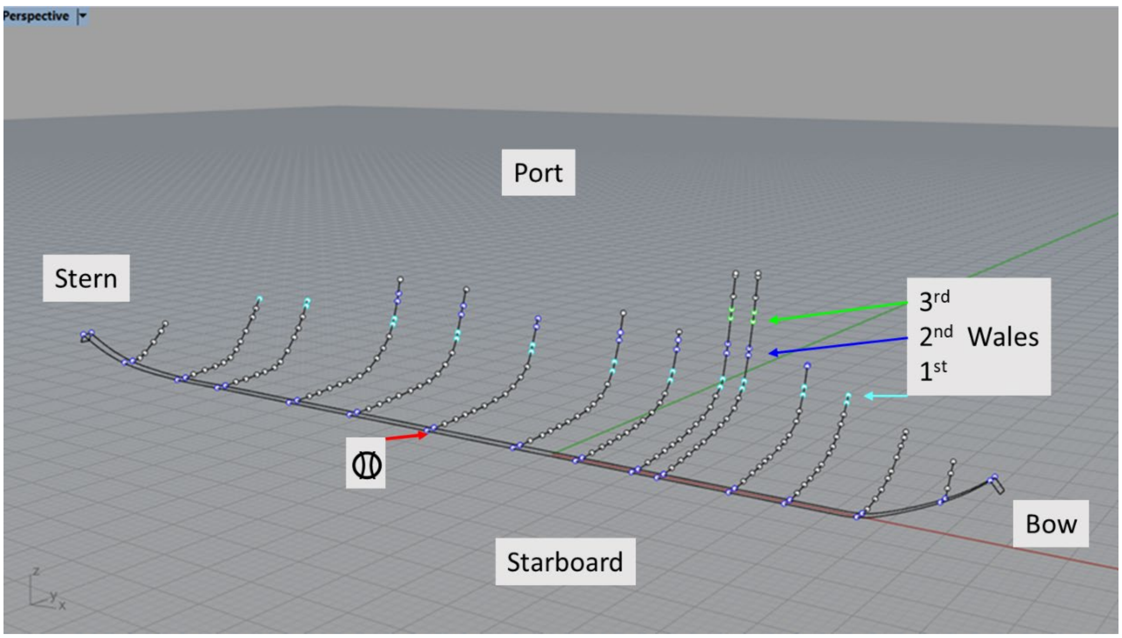


Figure 7-8. Reconstructed Body Line Segments. At each cross section, the hull planking seam points were connected to form body lines. The points reflect 11 strakes between the keel and the first wale. Strake joints are white, first wale joints are light blue, second wale joints are dark blue, and joints for the small surviving remnant of the third wale are green.

At this stage of the reconstruction process, Rhinoceros was pushed from a summation of two-dimensional modeling steps into its full capacity as a non-uniform rational basis spline (NURBS) surface modeling program, which produces a default representation of geometry based on mathematical relationships, rather than developing surfaces based on shapes and lines alone.[347] Critical to the success of this process was the use of Grasshopper, a Rhinoceros plug-in for visual-based parametric modeling, which creates a dynamic and editable workflow.[348] Grasshopper was used to manage input data, model the hull and keel to generate a volumetric model, calculate the ship's volume below the waterline (displacement) based on a user-defined ship's draft, and extract section curves from the resulting 3-D model. The power of the Grasshopper module, as developed and used during this modeling process, is that the automated work flow is applicable to any hull shape generated in Rhinoceros from any reconstruction path. Thus, instead of a single-use algorithm, the Grasshopper process (Appendix C) could be readily transferred into any Rhinoceros ship reconstruction.

The keel was streamed into Grasshopper and sampled at regular intervals for points to create ideal cross sections. These idealized curves were approximated with four points (Figure 7-9). It is important to note that the simplification and idealization of the actual archaeological data in Rhinoceros as a four-point input to Grasshopper was rectified later in the modeling process by reintroducing actual body line archaeological data. Point 1 represents the starting position at the keel; point 2 is an offset of point 1 controlled by a best fit parabola, used to mimic the width of the hull at the various sampled points along the keel; point 3 is a uniform horizontal and vertical offset of point 2, and point 4 is the intersection of the section curve with the hypothetical caprail of the hull. With these points selected as described, the line between points 1 and 2 represents

[347] Sincere thanks and credit to Andrew Harrell for his modeling assistance and technical review of this section.
[348] See Tedeschi 2014 for additional information on Grasshopper.

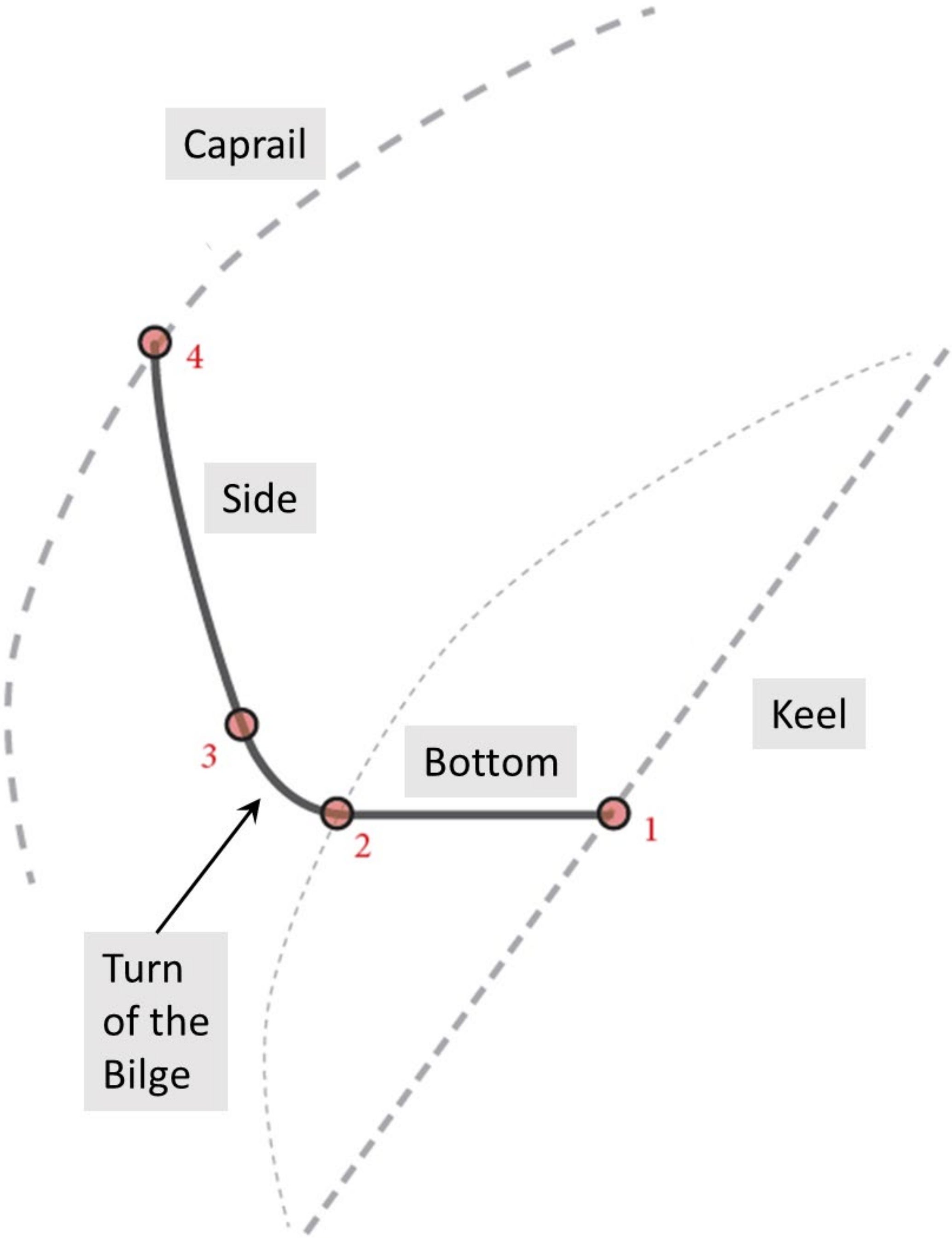


Figure 7-9. Grasshopper Input. Four points were taken from each section and used as input into Grasshopper parametric modeling to generate idealized cross sections.

the bottom of the ship, the curve between points 2 and 3 represents the turn of the bilge, and the line between points 3 and 4 represents the side of the hull. The four points were mirrored on the opposite side of the hull and connected to create idealized cross sections. Two lines, the assumed caprail curve and the line representing the seam between the keel and the garboard strake, were also mirrored to complete the approximation of the inner hull surface. The idealized cross sections were adjusted near the bow and stern to better approximate the less flat, more V-shape of the hull near these extremities by only creating Points 1 and 4, as described above.

As shown in the Grasshopper dynamic workflow diagram (Appendix C), a network surface was generated in Grasshopper using the ideal cross-section profiles, the caprail, and the keel. A network surface refers to the collection of 'u' and 'v' curves that define a non-flat, two-dimensional surface in the Rhinoceros environment. While all geometry is based in the x-y-z Cartesian coordinate system, Rhinoceros creates a new u-v local coordinate system unique to each surface. Each u-v coordinate system can have different deformations, transformations, and origins compared to the x-y-z coordinate system. For this methodology, the keel was used to define the u-axis construction, and the cross-section curves defined the v-axis construction and the caprail. In other words, forward and aft along the length of the keel is the u direction, and athwartships or outboard from the keel along the interior hull surface is the v direction.[349]

[349] See Tedeschi 2014, 138-40 for graphical representations of how a two-dimensional (2-D) flat plane can be bent into a zero-thickness surface in three dimensions (3-D), but described by isocurves using only u and v parameters.

Just as Grasshopper is a dynamic workflow plug-in to the Rhinoceros 3-D modeling program, Pufferfish is a shape-changing and surface offset plug-in to Grasshopper. Using the Pufferfish plug-in, the rough network surface was rebuilt to fair some of the irregularities (wrinkles) in the hull surface. Pufferfish was then used to create a solid hull by offsetting the rebuilt surface by adding the thickness of the hull planks. The rebuilt surface represented the inside of the hull; therefore, the 2.5 cm offset (the estimated planking thickness) was in the positive direction to create the hull exterior.

To define the keel, the hull volume was calculated to find its centroid, which is the geometric mean position of all the hull points. The hull centroid was projected onto the surface to find the u-direction isocurve that best approximated the longitudinal centerline of the hull. This hull centerline was widened by 5 cm to either side to define the width of the keel on the inner surface of the ship. The two parallel lines defined by widening the hull centerline were longitudinally extended above the polysurface model to become the inner edges of the stem and sternpost at either end of the ship. The length and curvature of the stem and sternpost defined by this process could be readily adjusted and do not impact the displacement calculations for the model. Finally, a surface was created between the two parallel lines to represent the inner surface of the stem, keel and sternpost assembly. As was done for the hull to account for planking thickness, the Pufferfish tool was used to offset this surface by 10 cm in the positive direction. This created a stem, keel and sternpost assembly with a 10 cm x 10 cm square cross section, protruding 7.5 cm below the planking of the ship's hull.

The accuracy of the developed model was analyzed by comparing the original data points and body lines to the resultant hull surface. To confirm maximum accuracy, each seam point of every body line (Figure 7-8) was evaluated based on its proximity to the interior surface of the computer-generated hull. The distances between the seam points and the hypothetical hull were calculated and displayed for an average distance, minimum distance, and maximum distance; these measurements could be aggregated by section as well as by combining all the hull points. In this way the best possible hull shape with minimum error from the actual archaeological data could be obtained. This procedure is somewhat analogous to taking the data for a 'least-squares fit' line calculation, but applying it to multiple points along a curved surface.

At this stage a final Grasshopper plug-in, Galapagos, was employed to complete the hull reconstruction. Galapagos is an evolutionary solver, able to perform repetitive calculations to minimize total error deviations. After the initial construction of the hull, the archaeological hull planking seam points for each body line segment (Figure 7-8) were overlaid onto the inner surface of the hull. Deviations were calculated in Grasshopper between the hull and the seam points along each body line. Using Galapagos, the deviations were minimized by manipulating parameters in the Grasshopper file in order to adjust the hull shape. By setting a target value of zero for the point deviations, Galapagos iterated hundreds of combinations of parameters to find the best-fit hull surface. The user-selected parameters were based on the positions of the four points used to create the idealized cross sections (Figure 7-9). Thus, the idealized points used to initiate the hull definition process in Grasshopper were replaced by the actual archaeologically observed points developed in Rhinoceros, and the final output of the hull shape was iteratively calculated to minimize error from the actual archaeological data. At this point, external and internal surfaces of the model hull were defined (Figure 7-10). Construction drawings, including frame component fit into cross-section model cuts, are provided in Appendix D.

Qualitatively, the certainty of the model reconstruction is directly related to the sufficiency of the remains. The shape of the lower portion of the ship model, including the turn of the bilge, is quite accurate. The extension of the wales to the stem and sternpost of the ship model is somewhat less certain; however, those connections occur above the waterline, thus any minor inaccuracy would not affect the calculation of the ship's displacement. As no remains of the upper works of the ship were recovered, the upper portion of the ship model, including the number of strakes above the upper wale and the shape of the caprail, could be inaccurate from the original construction of the Trstenik ship.

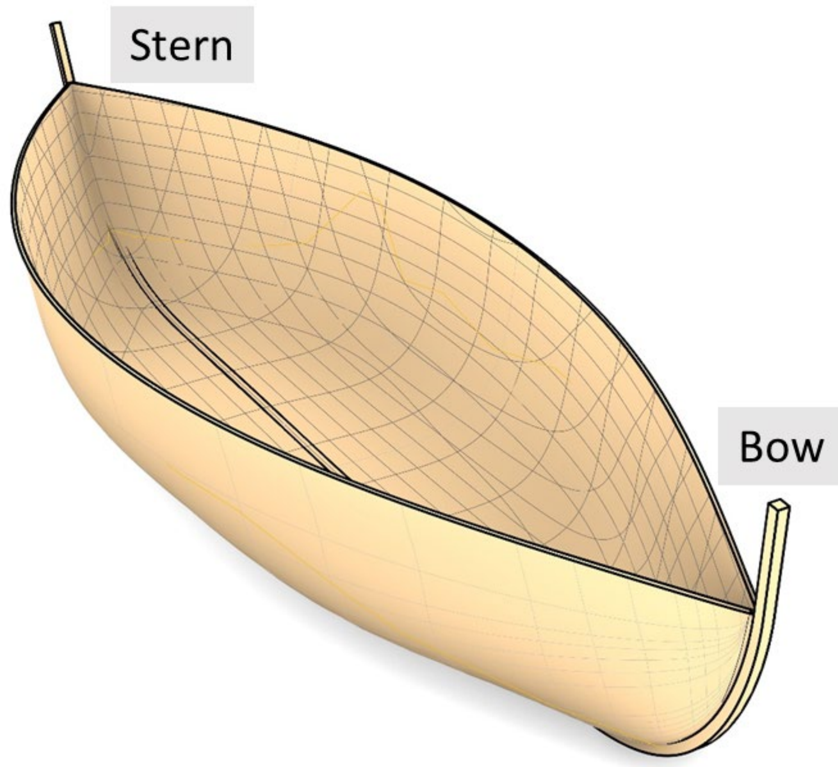


Figure 7-10. Trstenik Ship's Hull Shape. The model was generated using Rhinoceros, as enhanced by Grasshopper (visual-based parametric modeling), Pufferfish (surface offset and shape-changing plug-in), and Galapagos (evolutionary solver).

To determine the ship's volume below sea level and calculate displacement based on varying ship's draft, a 'bounding box' was created based on the outer extent of the solid hull and moved to the zero-draft position (Figure 7-11). Sea level was then controlled by a user parameter that moved the bounding box up or down in increments of 1 cm, equivalent to changing the draft of the ship. The Rhinoceros solid split tool was written into Grasshopper (Appendix C) to determine the intersecting volume between the external hull surface and the movable bounding box. The volume of these intersecting solids was multiplied by the density of saltwater to calculate an estimated displacement. Representative displacements based on the ship's draft are shown in Table 7-1.

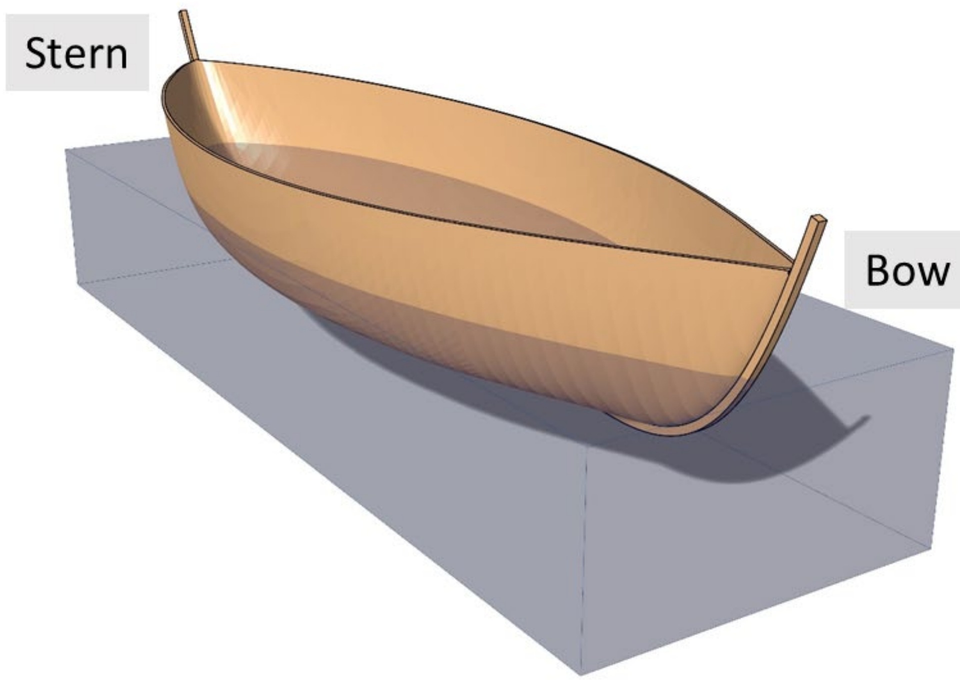


Figure 7-11. The Ship's Hull Inside a Bounding Box. The ship's draft was adjustable, facilitating displacement determination as a function of draft.

Ship's draft (m)	Displacement (tons)
0.8	21.5
0.9	25.1
1.0	28.8

Table 7-1. Trstenik Ship Hull Model Displacement Based on Draft.

Based on a review of Roman ship iconography, as well as an examination of the ships contemporaneous with the Trstenik ship exhibiting multiple wales (Section 7.1.5), the entirety of the first wale is typically visible in its entirety above the waterline even with the ships fully loaded. As the lowest point of the first wale of the reconstructed Trstenik hull is at 0.95 m above the bottom of the keel, a reconstructed displacement for the Trstenik ship is 25 tons at a draft of 0.9 m. This draft is quite reasonable for transporting heavy loads into shallow eastern Adriatic waters for cargo handling near shore, such as the shallow waters of the northern coastline of the Gulf of Kaštela or near the mouth of the Jadro River at Salona. This displacement is also comparable to that calculated during the Dramont E hydrostatic modeling process. That ship was estimated to have displaced 28.5 tons at a draft of 1.33 m. As the Dramont E ship had a more wineglass-shaped, less flat bottom, that model required a slightly deeper draft to produce approximately the same displacement.[350]

[350] Poveda 2012, 335.

7.3 Ship's Lines

To generate a set of ship's lines from the developed model, section curves were taken from the Rhinoceros model using the Grasshopper contour tool. While the displayed curves show equidistant spacing of the model surface, any interval can be obtained as desired. Two sets of contours were taken: one parallel and the other perpendicular to the keel. The resultant curves were rotated, flattened, and moved for optimal user viewing. Since the contour tool sampled the solid hull and solid keel, additional data management was needed to keep the multiple groups of contour data together for user viewing. Text was created for each contour curve to display the distance from the start of the section cuts. The lines generated are shown in Figure 7-12.

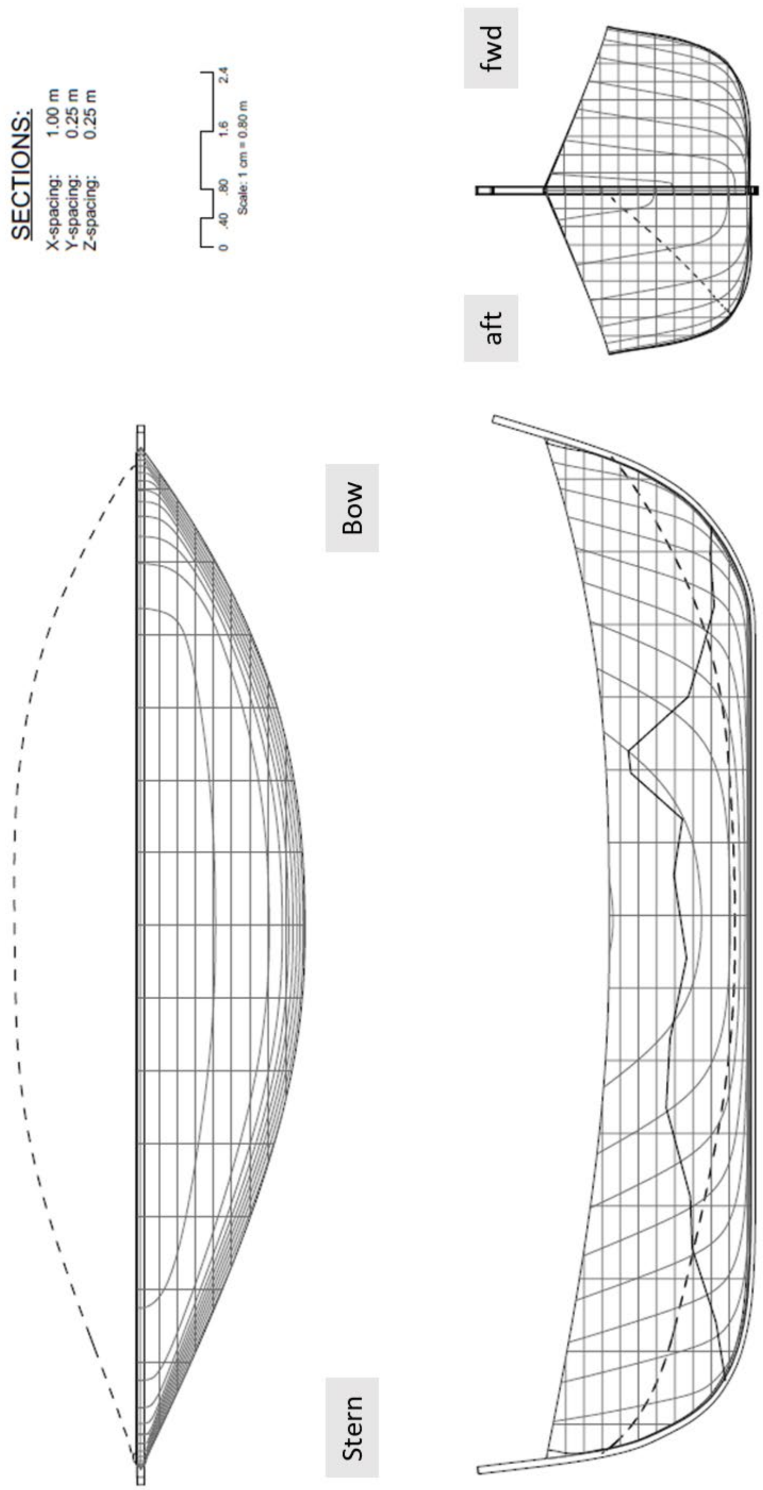


Figure 7-12. Trstenik Ship’s Lines.

8. CONCLUSIONS

8.1 The Trstenik Ship and Its Historical Context

Section 2 described the geographic and historical context that led to and supported the building, employment, and disposal of the ship found at Trstenik. Even with all useful and recyclable materials removed before scuttling the ship along a sea wall, and only the lower portion of the hull surviving, the ship speaks to us about its purpose, its life, and its architect. Its flat-floored design and mortise-and-tenon construction reflects a requirement to transport heavy cargo across open seas and ultimately unload the cargo in shallow waters. While the wood species used to construct the ship fail to pinpoint its construction location, the mortise-and-tenon construction technique indicates the ship was either built outside of Dalmatia or constructed in Dalmatia under the supervision of craftsmen experienced in what was a nonnative construction technique, so radically different from the laced craft contemporaneously constructed and operated by indigenous inhabitants. The ship's operational life dating to the mid-1st to early-2nd centuries CE is concurrent with the zenith of the Roman Empire in time, geographic area, shipping density, and prosperity.

Because of its demise as a scuttled craft, information often obtained from excavation of shipwrecks lost at sea is not available from the Trstenik wreck. Cargo, crew equipment, galley information, mast and rigging equipment, mast step, decking, and anything of value or potentially reusable had been removed from the well-worn hull before filling it with rocks to stabilize a sea wall three kilometers from Salona, the

Roman provincial capital of Dalmatia. However, those same rocks preserved the remaining timbers for analysis 2000 years later, and the sea wall conserved the hull curvature that allowed for an accurate computer reconstruction of the hull shape, facilitating iterative displacement calculations. The mere act of scuttling the ship so near the walls of Salona suggests the importance of the villas in the vicinity of the capital. If seagoing vessels were not able to handle cargo at these smaller, non-Imperial facilities geographically separated from the urban area, it is unlikely that there would be need to bolster a wooden retaining wall with the hull of a 25-ton merchant ship. This importance is also reflected by the partial scavenging, but not total dismantling, of the ship. Strengthening the sea wall was considered more valuable than continuing to operate an older, at-risk merchant ship, and also more valuable than the sum usefulness of all of the wood components not scavenged from the hull.

The Trstenik ship shows that Roman technology spread to the provinces rather than full adoption of local laced boat construction techniques. While often criticized for their plagiarism of Greek sculpture and architecture, in the case of expanding Roman influence into Illyricum, then Dalmatia, the Romans transferred their ship-building technology rather than copying local construction techniques or simply purchasing local ships for Imperial purposes. The construction of the Trstenik ship shares characteristics with contemporaneous craft around the Mediterranean employed in the transport of dense cargo, including *dolia*, roof tiles, metal ingots, raw or cut stone, and sarcophagi. Roman Dalmatia required the transport of heavy loads by sea; the Trstenik ship is one of the craft that performed this work.

The discovery of the Trstenik ship adds information to our understanding of provincial Roman life, including trade, routine ship operations, and ship design and construction. The transfer of Roman technology to the hinterlands cannot be determined only by reading ancient sources, which focus primarily on battles, leadership struggles, and other headlines of the era. Enhanced understanding of Roman contact with, penetration into, and domination of regions such as Dalmatia must also come from aggregating sites such as Trstenik into a more complete mosaic of Romanization over time.

8.2 The Trstenik Ship and Contemporaneous Roman Ships

The histories of ship construction and maritime trade in the classical and antique Mediterranean have been written based on underwater archaeological excavations undertaken in two major theaters: the northwestern coast of the Mediterranean (Spain, France, and Italy) and the Aegean coasts of Greece and Turkey, with modest contributions from the eastern Mediterranean coasts of southern Turkey and the Levant. This uneven geographical distribution of excavation effort has impacted our vision of shipping density in the ancient Mediterranean. For example, *dolia*-ship research points to Minturnae, Italy, as the likely construction source for all known *dolia* wrecks during ca. 30 BCE and 50 CE. This conclusion could become invalid should the distribution of *dolia* shipwrecks be expanded beyond the coasts of southern France and western Italy to include recently discovered *dolia* ships in the Adriatic and elsewhere.

Rapid industrial development and population growth along the coastline coupled with protection from looters limited the scope of early excavation effort expended in the eastern Adriatic. Those ships that have been excavated over the last half-century were largely “rescue excavations,” essentially the removal and analysis of cargo without any detailed study of the hull or analysis of the site. The inevitable result of this unbalanced effort is the perception of the Adriatic Sea as a backwater of *Mare Nostrum* rather than a well-traveled arm of the Mediterranean Sea. Future excavation in the Adriatic may well alter the Roman Republican and Imperial shipping density with the result that the region becomes more evenly balanced with the western side of the Italian peninsula.

8.3 Reconstruction and Analysis Tools

Technology changes—rapidly. During the development of this dissertation, the progress made in available computing power continued to follow Moore’s Law, which predicts that computer speed and capability will double every two years. In parallel with dramatic improvements in computational speed and data storage capability, software companies continue to enhance their products. Thus, the Agisoft PhotoScan photography procedures and post-photography 3-D modeling steps employed for this dissertation in 2015 and 2016 (Section 4) are already obsolete. The Rhinoceros automated processes used in 2019 to generate a hypothetical hull shape from the PhotoScan 3-D model (Grasshopper, Pufferfish, Galapagos; see Section 7) will continue to be modified and complemented by future plug-in modules with ever-increasing capability.

It is to the advantage of nautical archaeologists to stay engaged with other fields to capitalize on the continuing evolution of computer processing in both speed and capability. The primary disadvantage of the field of archaeology is its inability to be financially self-sufficient. Thus, alignment with other fields pushing the capacity of computing and modeling forward, such as video animation, remote survey and measurement, fluid hydrodynamics modeling for ship design, finite element modeling, etc., will allow nautical archaeologists to employ new technology as soon as it is developed. As the costs of underwater excavation and wood conservation continue to climb, adopting applicable technology into nautical archaeology is the best weapon to extract maximum information from each site at minimum cost for the future.

8.4 The Way Ahead: Micro and Macro

It is personally unsatisfying to know the Trstenik ship, a 2000-year-old relic in good condition, sits covered by sediment and geotextile only 50 meters from shore without any firm plan to continue its excavation. From a micro level, a full excavation of this hull could provide significantly more information about its construction technique, operational use, and hull repairs over time, as well as either confirmation or correction of the shape of the vessel determined in this dissertation. With future conservation and display of the Trstenik ship's remains, the residents surrounding the Gulf of Kaštela would become personally aware of the extent of underwater cultural heritage present just below the ocean's surface along their segment of the Adriatic coastline.

From a macro level, rapid examination, analysis and publication of sites such as Trstenik are a fiscally appropriate response to the necessity of growing the corpus of and knowledge about sites off the coast of Roman Dalmatia. Statistical analysis of ship construction techniques, wood used in shipbuilding, crew size, potential cargoes, and other facets available from nautical archaeology would improve the fidelity of our understanding of Adriatic Sea shipping density in classical antiquity and beyond. Increased emphasis on this arm of the Mediterranean is warranted based on insufficient past research efforts when compared to other Mediterranean regions, coupled with an awakening realization of its true importance and usage throughout history.

The key variable for the way ahead, micro and macro, is fiscal responsibility. Does the best use of limited archaeological funds warrant a full excavation of the Trstenik ship, a full excavation of some other Dalmatian coast wreck that could add even more information by detailed hull analysis, or visits to multiple Adriatic sites for less-comprehensive photographic analysis and subsequent computer reconstruction of numerous wrecks across time periods of interest? The Trstenik ship project illustrates the amount of information which can be extracted via photogrammetry and computerized processing tools. The potential of these tools will only expand going forward. The next generation of nautical archaeologists will have even more capability to expand the nautical archaeology knowledge base by adding information about multiple sites at minimal cost, while concurrently providing information to help select the best sites for expending large efforts to perform full excavations in the future.

REFERENCES

Agisoft, 2014, *Agisoft PhotoScan User Manual: Professional Edition, Version 1.1.* Agisoft LLC.

Arnaud, P., 2007, Diocletian's Price Edict: The Prices of Seaborne Transport and the Average Duration of Maritime Travel. *Journal of Roman Archaeology* 20: 321-35.

Babić, I., 2007, Some Observations on the Bell Tower of the Cathedral in Split. *Vjesnik za arheologiju i povijest dalmatinsku* 100: 145-70.

Bartel, B., 1980, Colonialism and Cultural Responses: Problems Related to Roman Provincial Analysis. *World Archaeology* 12.1: 11-26.

Bartoli, D., 2008, Marble Transport in the Time of the Severans: A New Analysis of the Punta Scifo A Shipwreck at Croton, Italy. Ph.D. dissertation, Texas A&M University, College Station.

Batović, Š., 1973, Prapovijesni ostaci na zadarskom otočju. *Diadora* 6: 5-165.

Beltrame, C. and D. Gaddi, 2005, The Rigging and the 'Hydraulic System' of the Roman Wreck at Grado, Gorizia, Italy. *International Journal of Nautical Archaeology* 34.1: 79-87.

Beltrame, C. and D. Gaddi, 2007, Preliminary Analysis of the Hull of the Roman Ship from Grado, Gorizia, Italy. *International Journal of Nautical Archaeology* 36.1: 138-47.

Beltrame, C. and V. Vittorio, 2012, Roman Ships Carrying Marble: Were These Vessels in Some Way Special?, in N. Gunsenin (ed.), *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology Istanbul 2009*, 141-8. Istanbul: Ege Yayınları.

Berlengi, G., 2006, *Prostorni Plan Uređenja Grada Solina*. www.solin.hr/vjesnici/ppu/zastita.pdf. Accessed 8/16/2019.

Boetto, G., 2000, New Technological and Historical Observations on the Fiumicino 1 Wreck from Portus Claudius (Fiumicino, Rome), in J. Litwin (ed.), *Down the River to the Sea: Proceedings of the Eighth International Symposium on Boat and Ship Archaeology Gdańsk 1997*, 99-102. Gdańsk: Polish Maritime Museum.

Boetto, G., 2001, Les navires de Fiumicino, in J. Descoeudres (ed.), *Ostia, port et porte de la Rome antique*, 121-9. Genève: Musées d’art et d’histoire.

Boetto, G., 2003, The Late-Roman Fiumicino 1 Wreck: Reconstructing the Hull, in C. Beltrame (ed.), *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology Venice 2000*, 66-70. Oxford: Oxbow Books.

Boetto, G., 2008, L'épave de l'Antiquité tardive Fiumicino 1; analyse de la structure et étude fonctionnelle. *Archaeonautica* 15: 29-62.

Boetto, G. and I. Radić Rossi, 2017, Ancient Ships from the Bay of Caska (Island of Pag, Croatia), in J. Litwin (ed.), *Baltic and Beyond: Change and Continuity in Shipbuilding*, 279-88. Gdańsk: National Maritime Museum.

Boetto, G., I. Uhač and M. Uhač, 2017, Sewn Ships from Istria (Croatia): The Shipwrecks of Zambratija and Pula, in J. Litwin (ed.), *Baltic and Beyond: Change and Continuity in Shipbuilding*, 189-98. Gdańsk: National Maritime Museum.

Bojanovski, I., 1980, Materijali, građevinske tehnike i strukture u unutrašnjosti antičke Dalmacije in *Materijali, tehnike i strukture predantičkog i antičkog graditeljstva na istočnom jadranskom prostoru*, 41-72. Zagreb: Odjel za Arheologiju—Centar za povijesne znanosti.

Borzić, I., 2009, Uvala Gradina na otoku Korčuli u svjetlu podmorskih arheoloških nalaza, in L. Bekić (ed.), *Jurišićev zbornik: Zbornik radova u znak sjećanja na Marija Jurišića*, 82-97. Zagreb: Hrvatski restauratorski zavod.

Borzić, I., 2018, All Roads Lead to Legions—The Provenance of Pottery Finds from Early Imperial Legion Camp in Burnum (Croatia), in M. Milićević Bradač and D. Demicheli (eds), *The Century of the Brave: Roman Conquest and Indigenous Resistance in Illyricum during the Time of Augustus and His Heirs*, 373-83. Zagreb: University of Zagreb.

Borzić, I. and I. Ožanić Roguljić, 2018, Hispanic Products in Dalmatia and the Croatian Part of Roman Pannonia. *Rei Cretariae Romanae Favtorvm Acta* 45: 511-23.

Braudel, F., 1995, *The Mediterranean and the Mediterranean World in the Age of Phillip II.* Berkeley: University of California Press.

Brusić, Z. and M. Domijan, 1985, Liburnian Boats, Their Construction and Form, in S. McGrail and E. Kentley (eds), *Sewn Plank Boats: Archaeological and Ethnographic Papers Based on Those Presented to a Conference at Greenwich in November 1984*, BAR International Series 276, 67-85. Greenwich: National Maritime Museum.

Brusić, Z., 2008, Underwater Excavation of the Hellenistic Harbour of Siculi in Resnik near Split, in I. Radić Rossi, A. Gaspari and A. Pydyn (eds), *Proceedings of the 13th Annual Meeting of the European Association of Archaeologists (Zadar, Croatia, 18-23 September 2007)*, 167-75. Zagreb: Hrvatsko arheološko društvo.

Bulić, F., 1899, Tre sarcofaghi romani nel villaggio di Vranjic (Urania?) sotto il livello del mare. *Bullettino di archeologia e storia dalmata* 22: 105-11.

Bulić, F., 1900a, Ritrovamenti antichi sull'isola Brazza risguardanti il Palazzo di Diocleziano a Spalato: Le lapidiene del Palazzo di Diocleziano. *Bullettino di archeologia e storia dalmata* 23: 18-23.

Bulić, F., 1900b, Ritrovamenti risguardanti i sarcofaghi romani sotto il livelo del mare nel villaggio di Vranjic presso Salona. *Bullettino di archeologia e storia dalmata* 23: 141-2.

Čače, S., 2006, South Liburnia at the Beginning of the Principate: Jurisdiction and Territorial Organization, in S. Čače, A. Kurilić and F. Tassaux (eds), *Les routes de l'Adriatique antique: géographie et économie*, 65-79. Bordeaux: Institut Ausonius.

Caldwell, C., 2012, The Balkans, in S. Johnson (ed.), *The Oxford Handbook of Late Antiquity*, 92-114. Oxford: Oxford University Press.

Cambi, N., 1975, Spanish Amphorae Found Near Split. *Arheoloski vestnik* 26: 115-24.

Cambi, N., 1983, Le anfore Dressel 20 nella Jugoslavia, in J. M. Blazquez Martinez (ed.), *Producción y comercio del aceite en la antigüedad: Segundo Congreso Internacional: Sevilla, 24-28 febrero 1982*, 363-89. Madrid: Universidad Complutense de Madrid.

Cambi, N., 1989, Anfore romane in Dalmazia, in *Amphores romaines et histoire économique: dix ans de recherche (actes du colloque de Sienne, 22-24 mai 1986)*, 311-37. Rome: De Boccard.

Cambi, N., 1998, Sarcophage aus salonitanischen Werkstatten, in G. Koch (ed.), *Akten des Symposiums '125 Jahre Sarkophag-corpus'*, 169-81. Mainz.

Cambi, N., 2001, I porti della Dalmazia, in C. Zaccaria (ed.), *Strutture portuali e rotte maritime nell'adriatico di età romana*, 137-59. Rome: École francaise de Rome.

Carlson, D., 2007, Mast-Step Coins among the Romans. *International Journal of Nautical Archaeology* 36.2: 317-24.

Carlson, D., 2011, The Seafarers and Shipwrecks of Ancient Greece and Rome, in A. Catsambis, B. Ford and D. Hamilton (eds), *The Oxford Handbook of Maritime Archaeology*, 379-405. Oxford: Oxford University Press.

Carre, M., 1993, L'épave à *dolia* de Ladispoli (Etrurie Méridionale). *Archaeonautica* 11: 9-29.

Carre, M. and M. Jézégou, 1984, Pompes à chapelet sur des navires de l'Antiquité et du début du Moyen-Âge. *Archaeonautica* 4: 115-43.

Carre, M. and R. Roman, 2008, Hypothèse de restitution d'un navire à *dolia*; la construction d'une maquette. *Archaeonautica* 15: 175-92.

Casson, L., 1951, Speed under Sail of Ancient Ships. *Transactions and Proceedings of the American Philological Association* 82: 136-48.

Casson, L., 1968, Sea-Digging off Italy. *Archaeology* 31.3: 219-20.

Casson, L., 1971, *Ships and Seamanship in the Ancient World.* Baltimore: The Johns Hopkins University Press.

Castro, F., C. De Juan and M. Santos, 2018, Early Mediterranean Shipwrecks, *ShipLAB Report 17 vol. 2, ver. 12,* unpublished report. College Station: Texas A&M University.

Charlin, G., J. Gassend and R. Lequement, 1978, L'épave antique de la baie de Cavalière (Le Lavandou, Var). *Archaeonautica* 2: 9-93.

Chevalier, P., 1995, *Salona II: Ecclesiae Dalmatiae.* Vol. 2—Illustrations et conclusions. Rome: École francaise de Rome.

Cibecchini, F., C. De Juan and S. Marlier, 2013, Das Wrack "Ouest Giraglia 2" vor Korsika—Zum Phänomen der Tanker in der frühen Kaiserzeit, in M. Reinfeld (ed.), *Archäologie im Mittelmeer: auf der Suche nach verlorenen Schiffswracks und vergessenen Häfen*, 29-38. Darmstadt Mainz: von Zabern.

Clerc, J. and J. Negrel, 1973, Premiers résultats de la campagne de fouilles 1971 sur l'épave B de la Pointe de la Luque. *Cahiers d'archeologie subaquatique* 2: 61-71.

Coode, J. and J. Cullen, 1965, Pinus L., in P. Davis (ed.), *Flora of Turkey and the East Aegean Islands*, 73-5. Edinburgh: Edinburgh University Press.

Dark, K. and P. Dark, 1997, *The Landscape of Roman Britain.* Phoenix Mill: Sutton Publishing Ltd.

Djaoui, D., S. Greck and S. Marlier, 2011, *Arles-Rhone 3: le naufrage d'un chaland antique dans le Rhône, enquête pluridisciplinaire.* Arles: Actes Sud.

Džino, D., 2003, The Influence of Dalmatian Shipbuilders on the Ancient Warships and Naval Warfare: The Lembos and Liburnica. *Diadora* 21: 19-36.

Džino, D., 2006, Welcome to the Mediterranean Semi-Periphery: The place of Illyricum in book 7 of Strabo. *Ziva Antika* 56: 113-28.

Džino, D., 2008, Strabo 7.5 and Imaginary Illyricum, in *Estratto da Athenaeum: Studi di Letteratura e Storia dell'Antichita*, 173-92. Pavia: Università di Pavia.

Džino, D., 2010a, Aspects of Identity-Construction and Cultural Mimicry among Dalmatian Sailors in the Roman Navy. *Antichthon* 44: 96-110.

Džino, D., 2010b, *Illyricum in Roman Politics 229 BC-AD 68.* Cambridge: Cambridge University Press.

Džino, D., 2012a, Bellum Pannonicum: The Roman Armies and Indigenous Communities in Southern Pannonia 16-9 BC, in M. Hauser, I. Feodorov, N. Sekunda and A. Dumitru (eds), *Actes du Symposium International: Le Livre. La Roumanie. L'Europe.*, 461-80. Bucarest: Bibliothèque métropolitain de Bucarest.

Džino, D., 2012b, Contesting Identities of Pre-Roman Illyricum. *Ancient West & East* 11: 69-96.

Džino, D., 2013, The Impact of Roman Imperialism on the Formation of Group Identities in Some Indigenous Societies from the Eastern Adriatic Hinterland, in A. Rufin Solas, M.-G. Parisaki and E. Kosmidou (eds), *Armées grecques et romaines dans le nord des Balkans: Conflits et intégration des communautés guèrrieres*, 145-69. Gdańsk: Fondation traditio Europae.

Džino, D., 2014, The Formation of Early Imperial Peregrine *Civitates* in Dalmatia: (Re)constructing Indigenous Communities after the Conquest, in M. Janković, V. Mihajlović and S. Babić (eds), *The Edges of the Roman World*, 219-31. Newcastle upon Tune: Cambridge Scholars Publishing.

Džino, D., 2016, Appian's Illyrike: The Final Stage of the Roman Construction of Illyricum. *Istraživanja* 27: 69-83.

Džino, D. and A. Domić Kunić, 2018, A View from the Frontier Zone: Roman Conquest of Illyricum, in M. Milićević Bradač and D. Demicheli (eds), *The Century of the Brave: Roman Conquest and Indigenous Resistance in Illyricum during the Time of Augustus and His Heirs*, 77-87. Zagreb: University of Zagreb.

Erdkamp, P., 2005, *The Grain Market in the Roman Empire: A Social, Political and Economic Study.* Cambridge: Cambridge University Press.

Euforgen, 2009, *Distribution Map of Brutia Pine*. www.euforgen.org. Accessed 11/10/2019.

Faivre, S., T. Bakran-Petricioli and N. Horvatinčić, 2010, Relative Sea-Level Change During the Late Holocene on the Island of Vis (Croatia)—Issa Harbour Archaeological Site. *Geodinamica Acta* 23.5-6: 209-23.

Faivre, S. and E. Fouache, 2003, Some Tectonic Influences on the Croatian Shoreline Evolution in the Last 2000 Years. *Zeitschrift fur Geomorphologie* 47.4: 521-37.

Fant, J., 2012, Contracts and Costs for Shipping Marble in the Roman Empire, in A. Gutierrez, P. Lapuente and I. Roda (eds), *Interdisciplinary Studies on Ancient Stone: Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference (Tarragona 2009)*, 528-32. Tarragona: Institut Català d'Arqueologia Clàssica.

Ferreira Dominguez, A., 2019, Ancient Tree Species Distribution, personal communication, 4/10/2019.

Finley, M., 1985, *The Ancient Economy.* Berkeley: University of California Press.

Foley, B., K. Dellaporta, D. Sakellariou, B. Bingham, R. Camilli, et al., 2009, The 2005 Chios Ancient Shipwreck Survey—New Methods for Underwater Archaeology. *Hesperia* 78: 269-305.

Foley, B. and D. Mindell, 2002, Precision Survey and Archaeological Methodology in Deep Water. *Enalia, The Journal of the Hellenic Institute of Marine Archaeology* 6: 49-56.

Fouache, E., S. Faivre, S. Gluščević, V. Kovačić, F. Tassaux, et al., 2005, Evolution of the Croatian Shore Line between Porec and Split over the Past 2000 Years. *Archaeologia Maritima Mediterranea* 2: 115-34.

Gaffney, V., S. Čače, M. Darmanin, S. Forenbaher, S. Frame, et al., 2006, A Game of Numbers: Rural Settlement in Dalmatia and the Central Dalmatian Islands, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 89-106. Oxford: Archaeopress.

Garnsey, P. and R. Saller, 2015, *The Roman Empire: Economy, Society and Culture.* Berkeley: University of California Press.

Gassend, J., 1982, *Le navire antique du Lacydon.* Marseilles: Musée d'Histoire.

Gassend, J., B. Liou and S. Ximénès, 1984, L'épave 2 de l'Anse des Laurons (Martigues, Bouches-du-Rhone). *Archaeonautica* 4: 75-105.

Giampala, D., V. Carsana, G. Boetto, F. Crema, C. Florio, et al., 2005, La Scoperta del Porto di *Neapolis*: dalla ricostruzione topografica allo scavo e al recupero dei relitti. *Archaeologia Maritima Mediterranea* 2: 47-91.

Glicksman, K., 2005, Internal and External Trade in the Roman Province of Dalmatia. *Opuscula Archaeologica* 29: 189-230.

Glicksman, K., 2009, The Economy of the Roman Province of Dalmatia. Ph.D. dissertation, Oxford University, Oxford.

Glicksman, K., 2010, Cultural Interaction and Economic Ambition in Roman Dalmatia. *Bollettino di Archeologia On Line* Speciale C: 37-42.

Gluščević, S., 2004, Hydroarchaeological Excavations and the Discovery of the Third Sewn Liburnian Ship: *Seriliae*, in the Roman Harbor of Zaton near Zadar. *Archaeologia Maritima Mediterranea* 1: 41-52.

Goodman, M., 2012, *The Roman World 44 BC-AD 180.* London: Routledge.

Grbić, D., 2011, Augustan Conquest of the Balkans in the Light of Triumphal Monuments. *Ziva Antika* 61: 129-39.

Guibal, F. and P. Pomey, 2003, Timber Supply and Ancient Naval Architecture, in C. Beltrame (ed.), *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology Venice 2000*, 35-41. Oxford: Oxbow Books.

Harris, W., 1993, Between Archaic and Modern: Some Current Problems in the History of the Roman Economy, in J. Humphrey (ed.), *The Inscribed Economy; Production and Distribution in the Roman Empire in light of* instrumentum domesticum, JRA Supplemental Series Number 6, 11-30. Ann Arbor: University of Michigan.

Harris, W., 2000, Trade, in A. Bowman, P. Garnsey and D. Rathbone (eds), *The Cambridge Ancient History, Volume XI: The High Empire, A.D. 70-192*, 710-40. Cambridge: Cambridge University Press.

Hedrick, L., A. Mitchell-Cook and J. Bruseth, 2017, Excavation inside a Cofferdam, in J. Bruseth, A. Borgens, B. Jones and E. Ray (eds), *La Belle: The Archaeology of a Seventeenth-Century Ship of New World Colonization*, 45-59. College Station: Texas A&M University Press.

Heslin, K., 2011, *Dolia* Shipwrecks and the Wine Trade in the Roman Mediterranean, in D. Robinson and A. Wilson (eds), *Maritime Archaeology and Ancient Trade in the Mediterranean*, 157-68. Oxford: Oxford Centre for Maritime Archaeology.

Hesnard, A., M. Carre, M. Rival, B. Dangréaux, M. Thinon, et al., 1988, L'épave romain *Grand Ribaud D* (Hyères, Var). *Archaeonautica* 8: 5-180.

Hopkins, K., 1980, Taxes and Trade in the Roman Empire (200 B.C.-A.D. 400). *Journal of Roman Studies* 70: 101-25.

Hopkins, K., 1983, Models, Ships, and Staples, in P. Garnsey and C. Whittaker (eds), *Trade and Famine in Classical Antiquity*, 84-109. Cambridge: Cambridge Philological Society.

Houston, G., 1988, Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports. *American Journal of Archaeology* 92.4: 553-64.

Ivčević, S., 2013, First-Century Military Gear from Salona, in *Weapons and Military Equipment in Funerary Context: Proceedings of the XVII Roman Military Equipment Conference, Zagreb, 24th–27th May, 2010*, 299-316. Zagreb: Arheološki muzej u Zagrebu.

Jézégou, M., 2003, Epave Les Battuts 2/Baie de l'Amitié, in *Bilan Scientifique du Département des Recherches Archéologiques subaquatiques et sous-marines 1998*, 28-9. Marseilles: Ministère de la Culture et de la Communication.

Joncheray, A. and J. Joncheray, 1997, Dramont I, description et étude de la coque d'une épave de Marbres d'Asie Mineure du premier siècle après J.-C. *Cahiers d'archeologie subaquatique* 13: 165-95.

Joncheray, A. and J. Joncheray, 2004a, L'Épave Barthélemy B, à Saint-Raphael (Var, France). *Cahiers d'archeologie subaquatique* 15: 7-72.

Joncheray, A. and J. Joncheray, 2004b, L'épave Lardier 4, à la Croix-Valmer (Var, France). *Cahiers d'archeologie subaquatique* 15: 73-117.

Joncheray, A. and J. Joncheray, 2009, L'épave romaine de la Rabiou, Saint-Tropez (Var). *Cahiers d'archeologie subaquatique* 17: 63-102.

Joncheray, J., 1975a, *L'épave "C" de la Chrétienne.* Gap: Cahiers d'archeologie Subaquatique.

Joncheray, J., 1975b, Une épave de bas empire: Dramont F. *Cahiers d'archeologie subaquatique* 4: 91-140.

Joncheray, J., 1977, Mediterranean Hull Types Compared 2. Wreck F from Cape Dramont (Var), France. *International Journal of Nautical Archaeology and Underwater Exploration* 6.1: 3-7.

Jurišić, M., 2000, *Ancient Shipwrecks of the Adriatic: Maritime Transport during the First and Second Centuries AD.* BAR International Series 828. Oxford: Archaeopress.

Jurišić, M., 2006, The Maritime Trade of the Roman Province, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 175-92. Oxford: Archaeopress.

Kamenjarin, I. and I. Šuta, 2011, *Antički Sikuli: Katalog Izložbe.* Kaštel Lukšić: Muzej grada Kaštela.

Katičić, R., 1976, *Ancient Languages of the Balkans.* The Hague: Mouton.

Keppie, L., 1996, The Army and the Navy, in A. Bowman, E. Champlin and A. Lintott (eds), *The Cambridge Ancient History, Volume 10: The Augustan Empire, 43 BC-AD 69*, 371-96. Cambridge: Cambridge University Press.

Kirigin, B., 2006, The Greek Background, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 17-26. Oxford: Archaeopress.

Kirigin, B., 2009, Ancient Greeks in Croatia, in J. Norwich (ed.), *Croatia: Aspects of Art, Architecture and Cultural Heritage*, 20-31. London: Francis Lincoln, LTD.

Kirigin, B., 2016, Salona and the Sea—Some Observations, in D. Davison, V. Gaffney, P. Miracle and J. Sofaer (eds), *Croatia at the Crossroads: A Consideration of Archaeological and Historical Connectivity*, 139-55. Oxford: Archaeopress.

Kovács, P., 2014, *A History of Pannonia during the Principate.* Bonn: Dr. Rudolf Habelt GMBH.

Kozličić, M. and M. Bratanić, 2006, Ancient Sailing Routes in Adriatic, in S. Čače, A. Kurilić and F. Tassaux (eds), *Les routes de l'Adriatique antique: géographie et économie*, 107-24. Bordeaux: Institut Ausonius.

Kurilić, A., 2012, Roman Naval Bases at the Eastern Adriatic. *Histria Antiqua* 21: 113-22.

Laurence, R., 1998, Land Transport in Roman Italy: Costs, Practice and the Economy, in H. Parkins and C. Smith (eds), *Trade, Traders and the Ancient City*, 129-48. London: Routledge.

Leder, T., T. Ujević and M. Čala, 2004, Coastline Lengths and Areas of Islands in the Croatian Part of the Adriatic Sea Determined from the Topographic Maps at the Scale of 1:25000. *Geoadria* 9.1: 5-32.

Lindhagen, A., 2016, Narona in Dalmatia—the Rise and Fall of a "Gateway Settlement" in K. Hoghammar, B. Alroth and A. Lindhagen (eds), *Ancient Ports: The Geography of Connections (Proceedings of an International Conference at the Department of Archaeology and Ancient History, Uppsala University, 23-25 September 2010)*, 225-51. Uppsala Sweden: Carlssons Tryckeri.

Liou, B., 1973, Recherches archéologiques sous-marines. *Gallia* 31.2: 571-608.

Liou, B., 1975, Recherches archéologiques sous-marines. *Gallia* 33.2: 571-605.

Liou, B. and C. Domergue, 1990, Le commerce de la Bétique au ler siècle de notre ère [L'épave *Sud-Lavezzi 2* (Bonifacio, Corse du Sud)]. *Archaeonautica* 10: 11-123.

Liou, B., J. Gassend and R. Roman, 1990, 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]. *Archaeonautica* 10: 157-264.

Liphschitz, N., I. Radić Rossi, C. Pulak and D. Ruff, 2018, The Roman Ship found at Trstenik (Gulf of Kaštela, Croatia)—The Determination of Wood Species. *Skyllis* 17.2: 148-52.

Lo Cascio, E., 2007, The Early Roman empire: The State and the Economy, in W. Scheidel, I. Morris and R. Saller (eds), *The Cambridge Economic History of the Greco-Roman World*, 619-50. Cambridge: Cambridge University Press.

Ludvigsen, M., R. Eustice and H. Singh, 2006, *Photogrammetric Models for Marine Archaeology*, OCEANS 2006 conference, 18-21 Sep 2006, Boston.

Magas, B., 2007, *Croatia through History: The Making of a European State.* London: SAQI.

Mardešić, J., 2006, Excavations at Salona between 1970 and 2000, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 81-8. Oxford: Archaeopress.

Marelić, T., 2016, Wind Influence on Sailing Ship Navigation across Croatian part of Adriatic Sea. *Geoadria* 21.2: 211-36.

Marin, E., 2002, New Hellenistic Finds from Salona and Narona, in N. Cambi, S. Čače and B. Kirigin (eds), *Greek Influence Along the East Adriatic Coast—Proceedings of the International Conference Held in Split from September 24th to 26th 1998*, 415-21. Split: Književni Krug.

Marin, E., 2006, The Urbanism of *Salona* and *Narona* inside Roman *Dalmatia*, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 73-82. Oxford: Archaeopress.

Marlier, S. and M. Sciallano, 2008, L'épave à *dolia* de l'île de la Giraglia (Haute-Corse). *Archaeonautica* 15: 113-51.

Marlier, S. and P. Sibella, 2002, La Giraglia, a *Dolia* Wreck of the 1st Century BC from Corsica, France: Study of Its Hull Remains. *International Journal of Nautical Archaeology* 31.2: 161-71.

Marriner, N., C. Morhange, S. Faivre, C. Flaux, M. Vacchi, et al., 2014, Post-Roman Sea-level Changes on Pag Island (Adriatic Sea): Dating Croatia's "Enigmatic" Coastal Notch? *Geomorphology* 221: 83-94.

Marsden, P., 1967, *A Roman Ship from Blackfriars, London.* Portsmouth: Grosvenor Press.

Marsden, P., 1994, Blackfriars Ship 1, 1962, in P. Marsden (ed.), *Ships of the Port of London: First to Eleventh Centuries AD*, 33-95. London: English Heritage.

Martin, R., 1965, *Manuel d'architecture grecque.* Vol. 1—Materiaux et techniques. Paris: Editions Picard.

Marzano, A., 2007, *Roman Villas in Central Italy: A Social and Economic History.* Leiden: Brill.

Marzano, A., 2013, Le *villae rusticae* romane e la loro dimensione economica: uno sguardo alla penisola italiana, in A. Rizakis and I. Touratsoglu (eds), *Villae Rusticae: Family and Market-Oriented Farms in Greece under Roman Rule: Proceedings of an international congress held at Patrai, 23-24 April 2010*, 6-19. Paris: De Boccard.

Matijašić, R., 2001, Le *ville rustiche* istriane (bilancio storico-archeologico), in M. Verzar-Bass (ed.), *Abitare in Cisalpina, L'edilizia privata nelle città e nel territorio in età romana*, 693-711. Trieste: Editreg.

Matijašić, R., 2018, *Res gestae* (28, 1) and the Establishment of Roman Colonies on the Eastern Adriatic, in M. Milićević Bradač and D. Demicheli (eds), *The Century of the Brave: Roman Conquest and Indigenous Resistance in Illyricum during the Time of Augustus and His Heirs*, 69-76. Zagreb: University of Zagreb.

McCann, A. and J. Oleson, 2004, *Deep-water Shipwrecks off Skerki Bank: The 1997 Survey.* JRA Supplementary Series #58. Portsmouth RI: Journal of Roman Archaeology.

McGrail, S., 2008, Sea Transport, Part 1: Ships and Navigation, in J. Oleson (ed.), *The Oxford Handbook of Engineering and Technology in the Classical World*, 606-37. Oxford: Oxford University Press.

McKay, A., 1975, *Houses, Villas and Palaces in the Roman World.* Ithaca: Cornell University Press.

McKee, E., 1983, *Working Boats of Britain: Their Shape and Purpose.* London: Conway Maritime Press.

Mees, A. and B. Pferdehirt, 2002, *Römerzeitliche Schiffsfunde in der Datenbank 'Navis I'* Mainz: Verlag des Römisch-Germanischen Zentralmuseums.

Meiggs, R., 1982, *Trees and Timber in the Ancient Mediterranean World.* Oxford: Clarendon Press.

Melia-Teevan, K., 2016, Framing the Debate: A Study of the Development of Ship Framing in the Mediterranean from the 5th Century B.C.E. to the 9th Century C.E. Masters thesis, Texas A&M University, College Station.

Mihajlović, I., 2011, A Roman Shipwreck with Sarcophagi near Sutivan on the Island of Brač. *Submerged Heritage* 1: 32-4.

Miholjek, I. and I. Mihajlović, 2011, Antički brodolomi s teretom sarkofaga na području Dalmacije. *Portal. Godisnjak Hrvatskog Restauratorskog Zavoda* 2: 215-21.

Miletić, Ž., 2006, Roman Roads along the Eastern Coast: State of Research, in S. Čače, A. Kurilić and F. Tassaux (eds), *Les routes de l'Adriatique antique: géographie et économie*, 125-36. Bordeaux: Institut Ausonius.

Milne, G., 1996, Blackfriars ship 1: Romano-Celtic, Gallo-Roman or *Classis Britannicae*?. *International Journal of Nautical Archaeology* 25.3&4: 234-8.

Morley, N., 2007a, The Early Roman Empire: Distribution, in W. Scheidel, I. Morris and R. Saller (eds), *The Cambridge Economic History of the Greco-Roman World*, 570-91. Cambridge: Cambridge University Press.

Morley, N., 2007b, *Trade in Classical Antiquity.* Cambridge: Cambridge University Press.

Oreb, F., 1984, Archaeological Excavations in the Eastern Part of Ancient Salona in 1979. *Vjesnik za arheologiju i historiju dalmatinsku* 77: 25-35.

Oreb, F. and B. Kirigin, 1980, Lučki objekat u Saloni: primjer gradnje na drvenim stupovima, in *Materijali, tehnike i strukture predantičkog i antičkog graditeljstva na istočnom jadranskom prostoru*, 111-4. Zagreb: Odjel za arheologiju—Centar za povijesne znanosti.

Pallares, F., 1987, Il relitto di Diano Marina nel commercio vinicolo antico, in *El vi a l'antiguitat, economia, producció i comerç al mediterrani occidental: actes I Colloqui d'Arqueologia Romana [Badalona, 28, 29, 30 de novembre i 1 de desembre de 1985]*, 298-307. Badalona: Museu de Badalona.

Pallares, F., 1991, Alcune considerazioni sui resti lignei dello scafo della nave romana del golfo di Diano Marina, in P. Gianfrotta (ed.), *IV rassegna di archeologia subacquea, IV premio Franco Papò: Atti Guardini Naxos 13-15 ottobre 1989*, 171-7. Messine: Azienda Autonoma di Soggiorno e Turismo.

Parker, A., 1992, *Ancient Shipwrecks of the Ancient Mediterranean and Roman Provinces.* BAR International Series 580. Oxford: Archaeopress.

Peacock, D. and D. Williams, 1986, *Amphorae and the Roman Economy: An Introductory Guide.* New York: Longman.

Percival, J., 1976, *The Roman Villa: An Historical Introduction.* Berkeley: University of California Press.

Pešić, M., 2008, Excavation and *In Situ* Protection of the Perforated *Dolia* in the Port of Vis, in I. Radić Rossi, A. Gaspari and A. Pydyn (eds), *Proceedings of the 13th Annual Meeting of the European Association of Archaeologists (Zadar, Croatia, 18-23 September 2007)*, 187-95. Zagreb: Hrvatsko arheološko društvo.

Polmar, N., 1983, *Guide to the Soviet Navy.* Annapolis: Naval Institute Press.

Pomey, P. and G. Boetto, 2019, Ancient Mediterranean Sewn-Boat Traditions. *International Journal of Nautical Archaeology* 48.1: 5-51.

Pomey, P., Y. Kahanov and E. Rieth, 2012, Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, Problems, and Future Research. *International Journal of Nautical Archaeology* 41.2: 235-314.

Poveda, P., 2008, *Une hypothèse de restitution du navire Dramont E (V° siècle ap. J.-C.)*, Cultures, economies, societes et environnement du debut de la Prehistoire au Moyen-Age: travaux en cours, 8 June 2008, Aix-en-Provence.

Poveda, P., 2012, Hypothetical Reconstruction of the Dramont E Shipwreck, in N. Gunsenin (ed.), *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology Istanbul 2009*, 331-6. Istanbul: Ege Yayınları.

Pulak, C., 1998, The Uluburun Shipwreck: An Overview. *International Journal of Nautical Archaeology* 27.3: 188-224.

Pulak, C., 2002, The Uluburun Hull Remains, in H. Tzalas (ed.), *Tropis VII: 7th International Symposium on Ship Construction in Antiquity*, 615-36. Athens: Hellenic Institute for the Preservation of Nautical Tradition.

Pulak, C., 2003, Mortise-and-Tenon Joints of Bronze Age Seagoing Ships, in C. Beltrame (ed.), *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology Venice 2000*, 28-34. Oxford: Oxbow Books.

Radić, I., 2003, The Adriatic within the Mediterranean: Some Characteristic Shipwrecks from the Roman Period, in C. Brebbia and T. Gambin (eds), *Maritime Heritage*, 155-65. Southampton: WIT Press.

Radić Rossi, I., 2004, K. Sućurac—Trstenik. *Hrvatski arheoloski godisnjak* 1: 228-30.

Radić Rossi, I., 2005a, Kaštel Štafilić—Resnik. *Hrvatski arheoloski godisnjak* 2: 355-6.

Radić Rossi, I., 2005b, Kaštel Sućurac—Trstenik. *Hrvatski arheoloski godisnjak* 2: 360-2.

Radić Rossi, I., 2006a, Due testimonianze particolari sull'economia marinara nella Dalmazia romana, in I. Radić Rossi (ed.), *Archeologia subacquea in Croazia*, 46-57. Venice: Marsilio.

Radić Rossi, I., 2006b, Kaštel Sućurac—Trstenik. *Hrvatski arheoloski godisnjak* 3: 402-4.

Radić Rossi, I., 2007, Kaštel Sućurac—Trstenik. *Hrvatski arheoloski godisnjak* 4: 456-8.

Radić Rossi, I., 2008a, Recenti scoperte sottomarine nella baia di Kaštela, in R. Auriemma and S. Karinja (eds), *Terre di mare: L'archeologia dei paesaggi costiere e le variazioni climatiche*, 285-98. Trieste: Università degli studi di Trieste.

Radić Rossi, I., 2008b, I doli forati. Nuove testimonianze dell'economia marinara in Dalmazia, in F. Lugli and S. A. Stoppiello (eds), *Atti del III Convegno Nazionale di Etnoarchaeologia, Mondaino, 17-19 marzo 2004,* BAR International Series 1841, 214-21. Oxford: Archaeopress.

Radić Rossi, I., 2008c, Rescue Excavations at Vranjic near Split, Croatia, in I. Radić Rossi, A. Gaspari and A. Pydyn (eds), *Proceedings of the 13th Annual Meeting of the European Association of Archaeologists (Zadar, Croatia, 18-23 September 2007)*, 151-66. Zagreb: Hrvatsko arheološko društvo.

Radić Rossi, I., 2009a, Il fenomeno dei *dolia* forati lungo il litorale croato, in S. Pesavento Mattioli and M.-B. Carre (eds), *Olio e pesce in epoca romana; Produzione e commercio nelle regioni dell'Alto Adriatico, Atti del convegno (Padova, 16 febbraio 2007)*, 121-32. Padova: Università degli studi di Padova.

Radić Rossi, I., 2009b, Arheološka Baština U Podmorju Kaštelanskog Zaljeva. *Archaeologia Adriatica* 2: 489-506.

Radić Rossi, I., 2012, Underwater Cultural Heritage and Maritime Archaeology in Croatia: An Overview. *European Journal of Archaeology* 15.2: 285-308.

Radić Rossi, I. and N. Lete, 2012, Kaštel Sućurac—Trstenik. *Hrvatski arheoloski godisnjak* 9: 718-21.

Rendić-Miočević, D., 1983, Salona 'Quadrata': Salonitanski *oppidum* (Caes., b. c. III 9) u svjetlu novih istraživanja, in *Zbornik za narodni život i običaje 49*, 529-45. Zagreb: Jugoslavenska akademija znanosti i umjetnosti.

Richards, N., 2008, *Ships' Graveyards: Abandoned Watercraft and the Archaeological Site Formation Process.* Gainesville: University Press of Florida.

Richards, N., 2011, Ship Abandonment, in A. Catsambis, B. Ford and D. Hamilton (eds), *The Oxford Handbook of Maritime Archaeology*, 856-78. Oxford: Oxford University Press.

Rico, C., 2004, Quand les briques romaines prenaient la mer. *Pallas* 66.4: 97-104.

Roman, R., 2018, Une nouvelle maquette de restitution hypothétique d'un navire á *dolia*. *Archaeonautica* 20: 233-8.

Rouge, J., 1966, *Recherches sur l'organisation du commerce maritime en Méditerranée sous l'Empire romain.* Paris: SEVPEN.

Royal, J., 2012, Illyrian Coastal Exploration Program (2007-2009): The Roman and Late Roman Finds and Their Contexts. *American Journal of Archaeology* 116.3: 405-60.

Ruff, D., 2017, An Ancient Laced Boat in the Shadow of a Senatorial Estate: 2017 Excavation of a Roman-era Vessel in Croatia. *INA Quarterly* 44.1/2: 18-23.

Ruff, D. and I. Radić Rossi, 2015, Excavation of an Early Imperial Roman Ship at Trstenik in the Gulf of Kaštela, Croatia. *INA Quarterly* 42.4: 10-17.

Russell, B., 2013a, *The Economics of the Roman Stone Trade.* Oxford: Oxford University Press.

Russell, B., 2013b, Roman and Late-antique Shipwrecks with Stone Cargoes: A New Inventory. *Journal of Roman Archaeology* 26: 331-61.

Sanader, M., 2004, *Ancient Greek and Roman Cities in Croatia.* Zagreb: Školska knjiga.

Sanader, M., 2014, *Dalmazia: Una provincia romana sull'Adriatico.* Roma e l'Impero vol 15. Milan: Mondadori.

Santamaria, C., 1995, *L'èpave Dramont 'E' à Saint-Raphaël (V siècle ap. J.-C.).* Paris: CNRS.

Šašel Kos, M., 2000, Caesar, Illyricum, and the Hinterland of Aquileia, in G. Urso (ed.), *L'Ultimo Cesare: Scritti riforme progetti poteri congiure*, 277-304. Roma: L'Erma de Bretschneider.

Šašel Kos, M., 2004, The Roman Conquest of Dalmatia in the Light of Appian's Illyrike, in G. Urso (ed.), *Dall'Adriatico al Danubio: L'illirico nell'età greca e romana*, 141-66. Pisa: Edizioni ETS.

Šašel Kos, M., 2005, *Appian and Illyricum.* Ljubljana: Narodni muzej Slovenije.

Šašel Kos, M., 2011, The Roman Conquest of Dalmatia and Pannonia under Augustus—Some of the Latest Research Results, in G. Moosbauer and R. Wiegels (eds), *Fines imperii—imperium sine fi ne? Römische Okkupations- und Grenzpolitik im frühen Principat*, 107-17. Rahden: Leidorf.

Šašel Kos, M., 2012, The Role of the Navy in Octavian's Illyrian War. *Histria Antiqua* 21: 93-104.

Šašel Kos, M., 2013, The Roman Conquest of Illyricum (Dalmatia and Pannonia) and the Problem of the Northeastern Border of Italy. *Studia Europaea Gnesnensia* 7: 169-200.

Šašel Kos, M., 2015, The Final Phase of the Augustan Conquest of Illyricum, in G. Cuscito (ed.), *Antichità Altoadriatiche*, 65-87. Trieste: Editreg.

Šašel Kos, M., 2017, Tiberius in Strabo's *Geography*: Echoes of His Activities in Illyricum, in G. Nemeth and A. Szabo (eds), *Tiberius in Illyricum: Contributions to the History of the Danubian Provinces under Tiberius' Reign (14-37 AD),* Hungarian Polis Studies Nr. 24, 139-56. Budapest: Debrecen.

Šašel Kos, M., 2018, Octavian 's Illyrian War: Ambition and Strategy, in M. Milićević Bradač and D. Demicheli (eds), *The Century of the Brave: Roman Conquest and Indigenous Resistance in Illyricum during the Time of Augustus and His Heirs*, 41-57. Zagreb: University of Zagreb.

Scheidel, W., 2013, Explaining the Maritime Freight Charges in Diocletian's Prices Edict. *Journal of Roman Studies* 26: 464-8.

Schiffer, M., 1996, *Formation Processes of the Archaeological Record.* Salt Lake City: University of Utah Press.

Šešelj, L. and M. Ilkić, 2015, Maritime Trade in the Pre-Roman Period in the Eastern Adriatic: A Preliminary Report on a Ceramic and Numismatic Evidence in *Liburnia*, in Y. Marion and F. Tassaux (eds), *AdriAtlas et l'histoire de l'espace adriatique du VI s. a.C. au VIII s. p.C.: Actes du colloque international de Rome (4-6 novembre 2013),* Scripta Antiqua 79, 419-33. Bordeaux: Ausonius.

Simpson, E., 2010, *The Gordion Wooden Objects.* Vol. 1: The Furniture from Tumulus MM. Leiden: Brill.

Škegro, A., 2006, The Economy of Roman Dalmatia, in D. Davison, V. Gaffney and E. Marin (eds), *Dalmatia: Research in the Roman Province 1970-2001,* BAR International Series 1576, 149-73. Oxford: Archaeopress.

Smith, A., 1836, *An Inquiry into the Nature and Causes of the Wealth of Nations.* Edinburgh: Printed for Thomas Nelson and Peter Brown.

Stančič, Z., N. Vujnović, B. Kirigin, S. Čače, T. Podobnikar, et al., 1999, *The Archaeological Heritage of the Island of Brač, Croatia.* BAR International Series 803. Oxford: Archaeopress.

Steffy, J., 1985, The Kyrenia Ship: An Interim Report on Its Hull Construction. *American Journal of Archaeology* 89.1: 71-101.

Steffy, J., 1994, *Wooden Ship Building and the Interpretation of Shipwrecks.* College Station: Texas A&M University Press.

Steffy, J., 1998, Seldom Discussed Features of Ancient and Medieval Ship Construction. *Archaeonautica* 14: 165-9.

Stipčević, A., 1977, *The Illyrians: History and Culture.* Park Ridge NJ: Noyes Press.

Šuta, I., 2011, Zaštitna arheološka istraživanja na Brižinama u Kaštel Sućurcu. *Kaštelanski zbornik* 9: 109-27.

Tchernia, A., 2016, *The Romans and Trade.* Oxford: Oxford University Press.

Tedeschi, A., 2014, *AAD Algorithms-Aided Design: Parametric Strategies Using Grasshopper.* Le Penseur.

Thompson, T. and D. Thompson, 2016, *Adriatic Pilot.* Cambridgeshire: Imray Laurie Norie & Wilson Ltd.

Tiboni, F. and S. Tusa, 2016, The Marausa Wreck, Sicily: interim report on a boat built in the Western Imperial Roman tradition. *International Journal of Nautical Archaeology* 45.2: 239-52.

Ward, C., 2000, *Sacred and Secular: Ancient Egyptian Ships and Boats.* Philadelphia: Archaeological Institute of America.

Werner, M., 1973, The Development of Stonework in Roman Dalmatia: Continuity and Innovation, in E. Borza and R. Carruba (eds), *Classics and the Classical Tradition: Essays Presented to Robert E. Dengler on the Occasion of His Eightieth Birthday*, 178-97. University Park: Penn State University.

Wicha, S., 2002, Épave Baie de l'Amitié, in *Bilan Scientifique du Département des Recherches Archéologiques subaquatiques et sous-marines 2001*, 43-4. Marseilles: Ministère de la Culture et de la Communication.

Wilkes, J., 1962, Studies in the Roman Province of Dalmatia. Ph.D. dissertation, Durham University, Durham.

Wilkes, J., 1969, *Dalmatia.* Cambridge: Harvard University Press.

Wilkes, J., 1972, The Population of Roman Dalmatia, in J. Vogt (ed.), *Aufstieg und Niedergang der römischen Welt: Geschichte und Kultur Roms im Spiegel der neueren Forschung*, 732-66. Berlin: de Gruyter.

Wilkes, J., 1974, Boundary Stones in Roman Dalmatia. *Arheoloski vestnik* 25: 258-71.

Wilkes, J., 1979, Importation and Manufacture of Stamped Bricks and Tiles in the Roman Province of Dalmatia, in A. McWhirr (ed.), *Roman Brick and Tile: Studies in Manufacture, Distribution and Use in the Western Empire*, 65-72. Oxford: British Archaeological Reports.

Wilkes, J., 1992, *The Illyrians.* Oxford: Blackwell Publishers.

Wilkes, J., 1996, The Danubian and Balkan Provinces, in A. Bowman, E. Champlin and A. Lintott (eds), *The Cambridge Ancient History, Volume 10: The Augustan Empire, 43 BC-AD 69*, 545-85. Cambridge: Cambridge University Press.

Wilkes, J., 2000, The Danube Provinces, in A. Bowman, P. Garnsey and D. Rathbone (eds), *The Cambridge Ancient History, Volume XI: The High Empire, A.D. 70-192*, 577-603. Cambridge: Cambridge University Press.

Wilkes, J., 2003, The Towns of Roman Dalmatia, in P. Wilson (ed.), *The Archaeology of Roman Towns*, 233-41. Oxford: Oxbow Books.

Wilkes, J. and T. Fischer-Hansen, 2004, The Adriatic, in M. Hansen and T. Nielsen (eds), *An Inventory of Archaic and Classical Poleis*, 321-38. Oxford: Oxford University Press.

Wilson, A., 2009, Approaches to Quantifying Roman Trade, in A. Bowman and A. Wilson (eds), *Quantifying the Roman Economy: Methods and Problems*, 213-49. Oxford: Oxford University Press.

Ximénès, S. and M. Moerman, 1994, La fouille de l'épave 1 de la calanque de L'Ane. *Cahiers d'archeologie subaquatique* 12: 95-112.

Ximénès, S. and M. Moerman, 1998, Fouille de l'épave de la calanque de l'Âne (Marseille). *Archaeonautica* 14: 299-302.

Yamafune, K., 2016, Using Computer Vision Photogrammetry (AgiSoft Photoscan) to Record and Analyze Underwater Shipwreck Sites. Ph.D. dissertation, Texas A&M University, College Station.

Zaninović, M., 1977, The Economy of Roman Dalmatia, in H. Temporini and W. Haase (eds), *Aufstieg und Niedergang der römischen Welt: Geschichte und Kultur Roms im Spiegel der neueren Forschung*, 767-809. Berlin: de Gruyter.

Zaninović, M., 2010, The Roman Army in Illyricum, in I. Radman-Livaja (ed.), *Finds of the Roman Military Equipment in Croatia*, 13-32. Zagreb: Arheološki muzej u Zagrebu.

Zaro, G. and M. Čelhar, 2018, Landscape as Legacy in Northern Dalmatia, in L. Miroševic, G. Zaro, M. Katić and D. Birt (eds), *Landscape in Southeastern Europe*, 49-67. Berlin: LIT Verlag.

Zotović, R., 2002, *Population and Economy of the Eastern Part of the Roman Province of Dalmatia.* BAR International Series 1060. Oxford: Archaeopress.

APPENDIX A

TIMBER CATALOG

The Timber Catalog has two functions. First, it lists the component name for every hull component identified during the excavation (keel, stem, sternpost, strakes, wales, frame components, and stringers), including information recorded during the excavation. Second, it cross-references all of the wood samples taken against the sampled components. Not all of the hull components were sampled. However, some hull assembly components (ex. treenails, pegs, tenons etc.) were sampled, and the Timber Catalog conserves those results.

Columns in the spreadsheet:

Component name: As discussed in Section 4.3.

Sample #: Unique number identifier of the wood sample taken from the component.

Tree species: Genus and species of the analyzed wood sample.

Tree: Common tree name of the analyzed wood sample.

Hard/Soft: Six conifers (soft woods) and 11 deciduous trees (hard woods) were detected during tree species analysis (Section 6.7). Results are recorded for analyzed wood samples: H – hard and S – soft.

Appearance (frame components only): Many of the frames visually appeared very fresh, almost undecayed after 2000 years underwater. Others were in a significantly degraded condition. To document the visually observed condition, four visual appearance codes were developed for future qualitative analysis: N – new; O – old; ? – indeterminant; and M – missing.

Remarks: Any noteworthy comment regarding the component as recorded underwater. As multiple divers recorded information during a single dive period, the amount of detail varies, and the items recorded are not perfectly consistent. Some divers recorded the number of treenails visible in a specific frame component; others did not. The available data is provided. For a discussion of "floating wood" (components which detached and began floating away during the excavation) see Section 4.3. For a discussion of "intermediate timbers" (short frame components installed outboard between full-length frames) see Section 6.4.5.

Keel Assembly

name	sample #	Tree species	Tree	Hard/Soft	Remarks
keel	166	*Fagus sylvatica*	European beech	H	5 samples taken (166, 183, 213, 245, 319); all European beech
stem	200	*Ulmus campestris*	Elm	H	
sternpost	45	*Fraxinus excelsior*	European ash	H	also sample 383

Strakes

name	sample #	Tree species	Tree	Hard/Soft	Remarks
SK1Pa	167	*Pinus nigra*	Black pine	S	also sample 161
SK1Pf	162	*Pinus halepensis*	Aleppo pine	S	also sample 321
SK1Sa	174	*Pinus nigra*	Black pine	S	also sample 318
SK1Sf	184	*Pinus nigra*	Black pine	S	
SK2Pa	168	*Cupressus sempervirens*	Mediterranean cypress	S	also samples 320, 322
SK2Pf	165	*Pinus halepensis*	Aleppo pine	S	
SK2Prepair	164	*Pinus nigra*	Black pine	S	also sample 163
SK2Sa	173	*Pinus nigra*	Black pine	S	
SK2Sf	185	*Pinus halepensis*	Aleppo pine	S	also sample 317
SK3Pa	169	*Pinus halepensis*	Aleppo pine	S	also sample 323
SK3Pf					
SK3Prepair	172	*Pinus halepensis*	Aleppo pine	S	
SK3Sa	175	*Cupressus sempervirens*	Mediterranean cypress	S	
SK3Sm	316	*Pinus sylvestris*	Scots pine	S	
SK3Sf	186	*Pinus halepensis*	Aleppo pine	S	
SK4P	324	*Cupressus sempervirens*	Mediterranean cypress	S	
SK4Sa	176	*Pinus halepensis*	Aleppo pine	S	
SK4Sm	315	*Pinus nigra*	Black pine	S	
SK4Sf	187	*Pinus pinea*	Stone pine	S	
SK5Pa	171	*Pinus halepensis*	Aleppo pine	S	
SK5Pf					
SK5Sa	177	*Pinus nigra*	Black pine	S	
SK5Sm	311	*Pinus halepensis*	Aleppo pine	S	
SK5Sf	297	*Pinus nigra*	Black pine	S	
SK6Pa					
SK6Pf					

Strakes

name	sample #	Tree species	Tree	Hard/Soft	Remarks
SK6S	178	*Cupressus sempervirens*	Mediterranean cypress	S	also samples 298, 310, 314 (probably some unidentified scarfs)
SK7Pa					
SK7Pf					
SK7Sa	179	*Pinus nigra*	Black pine	S	
SK7Sf	299	*Cupressus sempervirens*	Mediterranean cypress	S	
SK8P					
SK8Sa	180	*Pinus nigra*	Black pine	S	also sample 308
SK8Sf	300	*Cupressus sempervirens*	Mediterranean cypress	S	
SK9P					
SK9Sa	181	*Pinus nigra*	Black pine	S	
SK9Sm	307	*Cupressus sempervirens*	Mediterranean cypress	S	
SK9Sf	301	*Pinus nigra*	Black pine	S	
SK10P					
SK10Sa	182	*Pinus halepensis*	Aleppo pine	S	
SK10Sf	302	*Pinus nigra*	Black pine	S	also sample 305
SK11P					
SK11S					
SK12P					
SK12S	303	*Pinus halepensis*	Aleppo pine	S	also sample 378
SK13S	332	*Pinus halepensis*	Aleppo pine	S	
SK14S					
SK15S					
SK16S					

Wales

name	sample #	Tree species	Tree	Hard/Soft	Remarks
W1P	376	*Pinus pinea*	Stone pine	S	also sample 30
W1S	375	*Pinus pinea*	Stone pine	S	
W2P	293	*Pinus pinea*	Stone pine	S	
W2S	330	*Pinus pinea*	Stone pine	S	
W3S	304	*Pinus pinea*	Stone pine	S	

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F11	46	*Pinus halepensis*	Aleppo pine	S	O	1 cant frame; 1 treenail; bevelled; the lower surface follows the planking; keel recess
F12	47	*Castanea sativa*	Sweet chestnut	H	O	2 treenails
F12-1	49	*Pinus halepensis*	Aleppo pine	S	N	thicker than F12; different type of wood
F13	48	*Acer pseudoplatanus*	Sycamore	H	O	1 floortimber; 3 treenails; keel recess
F14	50	*Quercus cerris*	Turkey oak	H	O	4 treenails; probably ended about 10 cm before the keel (visible on the planking)
F14-1					O	2 treenails; probably crossed the keel originally (part is missing)
F15	52	*Fraxinus excelsior*	European ash	H	O	floortimber, 4 treenails
F15-1	51	*Pinus halepensis*	Aleppo pine	S	N	huge thick piece that overlaps with F15 (does not abut)
F15-11	21	*Castanea sativa*	Sweet chestnut	H	M	removed as 'floating wood'; outline of removed section appears on the planking
F15-12	53	*Pinus halepensis*	Aleppo pine	S	N	mislabeled as F15-11 in the orthophoto; 2 treenails
F16	54	*Pinus nigra*	Black pine	S	?	floortimber; 11 treenails; the first frame with a limber hole
F17					O	no limber hole
F17-1					O	possibly part of the same timber as F17; 5 treenails
F17-11					O	6 treenails
F18	55	*Pinus halepensis*	Aleppo pine	S	?	floor timber with limber hole (length: 2; height 3.5) and 10 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F18-11	28	*Cupressus sempervirens*	Mediterranean cypress	S	M	removed as 'floating wood'; outline of removed section appears on the planking
F18-12					O	broken on both sides
F18A-12					O	2 treenails; an intermediate timber not associated with a floor
F19	4	*Pinus halepensis*	Aleppo pine	S	M	removed as 'floating wood'; 2 pegs visible in outline where F19 was
F19-1					?	3 treenails
F19-11	56	*Quercus cerris*	Turkey oak	H	N	5 treenails
F19-12					O	3 treenails
F19-2					O	2 treenails
F20	57	*Acer pseudoplatanus*	Sycamore	H	?	12 treenails; rounded limber hole above the keel; length: 4.5, height: 5
F20-1	58	*Pinus halepensis*	Aleppo pine	S	?	3 treenails
F20-11	59	*Pinus halepensis*	Aleppo pine	S	N	5 treenails
F20A-11	60	*Quercus cerris*	Turkey oak	H	?	small futtock piece between F20-11 and F21-12; 1 treenail; an intermediate timber not associated with a floor
F21	67	*Pinus halepensis*	Aleppo pine	S	N	large floor timber with 13 treenails; limber hole (length: 3.5 cm, height: 6 cm);
F21-1	68	*Pinus halepensis*	Aleppo pine	S	?	futtock with 1 treenail, broken into 2 pieces at the treenail
F21-11	62	*Castanea sativa*	Sweet chestnut	H	O	4 treenails
F21-12	61	*Quercus cerris*	Turkey oak	H	?	2 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F22	69	*Acer pseudoplatanus*	Sycamore	H	?	Floor timber with limber hole (length: 3 cm, height: 4 cm) and 11 treenails. Approximately half of this frame appears to be missing.
F23	71	*Castanea sativa*	Sweet chestnut	H	O	F23 has a chunk missing over strake 13, with a small piece of 23 dangling over the hull break at strake 15. There are 6 treenails to starboard of centreline on F23, and 7 treenails to port.
F23-1					N	small futtock extension
F23-11	64	*Pinus halepensis*	Aleppo pine	S	?	F23-11 has 7 treenails, and is broken at strake 15. It would align well to the dangling small piece of F23.
F24	72	*Pinus halepensis*	Aleppo pine	S	O	Floor timber with 10 treenail and limber hole (above the keel); Dimensions of the limber hole= length: 4 cm, height: 4 cm
F25	73	*Castanea sativa*	Sweet chestnut	H	O	floor timber, 9 treenails (two are not marked); Limber hole above the keel, dimensions: length: 4 cm, height: 4 cm.
F25-1					O	small broken piece, 1 treenail
F25-11	65	*Acer pseudoplatanus*	Sycamore	H	O	futtock to the south, 9 treenails
F25-2	2	*Pinus halepensis*	Aleppo pine	S	M	removed as floating wood (drawing made)
F26	75	*Quercus petraea*	Sessile oak	H	?	10 treenails; Limber hole above the keel, dimensions: length: 3.5 cm, height: 4 cm

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F26-11	74	*Pinus pinea*	Stone pine	S	N	74 cm long. According to the color and surface of the wood, it doesn't look that these two pieces were made from the same type of the wood. Scarf between two frame timbers is almost diagonal. 2 treenails
F27	76	*Quercus cerris*	Turkey oak	H	N	10 treenails; limber hole (dimensions: length: 3cm, height: 3.5 cm)
F27-1	78	*Pinus halepensis*	Aleppo pine	S	N	2 treenails; inboard end is cut down at an angle
F27-11	66	*Pinus halepensis*	Aleppo pine	S	?	5 treenails (one is missing on the south end of the futtock)
F28	79	*Pinus halepensis*	Aleppo pine	S	N	Floor timber with limber hole (length: 5 cm; height: 4.3 cm) and 12 treenails. Notch cut in the timber (length: 15 cm; width: 5 cm; height: 2.5 cm); Two nails preserved, 56 cm to the south of the notch edge (likely attached stringer S17)and 62 cm to the north of the notch edge (possible stringer attachment).
F29	80	*Fraxinus excelsior*	European ash	H	O	floor timber; 10 treenails; limber hole (dimensions: length: 4.5 cm, height: 4 cm);
F29-1					O	2 treenails
F29-11	94	*Pinus halepensis*	Aleppo pine	S	N	4 treenails
F29-12	95	*Castanea sativa*	Sweet chestnut	H	O	4 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F30	82	*Juglans regia*	Walnut	H	?	Floor timber, 12 treenails; Nail is noticed 22.5 cm from the keel towards the south (likely attached stringer S31); Damaged heavily on the northern side; Limber hole above the keel, dimensions: length: 5 cm, height: 5 cm.
F31	83	*Pinus halepensis*	Aleppo pine	S	N	floor timber, 9 treenails and two holes with missing treenails. Limber hole above the keel, dimensions: length: 4.5 cm height: 4 cm
F31-1	84	*Pinus halepensis*	Aleppo pine	S	?	1 treenail. Diagonal gap between F31 and F31-1
F31-11	98	Quercus sp. deformed	Oak	H	O	poor condition
F31-12	96	*Pinus halepensis*	Aleppo pine	S	N	9 treenails
F31-X					O	small unlabeled frame piece on orthophoto between F31-11 and F31-12; 3 treenails; probably the same wood as F31-11
F32	86	*Acer pseudoplatanus*	Sycamore	H	?	floor timber, 8 treenails. Limber hole above the keel, dimensions: length: 4cm, height: 3 cm.
F32-1	85	*Acer pseudoplatanus*	Sycamore	H	?	2 treenails
F32-11	97	*Pinus halepensis*	Aleppo pine	S	N	6 treenails and one hole without treenail (on the northern part of the frame timber). Frame timber with regular shape on both sides
F33	89	*Pinus halepensis*	Aleppo pine	S	O	floor timber, 11 treenails, one is missing on the southern part of the timber

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F33-1	87	*Fraxinus excelsior*	European ash	H	O	6 treenails
F33-11	99	*Fraxinus excelsior*	European ash	H	O	10 treenails
F34	90	*Quercus petraea*	Sessile oak	H	O	floor timber, 14 treenails and one hole without treenail. Limber hole above the keel, dimensions: length: 3.5 cm, height: 3 cm
F34-1					N	3 treenails
F35	93	*Pinus nigra*	Black pine	S	N	floor timber, 10 treenails and limber hole above the keel, dimensions: length: 5 cm, height: 4 cm
F35-1	92	*Castanea sativa*	Sweet chestnut	H	O	2 treenails
F35-11	101	*Quercus petraea*	Sessile oak	H	O	small broken piece, 1 treenail
F35-12					N	extending under stringer 23, 5 treenails
F35-2	91	*Cupressus sempervirens*	Mediterranean cypress	S	O	3 treenails and one hole without treenail
F36	108	*Pinus halepensis*	Aleppo pine	S	?	floor timber, 12 treenails and two holes on the southern part of the timber. Notch in the floor timber (dimensions = length: 14.5 cm, width: 2.5 cm, height: 4 cm); Limber hole above the keel, dimensions: length: 4 cm, height: 4 cm
F36-11	102	*Pinus halepensis*	Aleppo pine	S	O	extending under stringer 23, 9 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F37	109	*Quercus petraea*	Sessile oak	H	O	floor timber, broken over the keel; 5 treenails (one is not marked); Limber hole above the keel is damaged, dimensions: length: 3 cm, height: 7 cm
F37-1					O	9 treenails; possibly the same wood species as F37
F37-11					O	possibly the same timber as F37-12
F37-12	103	*Castanea sativa*	Sweet chestnut	H	O	extending under stringer 23, 9 treenails
F38	110	*Pinus halepensis*	Aleppo pine	S		floor timber; is heavily damaged over the keel, at the place where was a limber hole. 4 treenails and one hole without treenail
F38-1					O	19 treenails; possibly the same timber as F38
F38-11	104	*Pinus halepensis*	Aleppo pine	S	?	4 treenails and one hole without treenail
F38-12	106	*Pinus halepensis*	Aleppo pine	S	?	extending under stringer 23
F39					O	floor timber, 8 treenails. Limber hole above the keel is damaged, dimensions: length: 3 cm, height: 5 cm
F39-1					N	4 treenails
F39-11	105	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23. 6 treenails and one hole (treenail is missing);

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F39-X					O	unlabeled frame on orthophoto between F39 and F39-11; same timber as F39, which separated into two pieces when the limber hole rotted out; 4 treenails
F40	111	*Pinus halepensis*	Aleppo pine	S	N	floor timber, 15 treenails and a hole without treenail. There is a notch in the eastern part of the frame timber, above keel, possibly the notch for the keelson. Dimensions = length: 14 cm, width: 4 cm, height: 2 cm; Limber hole above the keel, dimensions: length: 4 cm, height: 5 cm
F40-1	112	*Cupressus sempervirens*	Mediterranean cypress	S	N	overlapping with F39-1, F40 and F39 (it has regular shape at the ends; it is not connected or joined to the other frame timbers)
F40-11	107	*Pinus halepensis*	Aleppo pine	S	N	9 treenails
F41	120	*Castanea sativa*	Sweet chestnut	H	O	floor timber; 8 treenails and limber hole above the keel, dimensions: length: 4.5 cm, height: 6 cm
F41-1	113	*Quercus cerris*	Turkey oak	H	O	2 treenails
F41-11					O	broken in three parts and it is extending under S23. 5 treenails
F42	121	*Pinus halepensis*	Aleppo pine	S	?	floor timber; has 19 treenails and limber hole (length: 2.5 cm, height: 4 cm)
F42-11	126	*Pinus halepensis*	Aleppo pine	S	N	7 treenails
F42-12					?	under stringer 23

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F43	123	*Castanea sativa*	Sweet chestnut	H	O	floor timber, 10 treenails and limber hole above the keel, dimensions: length: 4 cm, height: 3 cm
F43-1	115	*Pinus nigra*	Black pine	S	N	2 treenails
F43-11	127	*Pinus nigra*	Black pine	S	N	extending under stringer 23, 9 treenails
F44					N	floor timber, 16 treenails; Limber hole above the keel, dimensions: length: 4 cm, height: 3 cm
F44-11	128	*Pinus halepensis*	Aleppo pine	S	N	8 treenails
F45	125	*Castanea sativa*	Sweet chestnut	H	O	floor timber, 7 treenails; Limber hole above the keel, dimensions = length: 5 cm, height: 4 cm. Notch in the floor timber (corresponding to the width of the keel, maybe for the keelson?), dimensions = length: 10 cm, width: 1 cm, height: 1 cm
F45-1	116	*Acer pseudoplatanus*	Sycamore	H	O	5 treenails
F45-11	129	*Castanea sativa*	Sweet chestnut	H	O	extending under S23, 5 treenails (one is not marked)
F45-12	132	*Pinus halepensis*	Aleppo pine	S	O	on outboard side of S23; does not line up well with F45-11
F46	119	*Pinus nigra*	Black pine	S	N	floor timber: length: 189 cm, width: 7 cm, 15 treenails; Limber hole above the keel, Dimensions: length: 3 cm, height: 5 cm; notch facing aft
F46-11	130	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23. 7 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F47	118	*Castanea sativa*	Sweet chestnut	H	O	floor timber, 10 treenails; Limber hole above the keel, dimensions: length: 3.5 cm, height: 5 cm
F47-1	117	*Pinus halepensis*	Aleppo pine	S	?	3 treenails
F47-11	131	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23, 6 treenails
F48	143, 153	*Ulmus campestris*	Elm	H	N	floor timber, 23 treenails; there is a label in the orthophoto for F48-1, but it is the same component as F48; sample results for F48 and F48-1 are identical (samples 143 and 153); Limber hole above the keel Dimensions: length: 4.5 cm, height: 5 cm
F48-11	133	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23. Dimensions length: 164 cm, average width: 5 cm, height: 6 cm; 7 treenails; gap between F48-11 and F48 is 2 cm; Some parts are preserved in bad condition
F49	145	*Castanea sativa*	Sweet chestnut	H	O	floor timber, 14 treenails. Dimensions: length: 201 cm; Limber hole at 113 cm, dimensions: length: 4.5 cm, height: 6 cm; one metal nail at 118 cm of length
F49-1	154	*Fraxinus excelsior*	European ash	H	O	futtock length: 73 cm, width: average 5 cm, height: average 6 cm; 3 treenails
F49-11	134	*Fraxinus excelsior*	European ash	H	O	Dimensions length: 72 cm, average width: 5.5 cm; 5 treenails; gap between F49-11 and F49 is 4.5 cm wide

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F49-12					?	extending under stringer 23; length: 53 cm, width: 7 cm; 1 treenail; gap between F49-12 and F49-11 is 1 cm wide
F50	146	*Quercus cerris*	Turkey oak	H	N	floor timber 14 treenails. Dimensions: length: 201 cm, width: average 7 cm, height: average 7 cm. Limber hole at 28. cm of the length; Dimensions: length: 3 cm, height: 5 cm
F50-11	135	*Pinus brutia*	Turkish pine	S	N	ends at stringer 23; Dimensions: 153 cm length, width: 6 cm, height: average 6 cm. 6 treenails; 1 nail at 88. cm. Semicircular recess from 71 -74.5 cm
F51	147	*Pinus halepensis*	Aleppo pine	S	?	floor timber; 12 treenails. Dimensions: length: 261 cm, width: average 6 cm, height: average 6 cm. Limber hole at 71 -75 cm of the length; Dimensions: length: 5 cm, height: 5 cm. 5 nails
F51-1	156	*Pinus halepensis*	Aleppo pine	S	?	length: 65 cm, width: average 7 cm; 2 treenails; 1 nail
F51-11					?	length: 38.5 cm, width: 5 cm, height: average 6 cm. 2 treenails; gap between F51-11 and F51 is 6.5 cm width
F51-12	136	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23; width: 8 cm, height: average 6 cm. 7 treenails; gap between F51-12 and F51-11 is 12 cm width

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F52	148	*Pinus halepensis*	Aleppo pine	S	N	floor timber 12 treenails; 3 nails; Dimensions: length: 244 cm, width: average 9 cm; notch at 108 cm. Dimension: 20.5 cm, width: 4 cm, height: 5 cm; Limber hole at 113 cm of the length; Dimensions: length: 3 cm, height: 5 cm
F52-11					N	length: 70.5 cm, width: 5 cm, 3 treenails; gap between F52-11 and F52 is 4 cm width
F52-12	137	*Pinus halepensis*	Aleppo pine	S	O	extending under stringer 23; Dimensions: length: 28 cm, width: 8 cm; 1 treenail? Bad condition, dislocated
F53	149	*Castanea sativa*	Sweet chestnut	H	O	12 treenails; Dimensions: length: 179 cm, width: average 4.5 cm; height: average 5 cm; Limber hole at 88 cm of the length; Dimensions: length: 3 cm, height: 3 cm
F53-1	157	*Quercus cerris*	Turkey oak	H	O	3 treenails; Dimensions: length: 103 cm, width: average 5 cm, height: 6 cm
F53-11	138	*Pinus halepensis*	Aleppo pine	S	N	is extending under stringer 23; 7 treenails; the end is sharp pointed, there is a gap between F53-11 and F53
F54	150	*Pinus halepensis*	Aleppo pine	S	N	13 treenails; Limber hole dimensions = length: 6.5 cm, height: 5 cm
F54-1	338	*Quercus cerris*	Turkey oak	H	?	small futtock; appears to be different wood than F54-X

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F54-11	140	*Pinus halepensis*	Aleppo pine	S	N	7 treenails
F54-X	158, 387	*Pinus halepensis*	Aleppo pine	S	N	unlabeled wood on orthophoto between F54 and F54-1; 6 treenails
F55	151, 160	*Pinus halepensis*	Aleppo pine	S	N	floor timber; 9 treenails, 4 nails; Dimensions: length: 149 cm, width: average 7. 5 cm; Rectangular notch at 54. cm. Dimension: 17.5 cm, width: 4 cm, height: 3.5 cm; Limber hole at 63 cm of the length; Dimensions: length: 5 cm, height: 3 cm
F55-1	159	*Pinus halepensis*	Aleppo pine	S	N	6 treenails; Dimensions: length: 87 cm, width: average 9 cm, height: 7 cm
F55-11	142	*Pinus halepensis*	Aleppo pine	S	N	5 Treenails; Dimensions: length: 52. 5 cm, width: average 6. 5 cm
F55-12	141	*Pinus halepensis*	Aleppo pine	S	N	extending under stringer 23. 6 treenails, 1 nail (in the visible part) Dimensions: length: 62.5 cm, width: average 6 cm; height: average 5 cm; connection point between F55-12 and F55-11 not well preserved, gap is width between 4 cm in upper part and 3 cm at bottom; At 13 cm a rounded mark 4 cm in diameter (greyish color) probably associated with nail corrosion for stringer S24
F55A-11					O	small futtock extending out from under S23; does not appear to be part of either F55-12 or F56-11

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F55-X	292	Quercus sp. deformed	Oak	H	?	unlabeled wood on orthophoto between F55 and F55-1; 3 treenails, 2 nails; Dimensions: length: 27 cm, width: average 5 cm, height: 4.5 cm. There is a 8.5cm gap between F55-X and F55, with remains of 2 treenails
F56	291	*Betula pendula/ B. pubescens*	Birch	H	N	floor timber; 9 treenails; Dimensions: length: 145 cm, width: average 5.5 cm; height: average 6 cm. Limber hole at 56.5 cm of the length; Dimensions: length: 4 cm, height: 3 cm
F56-1	282	*Acer pseudoplatanus*	Sycamore	H	?	5 treenails; Dimensions: length: 102 cm, width: average 8 cm, height: 6 cm
F56-11	287	*Pinus halepensis*	Aleppo pine	S	?	extending under stringer 23; 7 treenails; 1 nail; width: average 6 cm; height: average 6 cm
F57	284	*Fraxinus excelsior*	European ash	H	O	141 cm total length; thickness 4-5 cm; 65 cm from center of keel to stbd; treenails at 11.5, 46.5, 62 cm; 76 cm from center of keel to port; treenails at 20, 39, 67.5 cm; 7 treenails total
F57-1	281	*Quercus petraea*	Sessile oak	H	O	12 cm gap between 57 and 57-1; 91 cm long; treenails from inboard to outboard at 6, 23.5, 29, 37.5, 51.5, 61.5, 69; 7 treenails total; 13 cm gap to a 12 cm long piece of futtock

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F57-11	286	*Castanea sativa*	Sweet chestnut	H	O	91 cm visible before stringer S23; 4.5 - 5 cm thick; treenails from inboard to outboard at 8, 16, 33, 58, 87.5 cm; 5 treenails total; saw mark at 34 cm
F58	283	*Cupressus sempervirens*	Mediterranean cypress	S	N	166 cm long; 6-7 cm thick; treenails from stbd to port: 6.5, 22.5, 32, 39, 48, 57.5, 68, 88, 99, 106.5, 118, 126.5, 134, 141, 158; 15 treenails total; saw mark or wood split on top of strakes SK2S-SK3S; large knot on the port end
F58-11	285	*Pinus halepensis*	Aleppo pine	S	N	87 cm long; 6-6.5 cm thick; treenails from inboard to outboard at 5, 10, 17, 42, 57; 5 treenails total; clenched nail at 23 cm point (recovered - artifact #233)
F58-12	289	*Pinus halepensis*	Aleppo pine	S	N	13 cm long before going under S23; treenail at 12 cm; 5-5.5 cm thick
F59	280	*Quercus cerris*	Turkey oak	H	O	double notch over keel; aft 22 cm long, cut in 2.5 cm; fwd 22 cm long, cut in 2 cm; 153 cm long; 4.5-5 cm thick; 93 cm from center of keel to stbd; treenails at 0, 50, 60, 64, 73 cm; 60 cm from center of keel to port; treenails at 0, 14.5, 32, 42, 49; 9 treenails total

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F59-1	275	*Pinus halepensis*	Aleppo pine	S	N	in two pieces; first piece 52 cm long; 6-7 cm thick; pegs at 12, 29, 35 cm; second piece 65.5 cm long; 8-9 cm thick; treenails at 14, 47.5 cm possibly different wood species
F59-11	279	*Pinus halepensis*	Aleppo pine	S	N	goes under S23; 4 treenails
F60	276	*Pinus halepensis*	Aleppo pine	S	N	notch on fwd side; 13.5 cm wide x 2 cm deep (measurement may be inaccurate); 203 cm long; 7-8 cm wide; treenails from center of keel to stbd: 10.5, 17, 31, 43, 67, 88 cm; treenails from center of keel to port: 14, 31, 52, 62, 76, 84, 95, 98, 106 cm; 15 treenails total
F60-11	277	*Pinus halepensis*	Aleppo pine	S	N	113 cm long, 5-6 cm thick; treenails at 5, 8.5, 98 cm; 3 treenails total
F60-12	278	*Pinus nigra*	Black pine	S	?	small futtock under S23

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F61	272	*Quercus cerris*	Turkey oak	H	O	angled double notch over keel: 22 cm wide on both fwd and aft sides; fwd – 1.5 cm on port side, drops to 0 on stbd side; aft – 1.5 cm on stbd side, drops to 0 on port side; wood thickness between notches varies between 2-2.5 cm; 144 cm long, 4.5-5 cm thick; from center of keel to stbd is 82 cm long; there is a treenail at 53 cm; there is an indentation from 58-64 cm, straight across frame inboard, curved outboard; from center of keel to port is 62 cm long; treenails at 14, 22, 32, 45 cm; 5 treenails total
F61-1	273	broadleaf crushed		H	?	90 cm long; another 33 cm was present, but destroyed; 5-6 cm thick; treenails at 8, 21, 30, 62, 76, 86 cm; 6 treenails total
F61-11	271	broadleaf crushed		H	?	7 treenails
F61-12	270	*Pinus halepensis*	Aleppo pine	S	?	small futtock under S23
F61-2	274	*Cupressus sempervirens*	Mediterranean cypress	S	O	unlabeled extension of F61-1
F62	267	*Acer pseudoplatanus*	Sycamore	H	?	starting at strake SK2S; 191 cm long, 6-8 cm thick; treenails from stbd to port at 30, 48, 66, 77, 110, 121, 130, 141, 150, 158, 166, 180 cm; 12 treenails total
F62-1	266	*Pinus halepensis*	Aleppo pine	S	?	52 cm long; 6-7 cm wide; treenails at 11, 20 cm; nail holes at 24, 27 cm likely associated with stringer S41

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F62-11	268	*Pinus halepensis*	Aleppo pine	S	N	112 cm long; 5-6 cm wide; treenails at 18, 41, 48, 58, 73.5, 88.5 cm, 6 treenails total
F62-12	269	*Pinus halepensis*	Aleppo pine	S	N	25 cm long; 5-6 cm wide; one treenail at 11 cm
F63					N	167 cm long; 6-7.5 cm wide; begins at strake SK4S; treenails at 10, 30, 52, 75, 77, 91, 102, 116, 124, 156 cm; 10 treenails total
F63-11	262	*Pinus halepensis*	Aleppo pine	S	N	47 cm long; 6.5-7 cm wide; looks new; treenails at 20, 36 cm
F63-12	261	*Cupressus sempervirens*	Mediterranean cypress	S	N	63 cm long; treenails at 13, 27, 51, 57
F63-13					O	unlabeled frame outside the main area of the ship; in poor condition; no visible treenails
F64	263	*Pinus halepensis*	Aleppo pine	S	N	115 cm long; 7-8 cm wide; from starboard to port, treenails at 22, 25, 46, 73, 82, 103; Limber hole above the keel = length: 4 cm, height: 4 cm
F64-1	265	*Pinus halepensis*	Aleppo pine	S	?	83 cm long; 8-9 cm wide; treenails at 9, 19, 31, 47.5, 67 cm
F64-11	260	*Pinus halepensis*	Aleppo pine	S	N	begins at strake SK1S; 131 cm long; 6-7 cm wide; treenails at 22, 48, 86, 100, 106 cm
F65	256	*Pinus halepensis*	Aleppo pine	S	N	10 treenails; Limber hole dimensions = length: 4.5 cm, height: 4 cm
F65-1	255	*Castanea sativa*	Sweet chestnut	H	O	8 treenails
F65-11	258	*Castanea sativa*	Sweet chestnut	H	O	4 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F65-2	254	*Pinus halepensis*	Aleppo pine	S	N	unlabeled futtock outboard of F65-1; made of different wood than F65-1; also wider
F66	253	*Quercus petraea*	Sessile oak	H	?	Floor timber has 14 treenails, with a notch over the keel; limber hole dimensions = length:3 cm, height: 4 cm
F66-11	257	*Pinus nigra*	Black pine	S	N	4 treenails
F67	251	*Pinus halepensis*	Aleppo pine	S	N	floor timber, 12 treenails; Limber hole dimensions (length: 6.5 cm, height: 5 cm).
F67-1	252	*Pinus halepensis*	Aleppo pine	S	N	5 treenails
F67-11	249	*Pinus halepensis*	Aleppo pine	S	N	5 treenails; extends under S23
F67-12					O	unlabeled frame outside the main area of the ship; in poor condition; no visible treenails
F68	244	*Pinus halepensis*	Aleppo pine	S	N	13 treenails; Limber hole dimensions = length: 6.5 cm, height: 5 cm
F68-1	242	broadleaf crushed		H	O	6 treenails
F68-11	246	*Pinus halepensis*	Aleppo pine	S	N	7 treenails; extends under S23
F68-12					O	unlabeled frame outside the main area of the ship; in poor condition; no visible treenails
F68A-1	241	*Quercus cerris*	Turkey oak	H	O	small futtock unlabeled on orthophoto; between F68-1 and F69-1; an intermediate timber not associated with a floor
F69	233	*Acer pseudoplatanus*	Sycamore	H	?	Floor timber has limber hole (length: 4.5 cm, height: 3 cm) and 9 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F69-1	231	*Pinus halepensis*	Aleppo pine	S	N	6 treenails
F69-11	238	*Pinus halepensis*	Aleppo pine	S	N	6 treenails
F69A-1	230	*Fraxinus excelsior*	European ash	H	?	small futtock between F69-1 and F70-1; very similar in appearance to F69A-11; an intermediate timber not associated with a floor
F69A-11	235	*Fraxinus excelsior*	European ash	H	?	small futtock between F69-11 and F70-11; extends under S23; an intermediate timber not associated with a floor
F69-X	232	Acer ? deformed	Sycamore	H	?	unlabeled section between F69 and F69-1; 5 treenails
F70	239	*Pinus halepensis*	Aleppo pine	S	?	limber hole (length: 5.4 cm, width: 4.5 cm); 11 treenails
F70-1	229	*Pinus halepensis*	Aleppo pine	S	?	6 treenails
F70-11	234	broadleaf crushed		H	O	6 treenails and it is in very bad condition
F70-12	236	*Acer pseudoplatanus*	Sycamore	H	O	possibly the same type of wood as F70-11, but they are not connected
F70A-11	237	*Quercus cerris*	Turkey oak	H	O	small unlabeled futtock betweeen F70-12 and F71-11; wedged under S23; an intermediate timber not associated with a floor
F71	227	*Castanea sativa*	Sweet chestnut	H	O	broken into 2 pieces; has limber hole (length: 3 cm, height: 2.5 cm); 6 treenails

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F71-1	228	*Cupressus sempervirens*	Mediterranean cypress	S	?	has some part of small plank made of dark wood on the top of futtock which is connected with two treenails (maybe some kind of repair?); total of 7 treenails
F71-11	225	*Pinus halepensis*	Aleppo pine	S	N	7 treenails
F72	224	*Pinus halepensis*	Aleppo pine	S	?	limber hole (length: 4 cm, width: 2.3-3 cm), 7 treenails
F72-1	222	*Pinus halepensis*	Aleppo pine	S	?	1 treenail
F73	220	*Fraxinus excelsior*	European ash	H	O	Floor timber with one treenail is in very bad condition
F73-1	221	*Castanea sativa*	Sweet chestnut	H	O	9 treenails
F73-11	219	*Quercus cerris*	Turkey oak	H	O	7 treenails, it is very long, but in very bad condition to observe any details
F74	218	*Fraxinus excelsior*	European ash	H	?	Floor timber is thick with limber hole (length: 4 cm, width: 3 cm). It has 3 treenails
F74-1	223	*Ulmus campestris*	Elm	H	N	7 treenails
F74-11	214, 217	*Pinus halepensis*	Aleppo pine	S	N	6 treenails
F74-X	215	*Acer pseudoplatanus*	Sycamore	H	O	small unlabeled section between F74 and F74-11; 2 treenail holes; different wood than F74 and F74-11
F75	211	*Castanea sativa*	Sweet chestnut	H	O	section of F75 over the keel is missing, exactly where the scarf is between the keel and the stem; 4 treenails
F75-1	212	*Castanea sativa*	Sweet chestnut	H	O	4 treenails; poorly preserved

Frames

Component	Sample #	Tree species	Tree	Hard/Soft wood	Appearance	Remarks
F76	209	*Betula pendula/ B. pubescens*	Birch	H	?	Floor timber has limber hole (length: 4 cm, height: 2.5 cm) and two treenails
F76-1	208	*Pinus halepensis*	Aleppo pine	S	N	5 treenails
F76-11	210	*Acer pseudoplatanus*	Sycamore	H	O	is in very bad condition and there is no treenail
F77-1	205	*Castanea sativa*	Sweet chestnut	H	O	4 treenails; section over the stem is missing
F77-11	206	*Fraxinus excelsior*	European ash	H	?	5 treenails
F78-1	203	*Pinus halepensis*	Aleppo pine	S	?	2 treenails
F78-11	204	*Pinus halepensis*	Aleppo pine	S	?	2 treenails
F79-1	201	Fraxinus sp. deformed	Ash	H	O	canted frame
F79-11	202	*Fraxinus excelsior*	European ash	H	O	canted frame

Stringers

name	sample #	Tree species	Tree	Hard/Soft	Remarks
Installed Stringers					
S21	334	*Pinus halepensis*	Aleppo pine	S	
S23	248	*Pinus nigra*	Black pine	S	also sample 329
S24	333	*Pinus nigra*	Black pine	S	
S25	364	*Pinus halepensis*	Aleppo pine	S	
S26	25	*Pinus nigra*	Black pine	S	
S27	339	*Pinus halepensis*	Aleppo pine	S	
S31	36	*Pinus halepensis*	Aleppo pine	S	
S32	27	*Pinus halepensis*	Aleppo pine	S	
S33	360	*Pinus halepensis*	Aleppo pine	S	
S40	363	*Pinus halepensis*	Aleppo pine	S	
S41	18	*Cupressus sempervirens*	Mediterranean cypress	S	
S42	12	*Cupressus sempervirens*	Mediterranean cypress	S	
S43	361	*Pinus halepensis*	Aleppo pine	S	
S44	340	*Pinus nigra*	Black pine	S	
S45	362	*Pinus halepensis*	Aleppo pine	S	
S46	9	*Pinus nigra*	Black pine	S	

Stringers

name	sample #	Tree species	Tree	Hard/Soft	Remarks
Uninstalled (removed) Stringers					
S1	370	*Cupressus sempervirens*	Mediterranean cypress	S	
S4/S6?	20	*Pinus halepensis*	Aleppo pine	S	
S5	35	*Pinus nigra*	Black pine	S	
S8	33	*Pinus nigra*	Black pine	S	
S9	371	*Pinus halepensis*	Aleppo pine	S	
S10	34	*Cupressus sempervirens*	Mediterranean cypress	S	
S13	13	*Pinus nigra*	Black pine	S	
S19	16	*Pinus halepensis*	Aleppo pine	S	also sample 29
S27	339	*Pinus halepensis*	Aleppo pine	S	
S28	31	*Pinus nigra*	Black pine	S	
S30	22	*Pinus halepensis*	Aleppo pine	S	

Hull Assembly Components

name	sample #	Tree species	Tree	Hard/Soft	Remarks
Treenail F19-1	331	*Acer pseudoplatanus*	Sycamore	H	
Treenail F21-11	63	*Acer pseudoplatanus*	Sycamore	H	
Treenail F23	70	*Acer pseudoplatanus*	Sycamore	H	twig + pith
Treenail F25-2	1	*Acer pseudoplatanus*	Sycamore	H	
Treenail F27	77	*Acer pseudoplatanus*	Sycamore	H	
Treenail F30	81	*Alnus* sp.	Alder	H	
Treenail F33	88	*Cupressus sempervirens*	Mediterranean cypress	S	
Treenail F34	100	*Acer pseudoplatanus*	Sycamore	H	
Treenail F40-11	306	*Acer pseudoplatanus*	Sycamore	H	twig + pith, five rings
Treenail F43	122	*Acer pseudoplatanus*	Sycamore	H	
Treenail F46	144	*Quercus petraea*	Sessile oak	H	
Treenail F51-1	155	*Acer pseudoplatanus*	Sycamore	H	
Treenail F54	380	*Acer pseudoplatanus*	Sycamore	H	
Treenail F54	381	*Acer pseudoplatanus*	Sycamore	H	
Treenail F56-11	288	*Acer pseudoplatanus*	Sycamore	H	
Treenail F65-11	259	*Acer pseudoplatanus*	Sycamore	H	
Treenail F68-1	243	*Quercus cerris*	Turkey oak	H	
Treenail F69	240	*Acer pseudoplatanus*	Sycamore	H	
Treenail F71-11	226	*Acer pseudoplatanus*	Sycamore	H	
Treenail F73-11	335	*Olea europaea*	Olive	H	
Treenail F75-1	216	*Acer pseudoplatanus*	Sycamore	H	
Treenail F76	336	*Acer pseudoplatanus*	Sycamore	H	
Treenail F76	337	*Acer pseudoplatanus*	Sycamore	H	
Treenail S23	247	*Cupressus sempervirens*	Mediterranean cypress	S	at F69-11
Treenail floating	3	*Acer pseudoplatanus*	Sycamore	H	
Treenail floating	10	*Pinus nigra*	Black pine	S	
Treenail floating	42	*Quercus cerris*	Turkey oak	H	

Hull Assembly Components

name	sample #	Tree species	Tree	Hard/Soft	Remarks
Large tenon	296	*Cupressus sempervirens*	Mediterranean cypress	S	between W1S and W2S
Tenon	367	*Quercus cerris*	Turkey oak	H	SK3S at F19
Tenon	369	*Quercus cerris*	Turkey oak	H	SK3S at F19
Tenon	377	*Quercus petraea*	Sessile oak	H	found between F29 and F31
Tenon	328	*Quercus cerris*	Turkey oak	H	found at F37
Tenon	312	*Quercus petraea*	Sessile oak	H	betweeen SK5S and SK6S at F40
Tenon	44	*Quercus cerris*	Turkey oak	H	floating
Peg	313	crushed broadleaf		H	betweeen SK5S and SK6S at F40
Peg	326	*Fagus sylvatica*	European beech	H	found at F37
Peg	379	*Cupressus sempervirens*	Mediterranean cypress	S	in tenon in W2S between F31 and F29
Peg	382	*Acer pseudoplatanus*	Sycamore	H	floating
Timber plug in cut on S23	295	*Cupressus sempervirens*	Mediterranean cypress	S	

APPENDIX B

COMPENDIUM OF SIMILAR SHIPS

The Compendium of Similar Ships is discussed in detail in Section 7.1. For ease of review, the Compendium is summarized in the following table. Where a block is blank in the table, that information was not clearly promulgated in the applicable reference(s).

Abbreviations used:

FT: Floor timber

HF: Half frame

Wreck Name/Site	Approx. Date	Length (m)	Framing Elements	Frames fastened to Keel?	Fastening between hull and frames	Frame Spacing (m)	Notes	References	Reason for comparison
Chrétienne C	2nd BCE	15-16	FT	No	Treenails	0.46	FT and futtocks overlapped; evidence of reinforcing frames between FTs; 13-15 ton amphora cargo; 23 frames/traces of frames survived	Joncheray 1975a	Floors, lines
Cavalière	1st BCE	13	FT + HF	No	Treenails, copper alloy nails	0.23-0.28	Treenails driven from outside, reinforced with nails; triangular limber holes	Charlin et al. 1978	Age, lines
La Giraglia	1st BCE	20			Treenails, nails	0.13-0.22	*dolia* wreck	Marlier and Sibella 2002, Marlier and Sciallano 2008	Age, probable floors
Barthélemy B	1st CE	8-10	FT + HF	No	Treenails, nails	0.24	Tile wreck	Joncheray and Joncheray 2004a	Age

Wreck Name/Site	Approx. Date	Length (m)	Framing Elements	Frames fastened to Keel?	Fastening between hull and frames	Frame Spacing (m)	Notes	References	Reason for comparison
Calanque de l'Âne	1st CE	20-25	FT + HF			0.2-0.24	Tile wreck	Ximénès and Moerman 1994, 1998	Age
Dramont I	1st CE	25	FT + HF	No	Treenails	0.25	Marble carrier	Joncheray and Joncheray 1997	Age, wales
Napoli A	1st CE	12	FT + HF		Treenails, nails	0.21	Mostly floor timbers in center of hull	Giampala et al. 2005	Age, floors, wales
Ladispoli A	1st CE	18	FT	No	Treenails	0.22-0.25	Est. 26 successive floor timbers; *dolia* carrier	Carre 1993	Age, floors
Sud-Lavezzi 2	1st CE	20	FT + HF				Irregular framing pattern; 3 FTs together; lead ingot cargo	Liou and Domergue 1990	Age, floors
Balise de Rabiou	1st CE	15	FT + HF	No	Treenails	0.24-0.28	Jupiter scarf; nailed ceiling planking	Joncheray and Joncheray 2009	Age
Lardier 4	1st CE	22.5	FT	No	Treenails, Iron nails	0.27	Tile wreck; three consecutive floor timbers	Joncheray and Joncheray 2004b	Age, floors

Wreck Name/Site	Approx. Date	Length (m)	Framing Elements	Frames fastened to Keel?	Fastening between hull and frames	Frame Spacing (m)	Notes	References	Reason for comparison
Baie de l'Amitié	1^{st} CE	20	FT + HF	Yes		0.26	5 consecutive floors; 6 floors with triangular notches; some internal stitching	Wicha 2002, Jézégou 2003	Age, floors
Saint- Gervais 3	2^{nd} CE (1^{st} CE?)	17	FT + HF	Yes	Treenails, copper alloy nails	0.28-0.3	Three frames (FT?) bolted to keel; 70-80 tons; possible ponto?	Liou et al. 1990	Age, lines, wales
Grado	2^{nd} CE	10	FT + HF	Yes	Treenails, copper alloy nails, iron nails	0.14-0.17	Asymmet-rical FT and HF	Beltrame and Gaddi 2005, 2007	Age
La Bourse	2^{nd}-3^{rd} CE	23	FT + HF	Yes	Treenails	0.25	Eight floor timbers bolted to the keel	Gassend 1982	Lines, wales
L'Anse des Laurons 2	3^{rd} CE	15	FT + HF	Yes	Treenails, copper alloy nails	0.2-0.22	Four floor timbers bolted to keel	Gassend et al. 1984	Wales
Pointe de la Luque B	4^{th} CE	20	FT + HF	Yes	Treenails	0.1	Three floor timbers bolted to keel	Clerc and Negrel 1973; Liou 1973, 1975	Wales

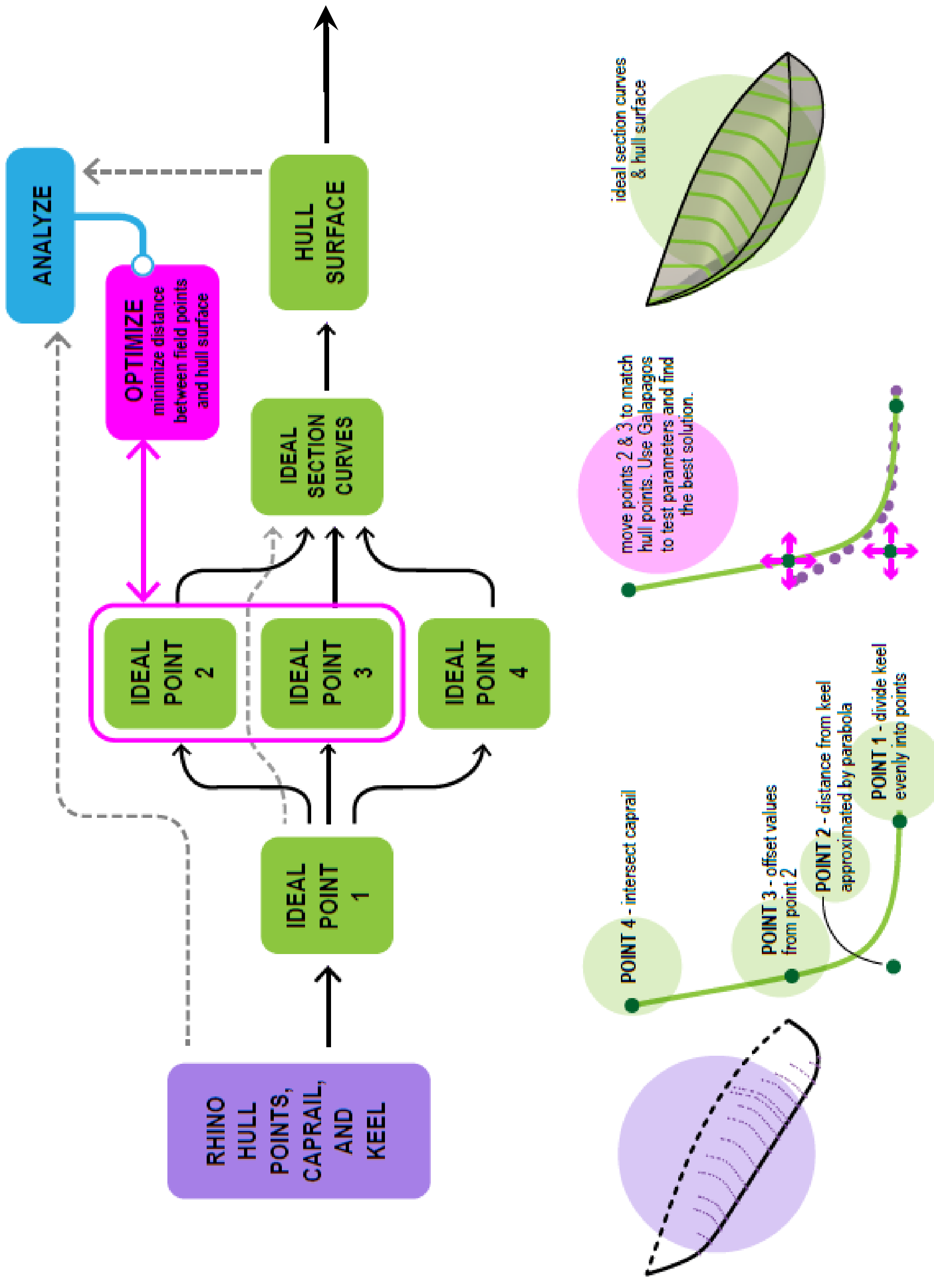
Wreck Name/Site	**Approx. Date**	**Length (m)**	**Framing Elements**	**Frames fastened to Keel?**	**Fastening between hull and frames**	**Frame Spacing (m)**	**Notes**	**References**	**Reason for comparison**
Dramont F	4th CE	10-12	FT + HF	Yes	Treenails	0.37	Flat floor timbers plus round turn of the bilge; only 1.1 x 2.1 m of hull survived. M&T joints were widely spaced, with some tenons loose or missing.	Joncheray 1975b, 1977	Floors
Fiumicino 1	4th-5th CE	17-18	FT + HF	Yes	Iron nails through treenails	0.19	Six floor timbers bolted to keel; loose, widely spaced, unpegged M&T joinery	Boetto 2000, 2001, 2003, 2008	Lines
Dramont E	5th CE	14	FT + HF	Yes	Treenails, nails	0.27	Five floor timbers bolted to keel; loose, widely spaced, unpegged M&T joinery; 28 ton displacement	Santamaria 1995; Poveda 2008, 2012	Lines, wales

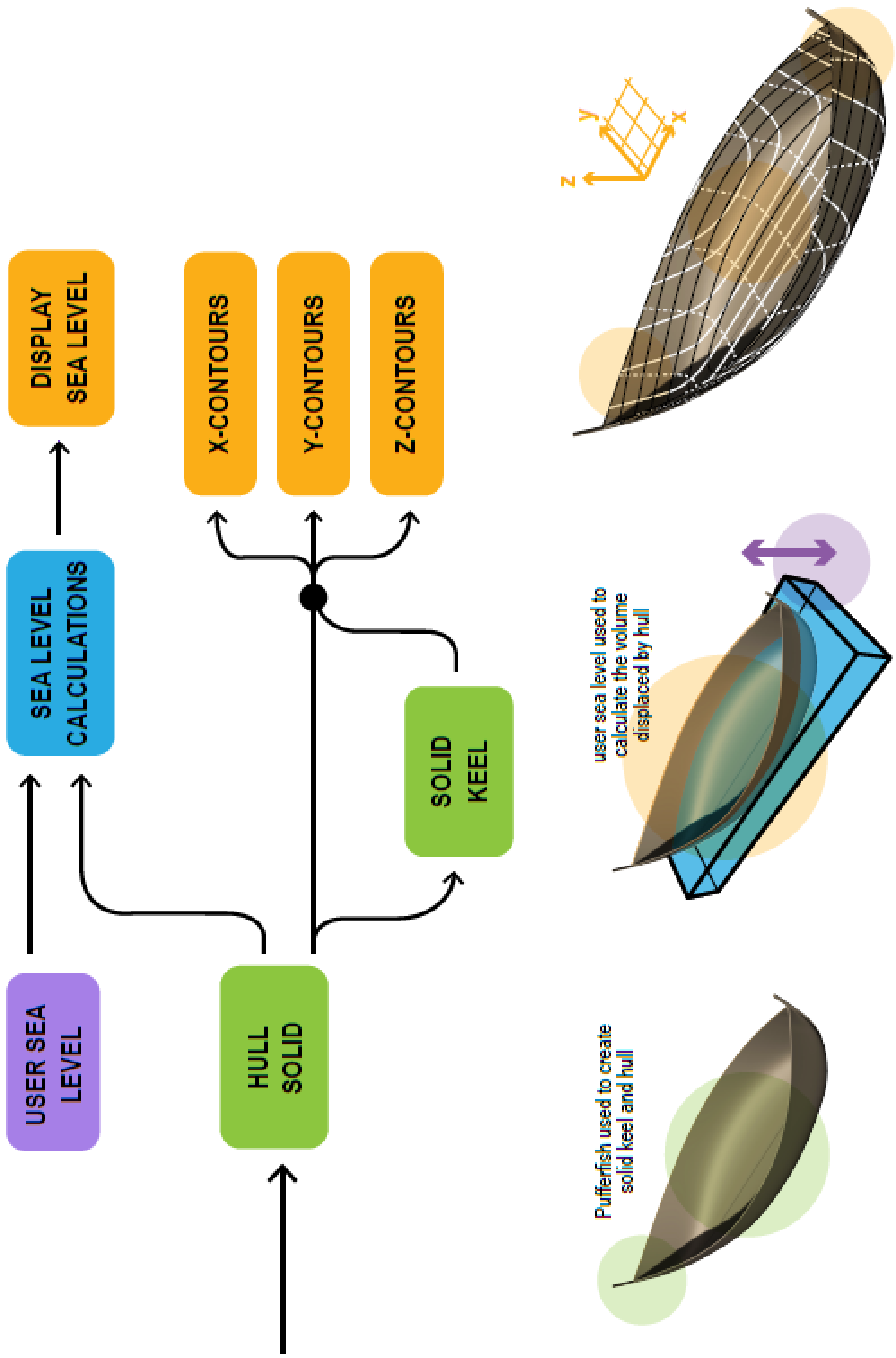
APPENDIX C

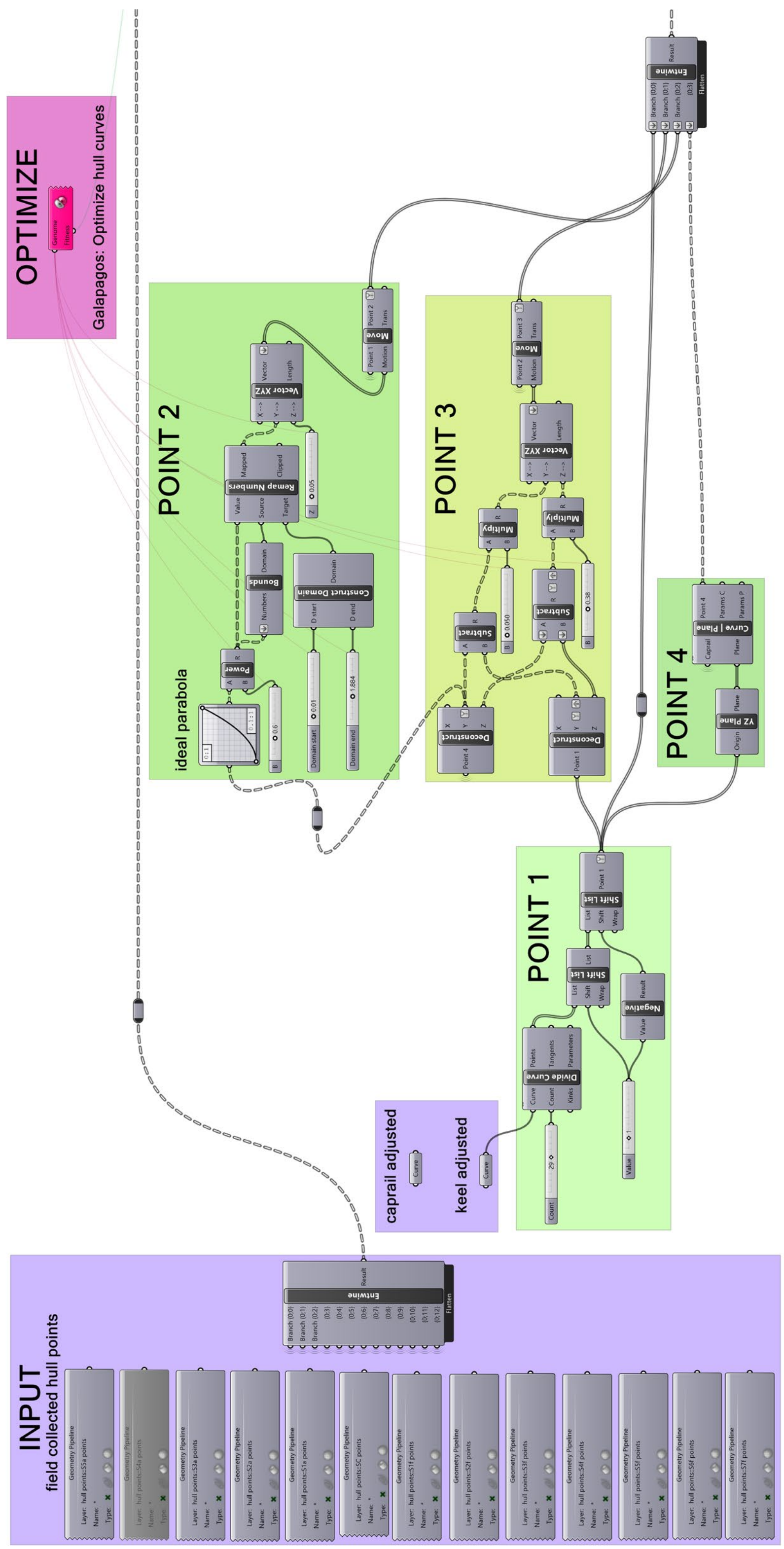
GRASSHOPPER FLOW CHART

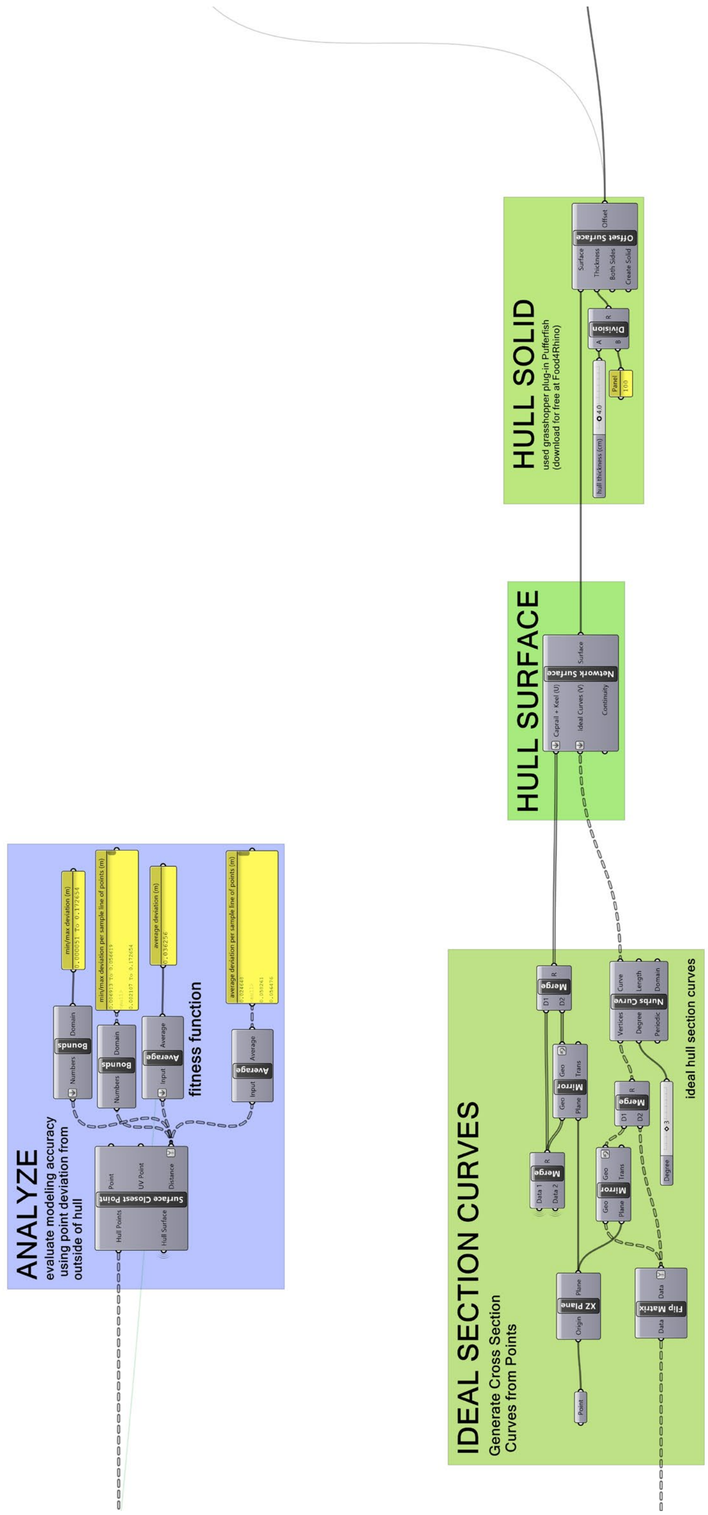
As discussed in Section 7, Grasshopper, a Rhinoceros plug-in for visual-based parametric modeling, was used extensively to complete the Trstenik ship hull model. Grasshopper was utilized to manage input data, model the hull and keel to generate a volumetric model, calculate the ship's volume below the waterline (displacement) based on a user-defined ship's draft, and extract section curves from the resulting 3-D model.

Extensive credit for model development and evolution is due to Andrew Harrell, an expert in 3-D modeling and landscape design with Rhinoceros. Andrew performed Grasshopper development and revision in support of this dissertation. The flow chart developed by Andrew to document the modeling process is shown in two different versions. First, a higher-level flow chart (2 pages) is provided to document the conceptual design of the Grasshopper modeling process. Then a detailed snapshot of the Grasshopper module commands (3 pages) is provided to illustrate the actual workflow of the plug-in.

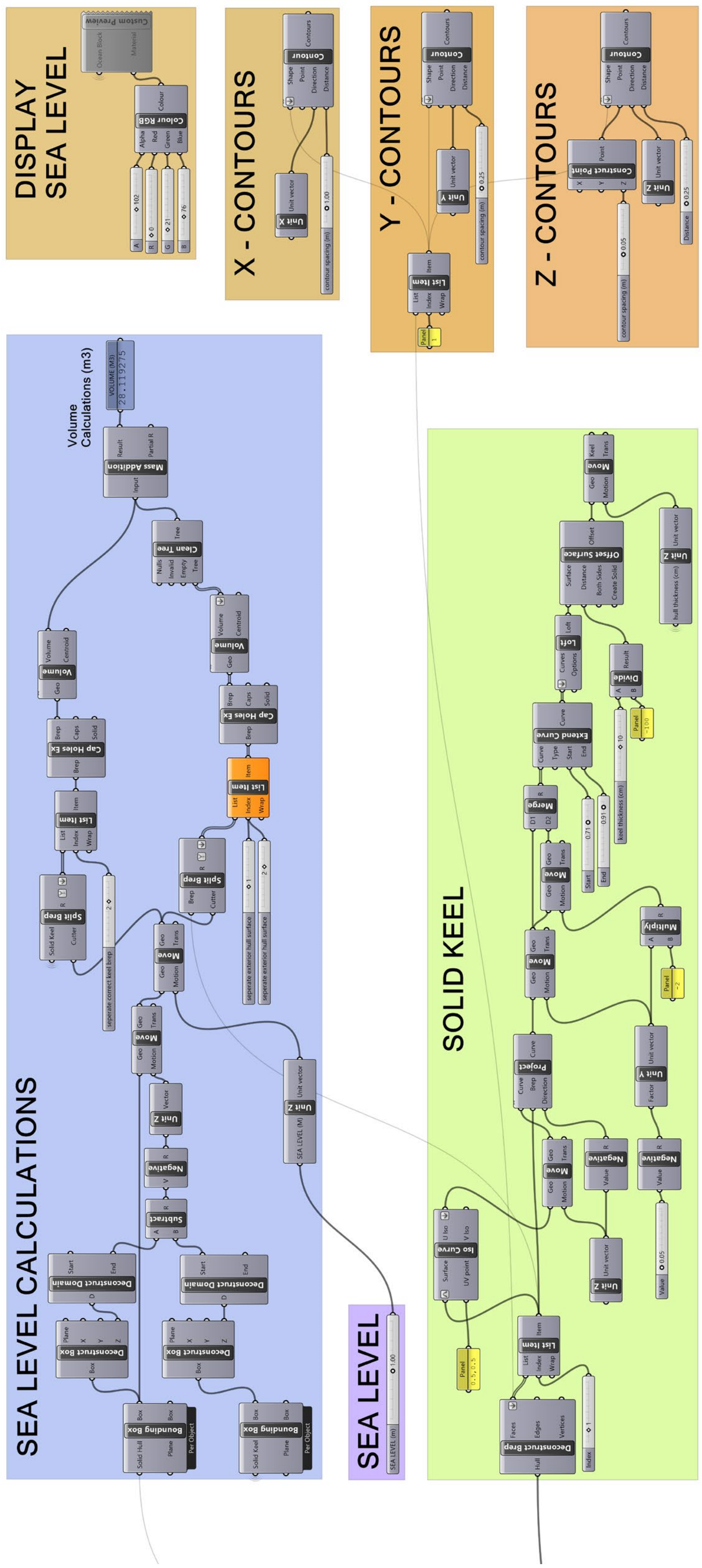

RHINO HULL POINTS, CAPRAIL, AND KEEL
IDEAL POINT 1
IDEAL POINT 2
IDEAL POINT 3
IDEAL POINT 4
IDEAL SECTION CURVES
HULL SURFACE
ANALYZE
OPTIMIZE
minimize distance between field points and hull surface
POINT 4 - intersect caprail
POINT 3 - offset values from point 2
POINT 2 - distance from keel approximated by parabola
POINT 1 - divide keel evenly into points
move points 2 & 3 to match hull points. Use Galapagos to test parameters and find the best solution.
ideal section curves & hull surface


USER SEA LEVEL
HULL SOLID
SEA LEVEL CALCULATIONS
DISPLAY SEA LEVEL
SOLID KEEL
X-CONTOURS
Y-CONTOURS
Z-CONTOURS
Pufferfish used to create solid keel and hull
user sea level used to calculate the volume displaced by hull
z
y
x


OPTIMIZE
Galapagos: Optimize hull curves
POINT 2
ideal parabola
POINT 3
POINT 4
POINT 1
caprail adjusted
keel adjusted
INPUT
field collected hull points



ANALYZE
evaluate modeling accuracy
using point deviation from
outside of hull
fitness function
IDEAL SECTION CURVES
Generate Cross Section
Curves from Points
ideal hull section curves
HULL SURFACE
HULL SOLID
used grasshopper plug-in Pufferfish
(download for free at Food4Rhino)


DISPLAY SEA LEVEL
X - CONTOURS
Y - CONTOURS
Z - CONTOURS
SEA LEVEL CALCULATIONS
Volume Calculations (m3)
SEA LEVEL
SOLID KEEL

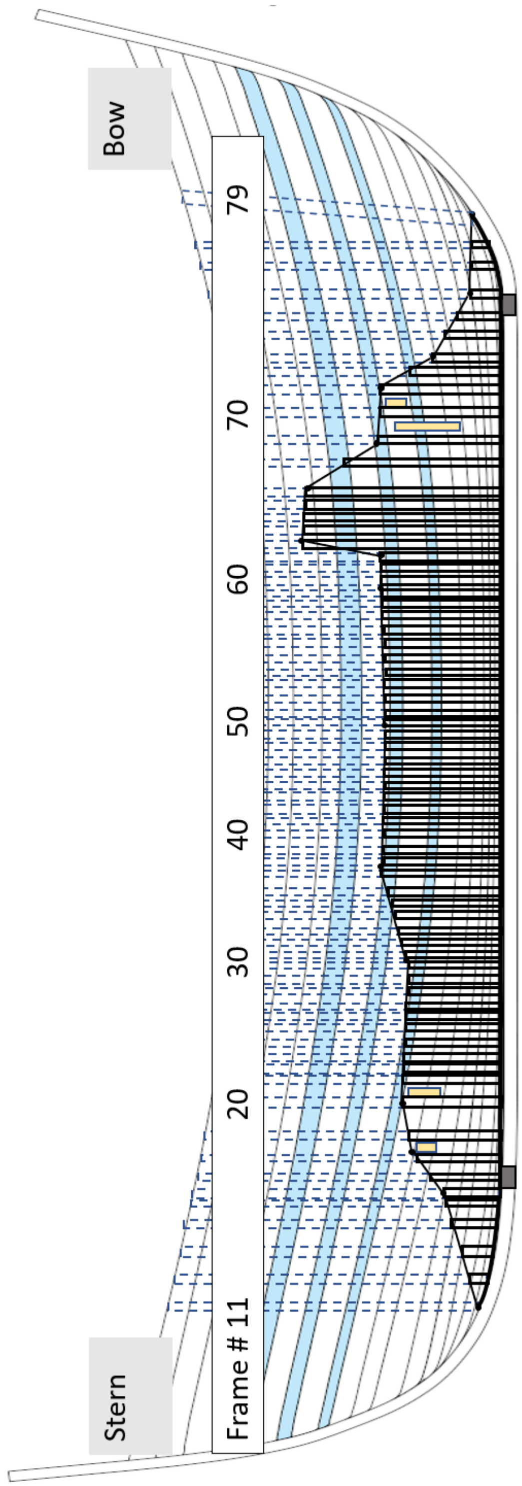
APPENDIX D

CONSTRUCTION DRAWINGS

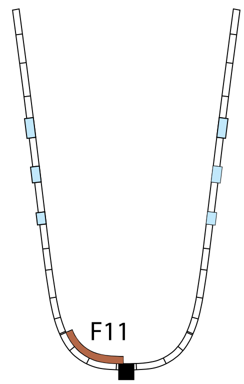
The Construction Drawings in this appendix were developed by projecting the Rhinoceros hull as a 2-D side view, and then drawing the frame positions at their appropriate locations. The three wales are shown in blue, and the keel is in black. The hull is highlighted to indicate the surviving portion of the ship. To complete the height of the ship, four additional strakes were added above the third wale. This is a modeling conjecture; as discussed in Section 6.3.1, two strakes are definitely present above the third wale, along with a trace of a third strake. The end result of the model is a keel supporting two symmetrical sides of the ship. The pattern seen in the cross sections is keel, 11 strakes, wale/strake/wale/strake/wale, and finally four strakes to extend to the hypothetical caprail.

The external side view of the ship shows the starboard side of the hull, with the locations of frames 11-78 indicated by rectangles. The location of canted frame 79 (Section 6.4.9) is shown at the bow. The sternpost to keel scarf (frame 17) and the keel to stem scarf (between frames 75 and 76) are marked by gray rectangles. As the ship was not disassembled, the exact designs of the scarfs are not known. The four intermediate timbers (Section 6.4.5) on the starboard side (F18A-12, F20A-11, F69A-11 and F70A-11) are shown as yellow rectangles.

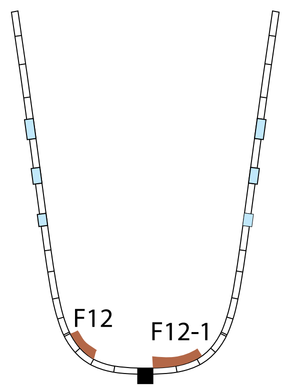
The cross sections start at the aft end of the ship (frame 11) and are shown looking from forward to aft. Thus, the port side of the ship is to the right. Due to excavation time constraints, detailed measurements of frames, including treenail locations and exact height of frame components above the planking, were not able to be taken. The section diagrams for the frames in this appendix were developed by overlaying the extent of the surviving frame components onto the computer-generated model at the location of each frame. The end result is a qualitative perspective of each frame's composition of frame components, accurately illustrating the axial extent of each frame component across the strakes without perfectly showing where treenails connect each frame component to a strake of hull planking and without attempting to illustrate any changes in frame component height above planking across the extent of the cross-section.


Bow
Stern
Frame # 11
20
30
40
50
60
70
79

Frame 11



Frame 12



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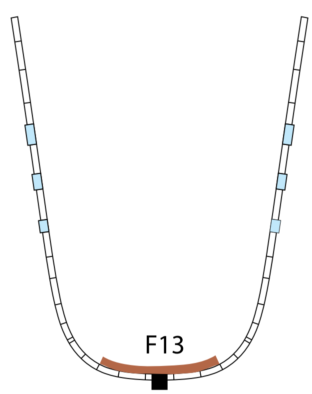

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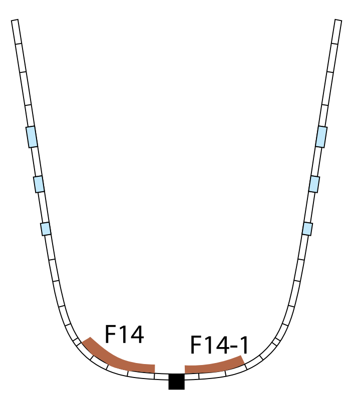

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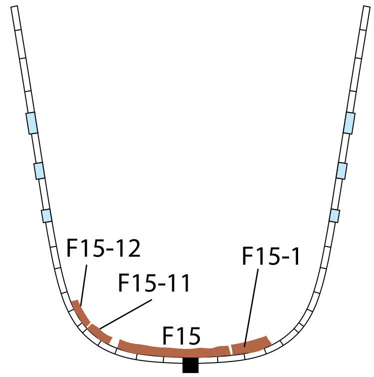

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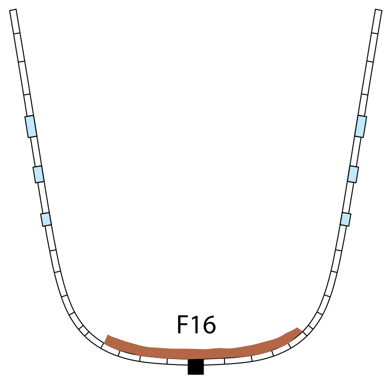

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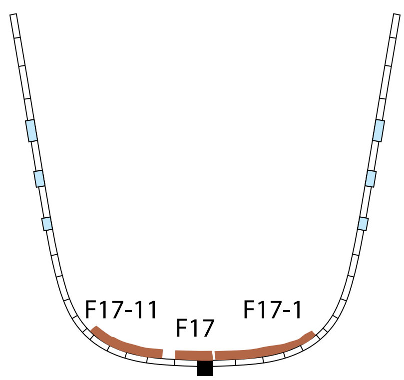

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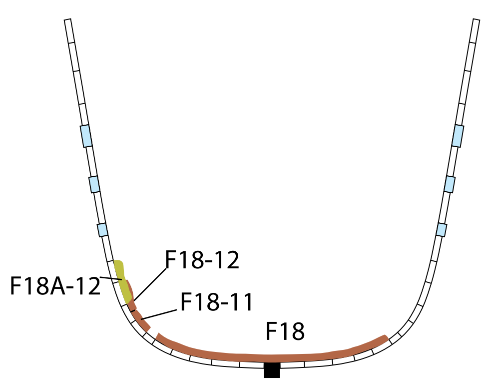

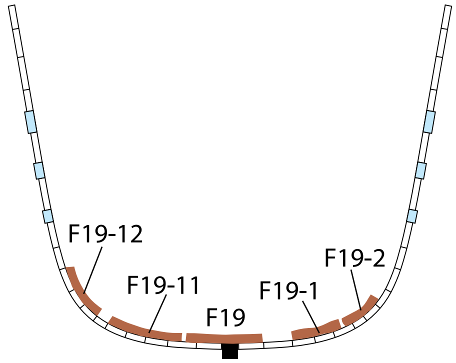

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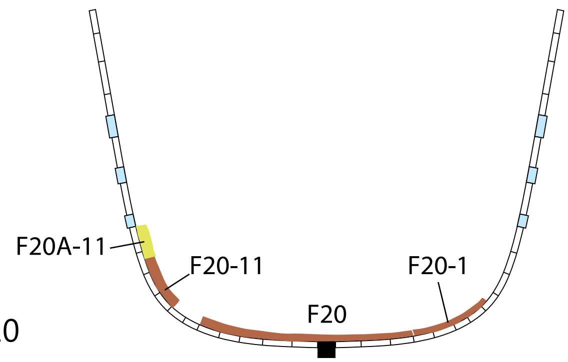

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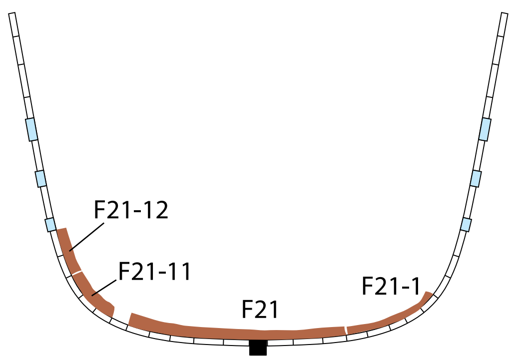

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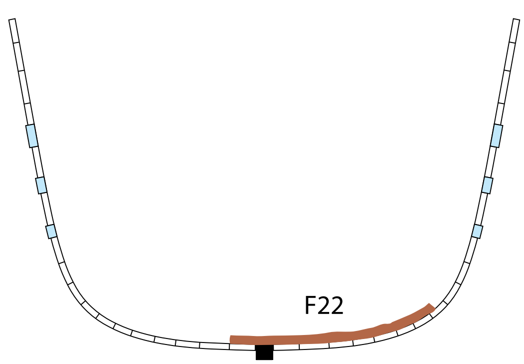
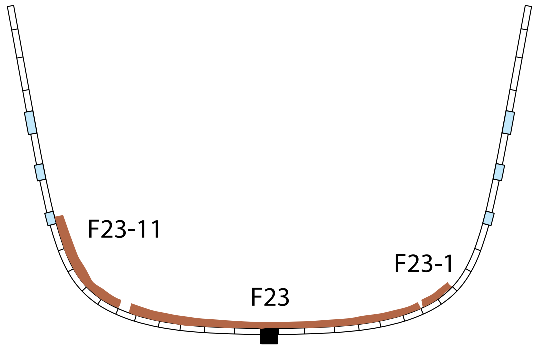


Frame 22

Frame 23



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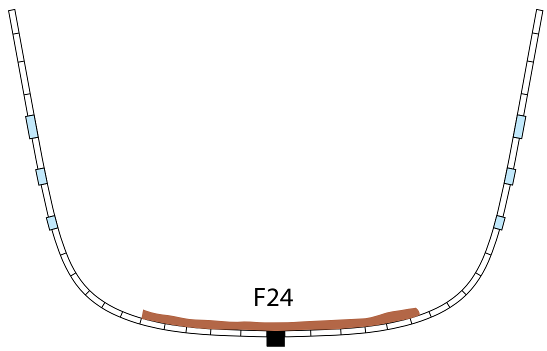

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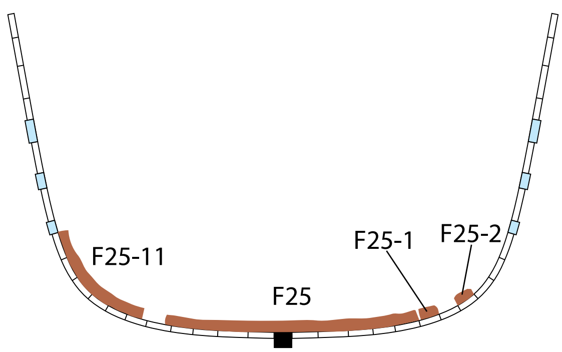

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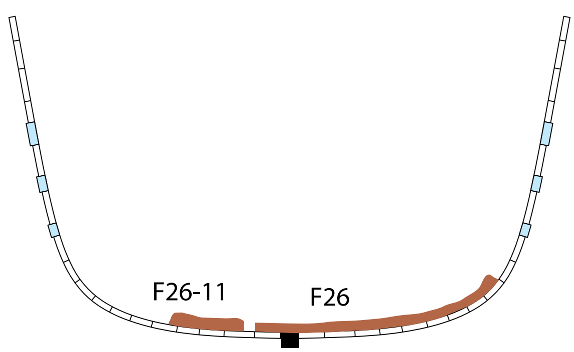

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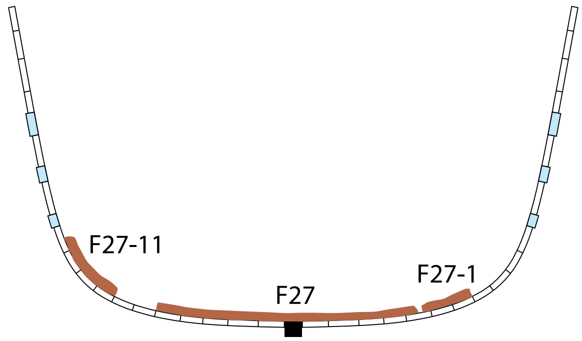

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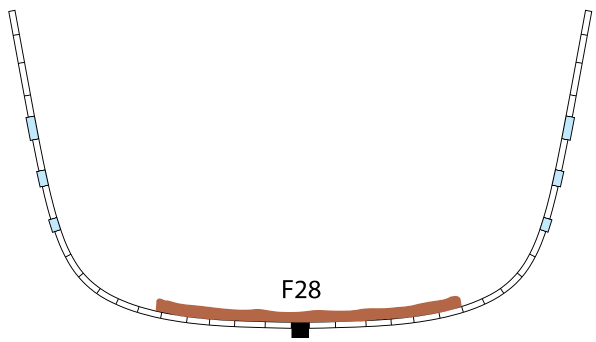

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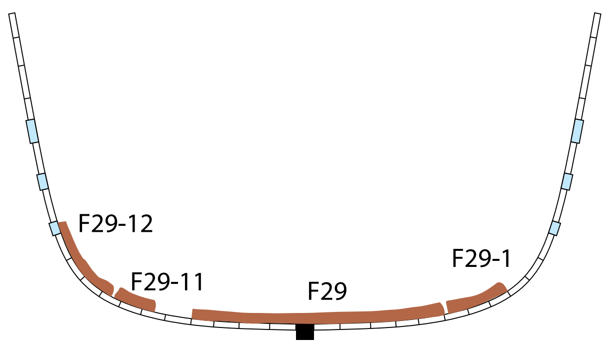

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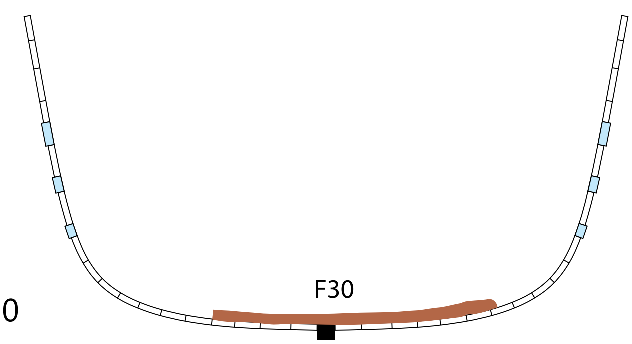

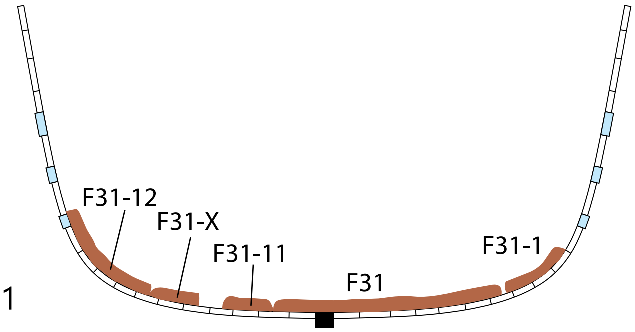

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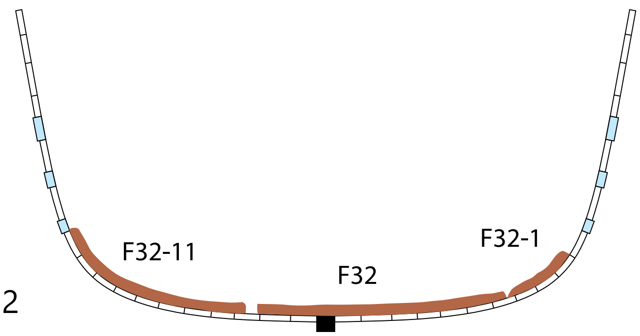

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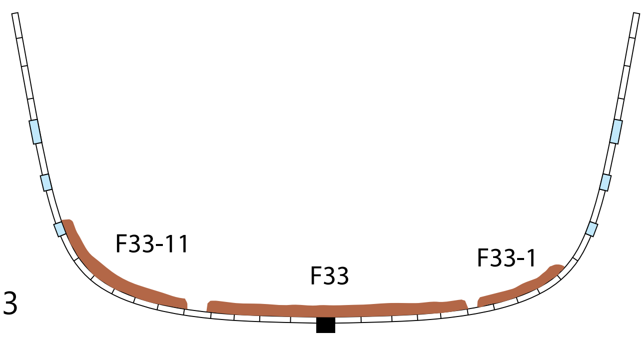

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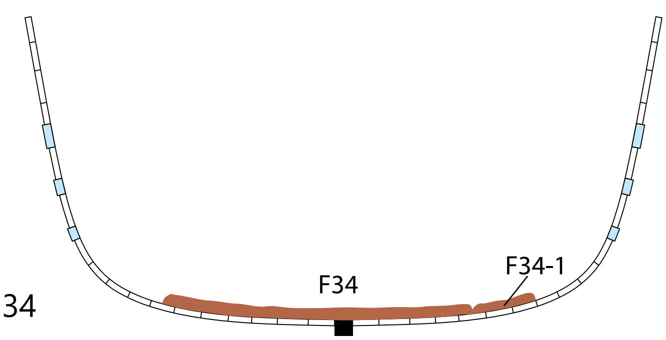

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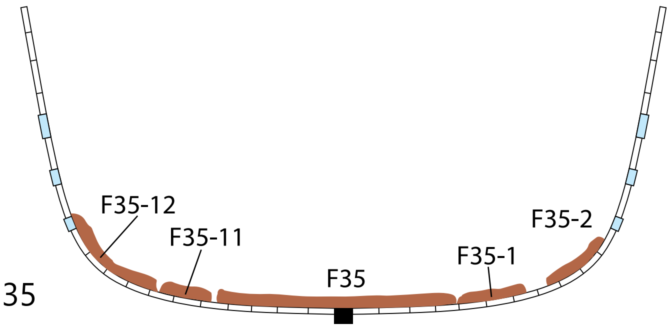

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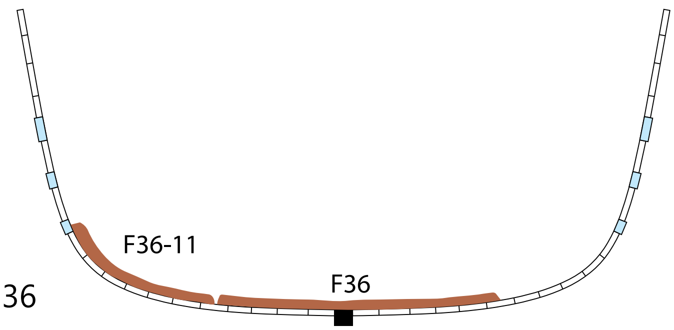

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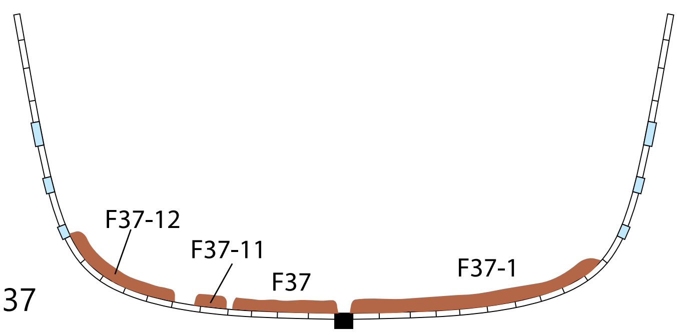

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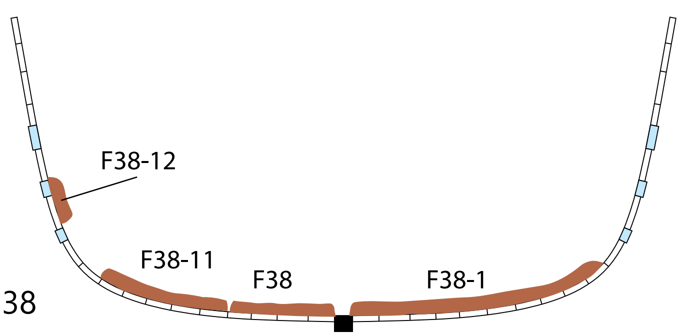

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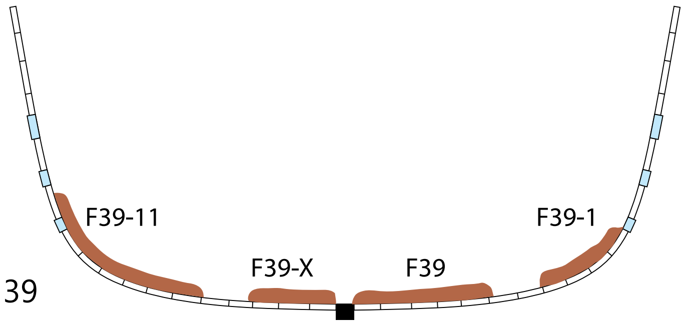

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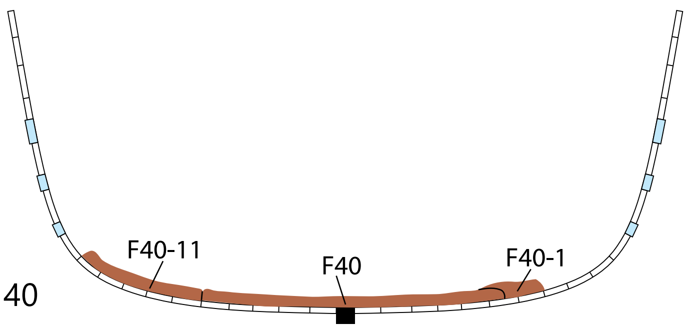

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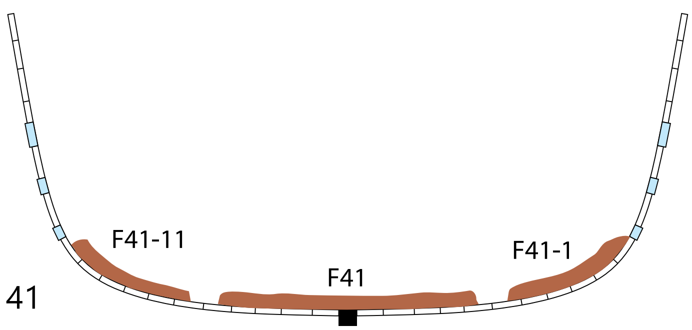

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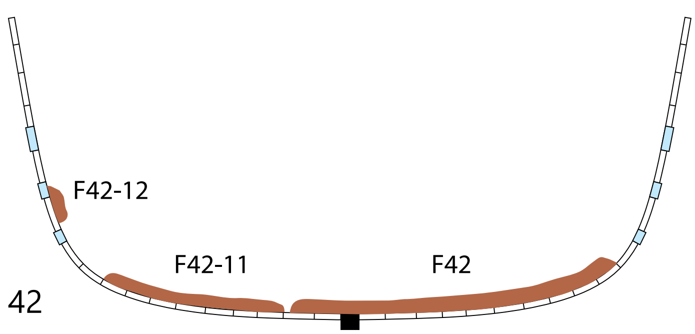
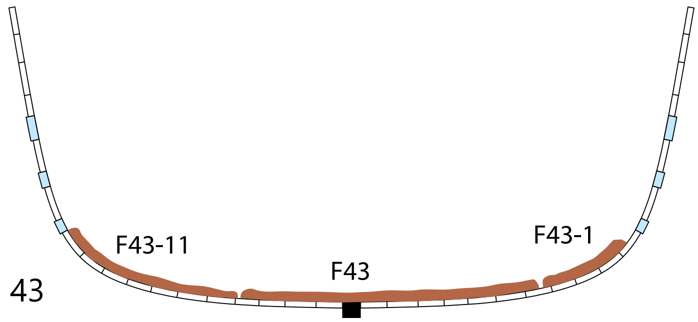


Frame 42

Frame 43



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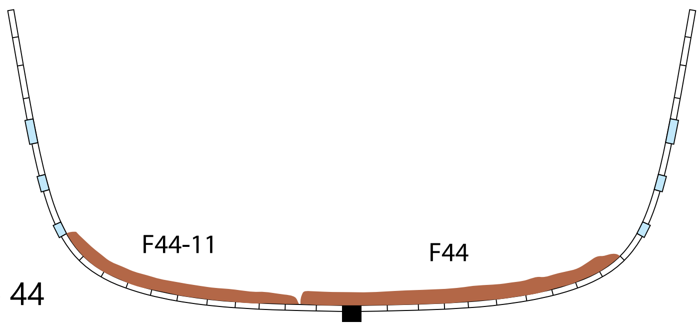

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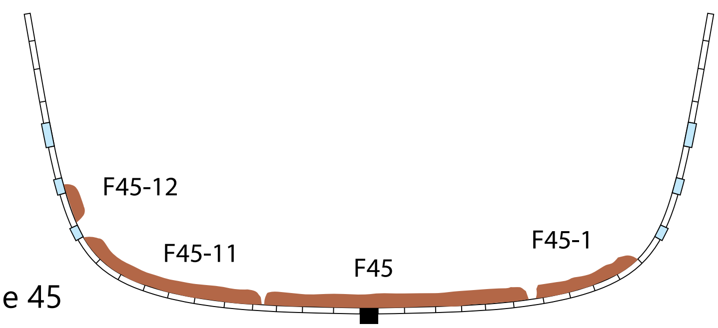

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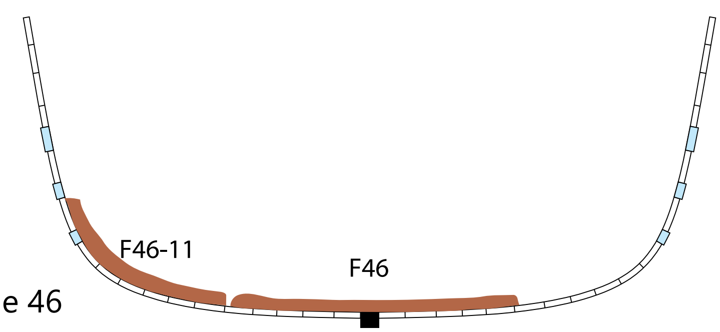

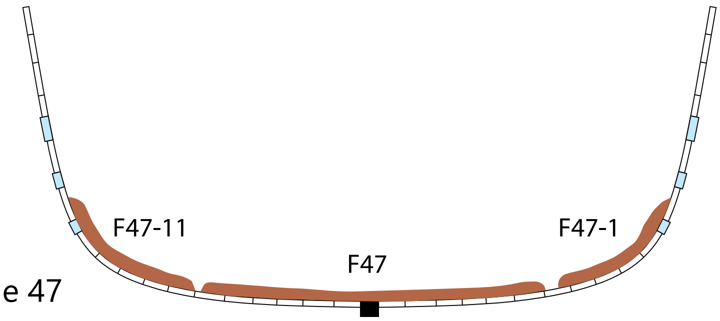

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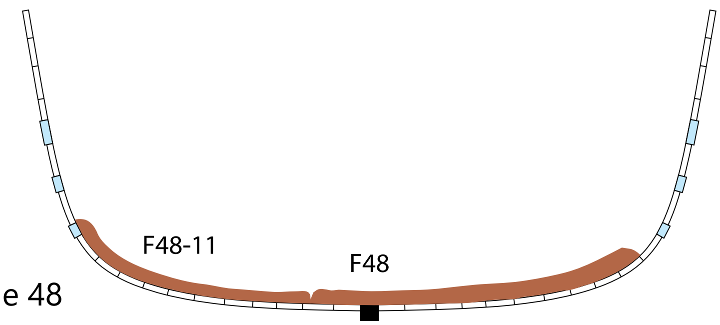

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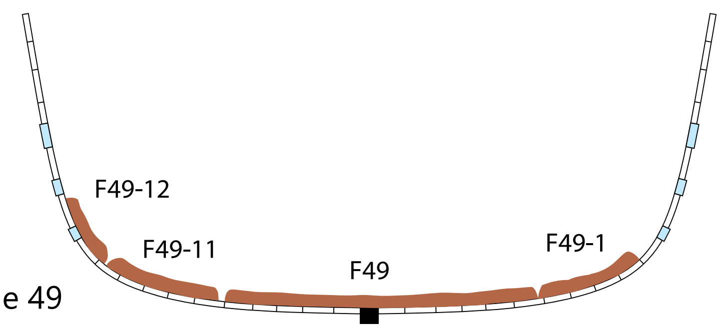

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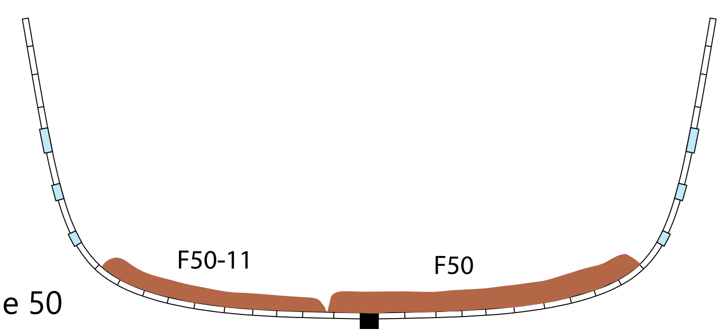

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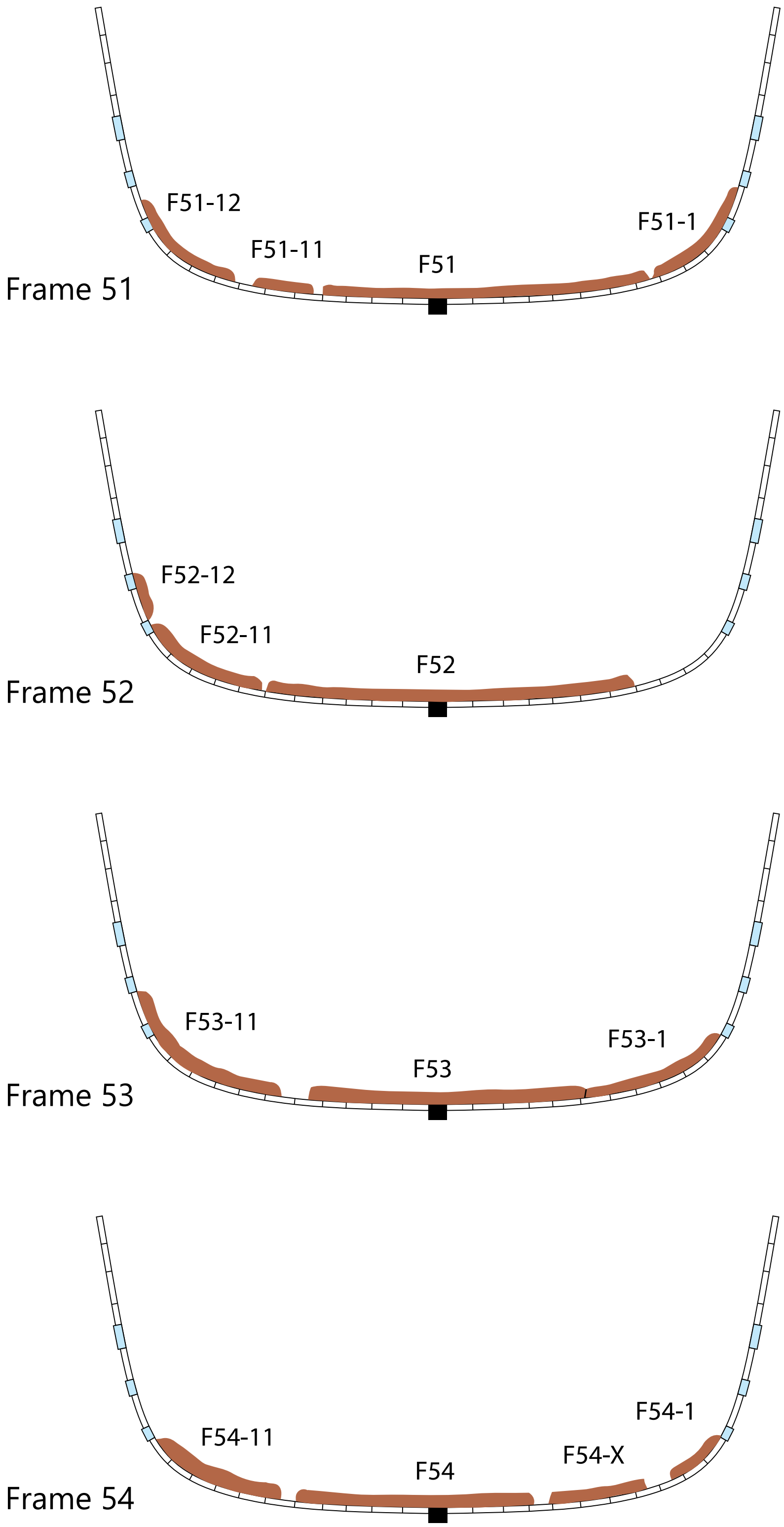
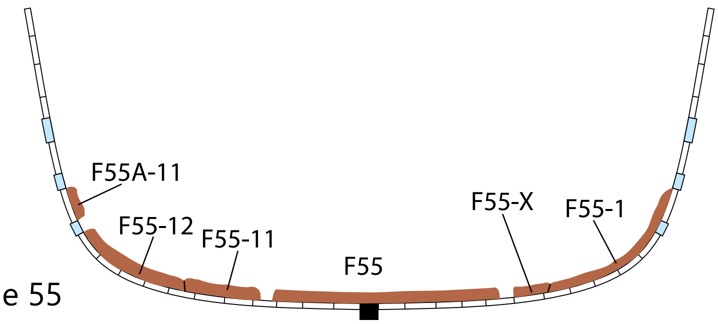

Frame 51
F51-12
F51-11
F51
F51-1
Frame 52
F52-12
F52-11
F52
Frame 53
F53-11
F53
F53-1
Frame 54
F54-11
F54
F54-X
F54-1



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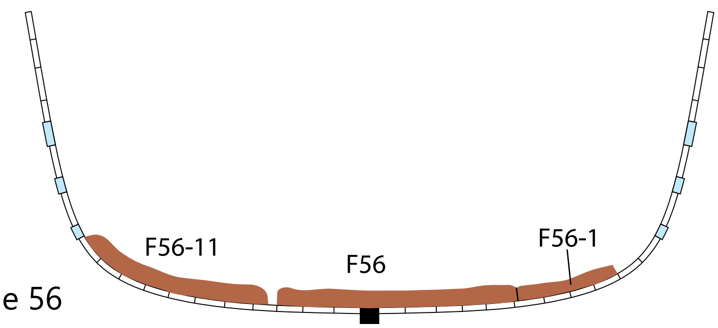

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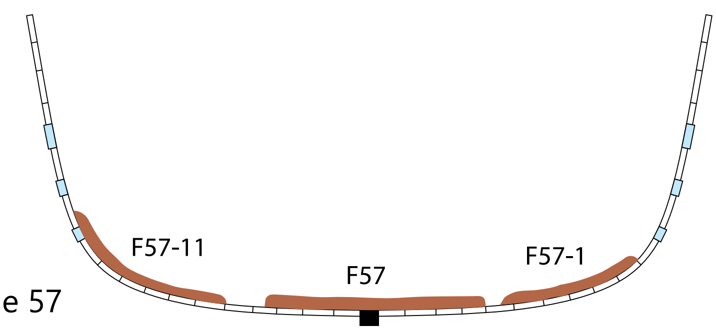

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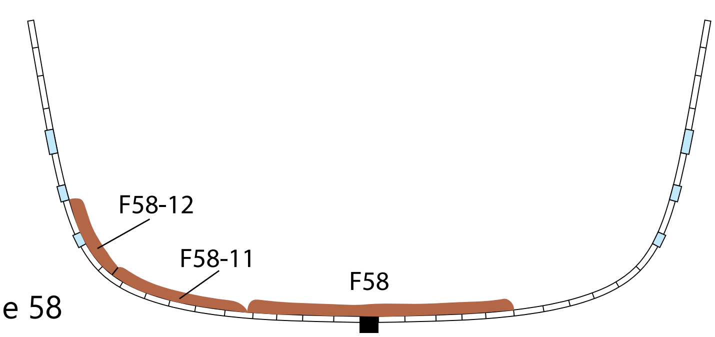

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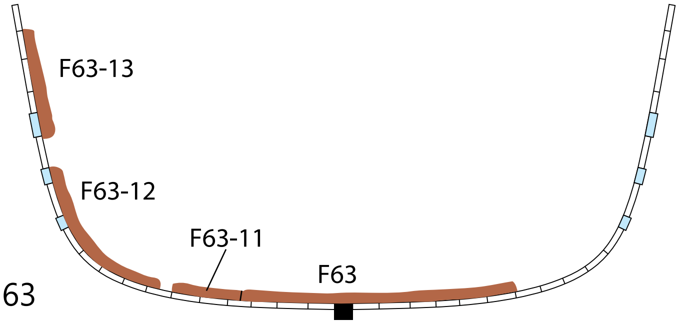

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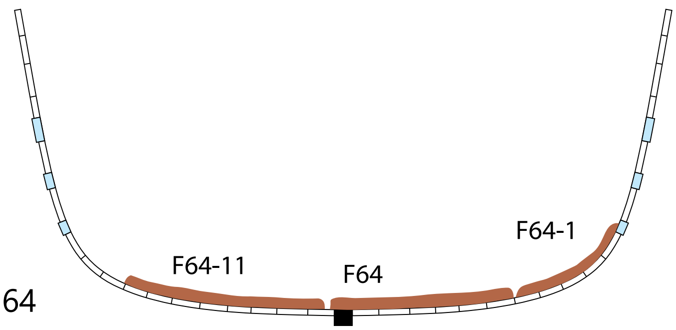

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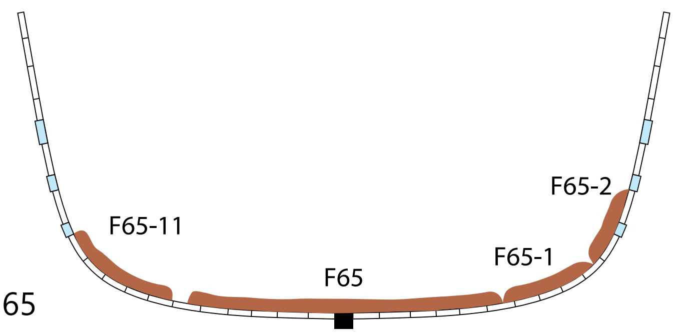

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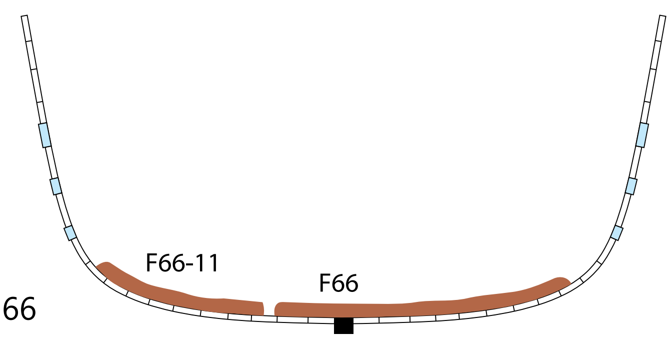

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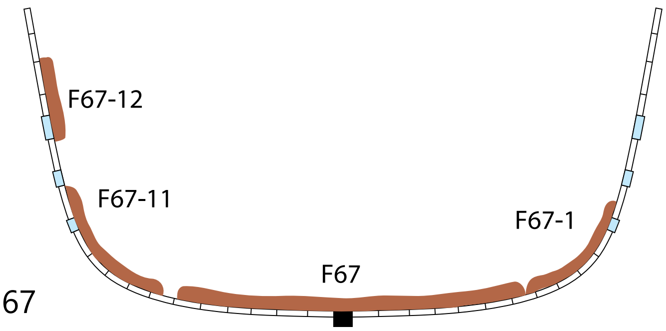

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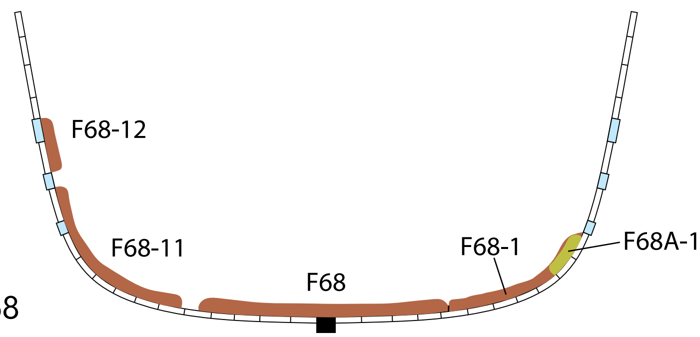

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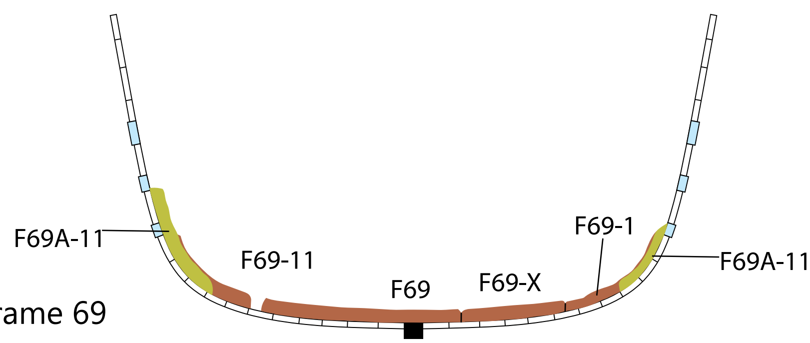

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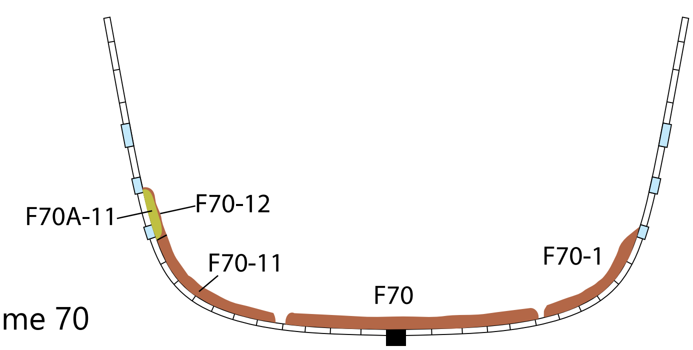

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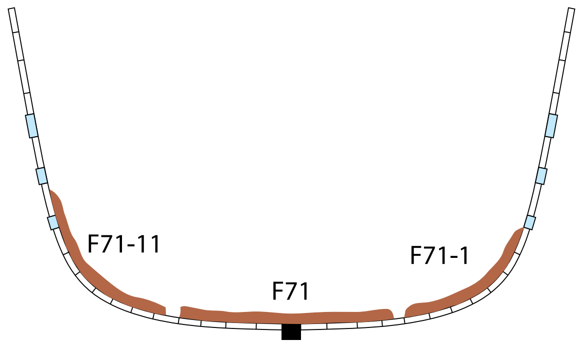

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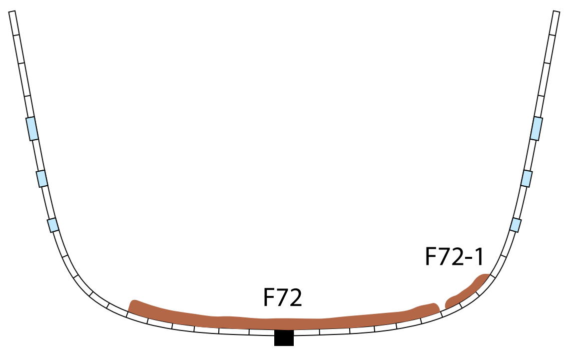

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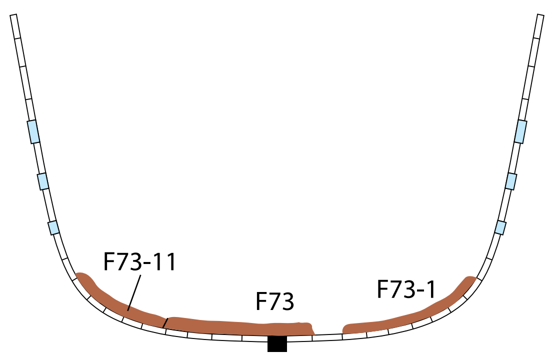

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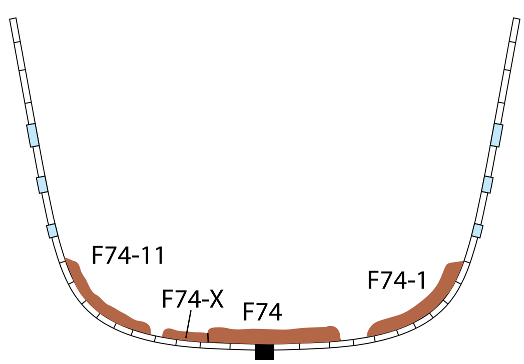
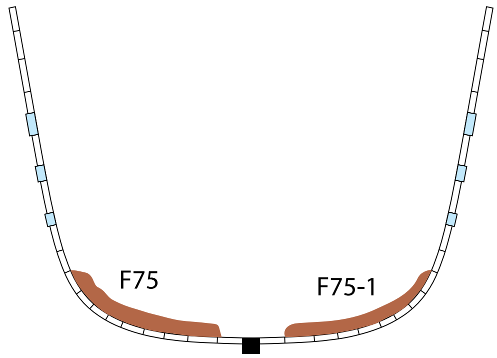


Frame 74

Frame 75



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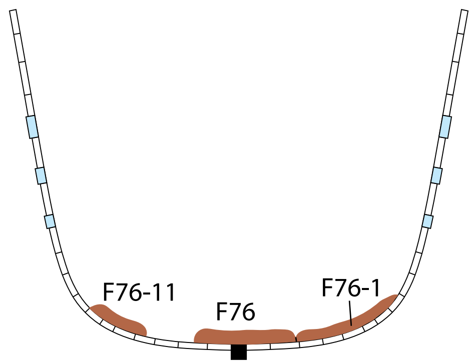

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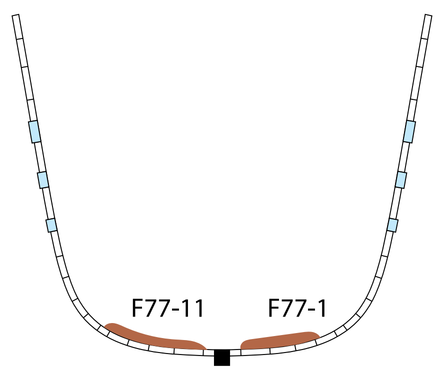

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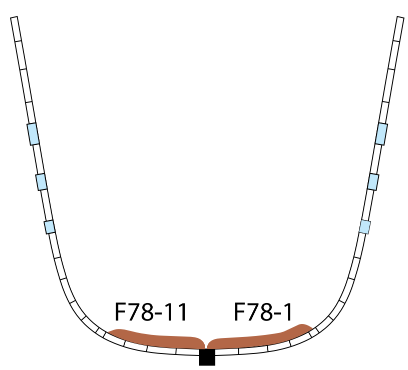

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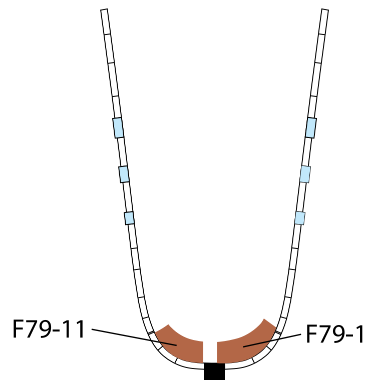

APPENDIX E

ANCIENT SOURCES

Source	Work	Abbreviation
Appian	*Illyricum*	App. *Ill.*
Caesar	*Bellum Civile*	Caes. *BCiv.*
Cassius Dio	*Historia Romana*	Cass. Dio
Cato	*De agricultura*	Cato, *Agr.*
Cicero	*De republica*	Cic. *Rep.*
Columella	*De re rustica*	Columella, *Rust.*
collection	*Corpus Inscriptionum Latinarum*	*CIL*
Eutropius	*Breviarium Historiae Romanae*	Eutr.
Herodotus	The Histories	Hdt.
Livy	*Ab Urbe Condita Libri*	Livy
Martial	Epigrams	Mart. *Epigr.*
Pliny	*Naturalis Historia*	Plin. *HN*
Polybius	The Histories	Polyb.
Strabo	Geography	Strab. *Geog.*
Suetonius	*Tiberius*	Suet. *Tib.*
unknown	*Bellum Alexandrinum*	*BAlex.*
Varro	*De re rustica*	Varro, *Rust.*
Velleius Paterculus	*Historiae*	Vell. Pat.
Vitruvius	*De architectura*	Vitr. *De arch.*