THE HULL REMAINS OF THE LATE HELLENISTIC SHIPWRECK AT KIZILBURUN, TURKEY

A Thesis

by

JOHNNY DWAYNE LITTLEFIELD

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

MASTER OF ARTS

Approved by:

Chair of Committee,	Deborah N. Carlson
Committee Members,	Cemal M. Pulak
	Christoph F. Konrad
Head of Department	Cynthia Werner

December 2012

Major Subject: Anthropology

ABSTRACT

At least 64 shipwrecked stone transports have been discovered throughout the Mediterranean region dating primarily to the Roman period. Few have been excavated and even fewer have had more than scant hull remains recovered. None have been thoroughly examined with a focus on the construction of the vessel. Consequently, little is known about stone transport or the construction of stone transport ships from archaeological contexts or ancient historical sources.

In 1993, on an Institute of Nautical Archaeology (INA) shipwreck survey along the western Turkish coast, the Kızılburun column wreck was discovered. At present, excavated ceramics suggest the date of the Kızılburun shipwreck lies in the first century B.C.E.; the Late Hellenistic period (323-31 BCE). Analyses of the marble consignment have revealed that the ship carried a primary cargo of architectural elements quarried on the island of Proconnesus. Subsequent investigations point to a likely destination of the ancient city of Claros on the Karian coast of Asia Minor (modern day Turkey).

Between 2005 and 2011 excavations were carried out on the column wreck by an international team of archaeologists, INA staff members, and graduate students led by Donny Hamilton and Deborah Carlson, both of Texas A&M University. The 2005 excavation season produced the first, albeit scant, hull remains, with more timbers being recovered between 2006 and 2009. The most substantial hull remains were recovered in 2007 following the removal of the eight large marble column drums to a more remote part of the site. The intense weight and pressure exerted by the heavy cargo on the hull remains aided the preservation by creating an environment that was unfavorable for wood consuming organisms and other biological agents.

Recording and detailed examination of the hull remains was conducted during the summer of 2008, fall of 2009, and fall of 2010. This thesis presents the analyses and interpretation of the Kızılburun ship's wooden hull remains and copper fasteners. Additionally, after

discussing the methods of recording and cataloging of the ship's extant remains, I place the ship in its historical and technological contexts, demonstrating that it was of contemporaneously common dimensions and construction, as opposed to a more robust construction that is often assumed of ancient stone-carrying vessels.

DEDICATION

In the summer of 1988, my sister, Angie Littlefield, died after a life-long paralysis and associated health problems. During her life, Angie was perpetually happy and smiling despite her debilitating situation. Her death forced me to examine my own life and recognize that we are never guaranteed a tomorrow, never guaranteed even one additional minute. This realization eventually led to my departure from a long-term unsatisfying career to chase a dream of becoming an archaeologist and eventually a nautical archaeologist. The realization of this dream has been the only redeeming factor gleaned from her death.

I dedicate this research to my sister, Angie, who is a constant source of inspiration to me and those who knew her. She is loved and remembered.

ACKNOWLEDGEMENTS

This thesis has been four years in the making! Over the course of this time, many people have contributed to the work in many differing manners. My gratitude and respect to each cannot be properly expressed.

In the fall of 2007 I enrolled in the Nautical Archaeology Program at Texas A&M University after much help and advice from Dr. Deborah Carlson. In the summer of 2008, Dr. Carlson offered the opportunity to catalog the wood remains from the Kızılburun shipwreck, as there was a break in the ongoing excavations. At the end of the summer I was offered the opportunity to use the material as the basis for this thesis and in 2009 I joined the final season of excavation at Kızılburun. I am forever grateful to Dr. Carlson for these and more opportunities, for keeping me from straying too far from a completion schedule, and for her support and confidence in my work.

Sincere gratitude is put forward to Dr. Cemal Pulak who has offered advice and support from the beginning of the project and helped me to understand many of the perplexing questions that the sparse wood remains have presented. Numerous casual conversations occurred while sitting on the sofa in the Old World Lab that have benefitted my understanding of not only ship construction, but the methods and behavior of ancient shipwrights, as well as academia in general. Gratitude is also offered to Dr. Christoph Konrad for having, and maintaining, an interest in nautically-based research and serving as a reader of this work.

In the course of this work I have benefited immensely from discussions with Dr. Fred van Doorninck, Dr. Wendy van Duivenvoorde, Sheila Matthews, Orkan Köyağasıoğlu as well as fellow Texas A&M University students Michael Jones, Rebeccah Ingram, Bradley Krueger, Ryan C. Lee and Kimberly Rash Kenyon. I sincerely thank all of these people and many others who have not only answered questions, but who have challenged my logic, albeit at times, not so logical.

Several people and organizations offered financial and moral support that was essential to the retention of my sanity at times. Special thanks to Dr. Deborah Carlson and Dr. Donny Hamilton for both, for without their support, not only would this work have not been possible, but daily living would have been a formative challenge. Immense appreciation is due the Anthropology Department office staff. Cindy Hurt and Rebekah Luza handled, with their usual expertise, financial logistics, course registration, and a plethora of other problems from half way around the globe while I conducted work in Bodrum, Turkey.

I gratefully recognize the opportunities and financial support afforded me by the Institute of Nautical Archaeology (INA), with distinct appreciation being offered to the staff of the INA's Bodrum Research Center (BRC), whom helped tremendously with problems presented to a student living in a foreign land with limited language skills. Often they made jokes about my linguistic handicap, but eventually I began to understand more and more Turkish with their patience. I was the proverbial fish out of water in so many ways. Their help and support cannot be overstated. Special recognition must also be given to illustrators Mustafa Korkmaz and Seçıl Kayacık for their contributions.

Finally, the advice, friendship and support of BRC Director and hayat arkadaşım Tûba Ekmekçi can never be expressed adequately. Both she and Talya has shown incredible patience as I worked late nights and weekends while they quietly (mostly) waited for me to reach a point where I didn't feel guilty for leaving the wood laboratory, office, or library and return home. Thank you both. You are my "Canımlar."

I am certain that I overlooked many important and substantial contributors to this work and for this I apologize to both those overlooked, and to the reader who may never realize the many contributions afforded by the people we surround ourselves with daily, but also of the many individuals encountered in brief meetings, conferences, and conversations.

TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

Page

Page

CHAPTER I
INTRODUCTION

In the first century C.E., Pliny the Elder stated that ships were built for the sake of [transporting] marble, which many have read as Pliny implying that specialized ships were constructed specifically for stone transport in his lifetime.[1] Around the same time, Petronius referred to the *navis lapidaria* or stone carrier.[2] This casual allusion to the *navis lapidaria* is the only known literary reference to such a ship.[3] There are no definitive iconographic representations of *naves lapidariae* from the Classical, Hellenistic or Roman Imperial Periods known to the author.[4] With so little information about stone transport in ancient times passed down through the ages, one may be surprised to find that there are at least 64 architectural stone cargoes that have been discovered in the waters of the Mediterranean, dating from the second century B.C.E. to the sixth century C. E.[5] Few of these shipwrecks have had more than superficial examination, and even fewer have been subject to archaeological excavation.[6] Consequently, at present, little is known about the construction of ancient stone carrying vessels from the archaeological record and even less information is available from the literary and iconographic record.

---

[1] Plin. *NH* 36.1.2. "We remove the barriers created to serve as the boundaries of nations, and ships are built specially for marble, when we see the prices paid for these vessels, when we see the masses of marble that are being conveyed and hauled…"

[2] Petron. *Sat.* 117.

[3] Casson (1971, 169 n. 4) argues that a corrupted Greek papyrus of the third century B.C.E. also refers to "stone-carriers" (P. Cairo Zen. 591726), but this is not unequivocally accepted.

[4] See Gianfrotta and Pomey (1980, 212) for one possible exception, albeit highly unlikely. The carved vessel is certainly not a seagoing ship as it is shown being hauled up the Tiber River, from Ostia to Rome. A second possible representation exists on the base of the obelisk of Theodosius in Istanbul, Turkey although this may portray a sled for moving the obelisk. This example is included due to the dating of the transport of the obelisk, likely in the first quarter of the fourth century C.E. and erection of the obelisk slightly later during the reign of Theodosius (Traquair and Wace 1909). One other possible example is presented by Beltrame and Vittorio (forthcoming) and *may* illustrate a vessel without a mast or side rudders, but possibly a cargo of monolithic columns.

[5] Information compiled from: Parker 1992a; Royal 2008, 62-3; Russell 2011, 14-1; and INA survey notes spanning many years of Mediterranean and Aegean Seas survey. Also, see Carlson 2009, 478-9. These sites do not reflect cargoes of statuary, sarcophagi, or rubble which would significantly increase the number of sites.

[6] Carlson 2006, 3; Carlson 2007, 8; Carlson 2009, 477.

Due to the scant data pertaining to this presumed ship type, discussions of its existence and construction features are filled with speculation and debate. This began in 1920 and raged until 1948 in the pages of *Mariner's Mirror* between Ballard,[7] Anderson,[8] and Solver[9] concerning the transport of obelisks out of Egypt. The debate was revisited by Sleeswyk[10] in 1987 and was addressed again between 2000 and 2003 by Wirshcing.[11] While these authors specifically dealt with obelisk transport, much of the speculation centered around the transport of heavy cargoes in the Roman period as well as that of a much earlier time.

Casson suggests that a *lithegos* or stone-carrier would have been shorter and sturdier than a grain-carrier of the same tonnage.[12] Rougé advocates that Graeco-Roman stone-carriers must have been more robustly constructed.[13] This is reiterated by L'Hour and Long.[14] Gianfrotta and Pomey write of purpose-built ships for carrying marble,[15] as does Snodgrass.[16] Beltrame also argued this point in a paper presented at the International Symposium on Boat and Ship Archaeology (ISBSA) in which he described features a *navis lapidaria* should have, such as double hull planking, robust construction, overall large size, etc.[17] The study of the hull remains excavated at Kızılburun, Turkey provides an opportunity to contribute archaeologically derived data to this corpus and help strengthen or clarify many common assertions and convictions about stone-transport ships in the Late Hellenistic period.[18]

[7] Ballard 1920a; 1920b; 1926; 1927; 1941; 1947. Also see Dyer 1926; 1927.
[8] Anderson 1925; 1926; 1927; 1941. Also see Clowes 1927.
[9] Sølver 1940; 1947; 1948.
[10] Sleeswyk 1987.
[11] Wirsching 2000; 2003.
[12] Casson 1971, 173.
[13] Rougé 1966, 76-7.
[14] L'Hour and Long 1986 (cf. Fitzgerald 1995).
[15] Gianfrotta and Pomey 1980, 211-2.
[16] Snodgrass 1983, 22.
[17] Beltrame and Vittorio, forthcoming.
[18] The Hellenistic period is defined by the death of Alexander the Great in 323 B.C.E. and the Battle of Actium in 31 B.C.E. References to the Roman Imperial period refer to dates between the Battle of Actium and the fall of the Roman Empire in 476 C.E.

DISCOVERY AND DATING OF THE KIZILBURUN SHIPWRECK

The Kızılburun column wreck was first located, along with four other shipwrecks, in 1993 during an Institute of Nautical Archaeology (INA) coastal survey. The survey was directed by Texas A&M University professor Cemal Pulak off the Aegean coast of Turkey (Figure 1.1), and these particular wrecks were located southwest of Izmir at Kızılburun, Turkish for "Crimson Cape."[19] At the time of discovery the only diagnostic artifact found on the column wreck was a single Lamboglia 2 amphora. The presence of this amphora suggested a date in the second or first century B.C.E. for the shipwreck, although the amphora was not conclusively associated with the stone cargo.[20]

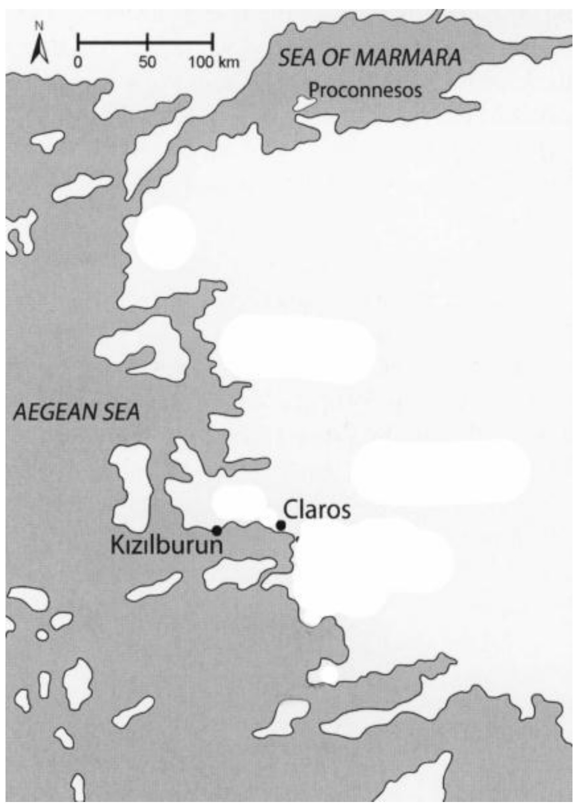


Figure 1.1. Turkish coast map showing Kızılburun, Claros, and Proconnesos. After Carlson and Aylward 2010, 146 fig.1.

[19] Pulak and Rogers 1994, 17-19.
[20] Pulak and Rogers 1994, 19.

In 2001, a second survey team, working under a filming and documentation permit, returned to Kızılburun to further document the five shipwrecks discovered in 1993. While divers photographed and sketched visible artifacts, three additional Lamboglia 2 amphorae were discovered that were in clear association with the column wreck and strengthened the idea that the vessel dates to the late second or early first century B.C.E.[21]

Between 2005 and 2009, an international team of archaeologists, graduate students, and INA staff members excavated the remains of the Late Hellenistic column wreck at the small natural bay adjacent to Kızılburun. Former INA president and Texas A&M University professor Donny Hamilton served as project director, with current INA President and Texas A&M University professor Deborah Carlson serving as archaeological director.[22] Ongoing analysis of excavated ceramics suggests the date of the Kızılburun shipwreck lies in the second or third quarter of the first century B.C.E. [23]

At the time of its demise, the Kızılburun ship was transporting a cargo of roughly finished, and presumably freshly quarried, marble objects including grave stones and basins as a subsidiary cargo and elements of a monumental marble column, in the form of eight individual drums and a single Doric capital, as its primary cargo.[24] The cargo was situated on the seafloor in the same manner it was originally laden in the ship. The eight drums were arranged in two files of four, with the capital and two large marble blocks resting atop the drums (Figure 1.2); the drums themselves rested only centimeters apart with the top surfaces canted inward towards each other (Figure 1.3). The surviving cargo is suggestive of the size of the hull that once held the marble cargo. The total calculated weight of the marble cargo, both primary and secondary, is approximately 60 tons.[25] The canted position of the drums when considered together with the weight of the cargo, allows for some initial

[21] Carlson 2006, 5. Through the course of excavations, at least one dozen Lamboglia 2 amphorae have been discovered in clear association with the wreck (Carlson and Aylward 2010, 145).
[22] For more on the site and excavations see Carlson 2006; Carlson 2007; Carlson 2009; Carlson and Aylward 2010; Carlson and Atkins 2008; Carlson and Hamilton 2009.
[23] Carlson and Aylward 2010, 145.
[24] See Carlson and Aylward (2010, 147-54) for detailed information on the column elements.
[25] Carlson and Aylward 2010, table 2, 156.

premises to be established. This seemingly heavy cargo, although constituting a concentrated mass, is not necessarily a large one by standards set forth by Parker. In fact, by Parker's criteria, a cargo of this weight would be placed in the small category.[26] The size of the Kızılburun ship will be addressed in Chapter VI.

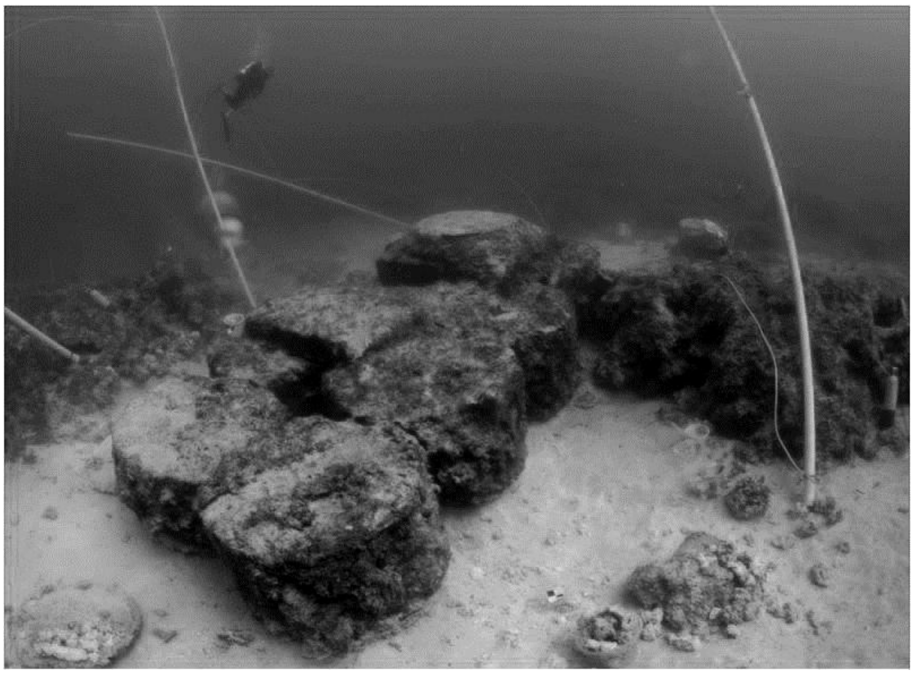


Figure 1.2. Early 2005 site photograph looking upslope. Photograph by Don Frey.

[26] In a seminal work of collective shipwreck material and reports, Parker categorizes and summarizes many aspects of ancient ships and shipping. He distinguishes three size categories of ancient Mediterranean ships: small (<75 tons), medium (75-200 tons), large (>200 tons), Parker 1992a, 26-7. Parker further states that most ships fell into the small category. Houston (1988, 553-4) supports this idea, adding that most ships were less than 100 tons capacity.

Figure 1.3. Column drums at seafloor level, looking downslope. Note the capital on top of drums 1 and 2. Photograph by Don Frey.

Due to the large surface area and concentrated weight of the marble drums, it was the initial hope of investigators that the hull might have been preserved in the substrate beneath the cargo. A ship's hull associated with such a cargo holds the potential to answer many questions about Hellenistic period seafaring technology as well as addressing the topic of specialized ship construction for the purpose of marble transport.[27]

The ship came to rest on a gentle slope of seabed peppered by several large boulders, with the upslope portion at a depth of 42 m (140 ft) and the lower portion at 45 m (150 ft). Although recreational S.C.U.B.A. (scuba hereafter) diving is prohibited along this section of the Turkish coast, divers were occasionally sighted during the excavations. The depth at which the shipwreck lies was considered an advantage that made it a candidate for excavation as it is relatively deep for recreational divers that commonly explore or loot artifacts from sites in shallower depths, yet it lies within the standard safe working limits of

[27] Carlson and Atkins 2008, 23; Carlson 2006, 3; Carlson 2009, 477.

INA archaeologists as set forth by Dr. Richard Vann of Duke University and the Divers Alert Network.[28] Further, the depth of the site meant that it was not visible from the surface and vaguely visible from within the water column aiding in its seemingly unmolested state at the time of discovery. Nevertheless, evidence suggests some disturbance, likely by fishermen's nets, has displaced artifacts in an upslope direction. However, any presumed artifact displacement did not affect the hull remains as only a few tiny fragments were recovered from the surface; most being excavated from the seafloor under and between the heavy marble column drums. As the recovery of the wood remnants and fasteners that comprise the remains of the vessel was a process stretching over multiple years, a brief summary of each season, as it relates to these artifacts, is presented here.

2005 SEASON

The inaugural excavation of 2005 yielded more than 250 non-ferrous metal nails. Many of these were found in excavation Areas 19 and 20 directly adjacent to drums 1 and 2, with heads down and positioned in rows in roughly an east-west orientation. The cargo appeared to have an approximately north-south central axis, suggesting the keel, when found, would mimic this axis and indicated that the rows of fasteners likely represented nails used in securing the hull planking to the framing. This was one of the first clues that the site revealed concerning the construction details of the ship, as tentative frame spacing was deduced before any diagnostic wood remains had been uncovered.

Excavators recovered only 15 random, disarticulated fragments of hull wood during the 2005 field season. All 15 pieces were tiny, non-diagnostic remnants, although one fragment preserved what appeared in the field to be a partial peg hole and a partial tenon, suggesting in the early stages of excavation that the ship was of typical Graeco-Roman construction using pegged mortise-and-tenon joinery.[29] Although the deduction that the ship was of typical Graeco-Roman construction was correct, the information the deduction was based

[28] Specialized dive tables were developed by Dr. Vann for INA projects down to depths of 58 m (190 feet) using in-water decompression on 100% oxygen.

[29] Casson 1971, 202-3; DeVries 1972, 49; Fitzgerald 1995, 132; Pomey 2004, 25; Pulak 2000, 28; Throckmorton 1987, 92. As Pomey (2004, 25-6) points out, this is a feature that has been well established over the last four decades of shipwreck excavation and study.

on was incorrect, as it was later discovered in laboratory analysis that the fragment did not contain a tenon fragment, nor a tenon peg.

After the initial season, with little wood remains recovered in the areas of the site surrounding the column cargo (Figure 1.4), focus turned to the possibility of wood remains surviving under the large column drums. Plans were formulated during subsequent field seasons for removing of the large drums from the area of the hull and storing them elsewhere before raising them to the surface for conservation and analysis.

Figure 1.4. Alexis Catsambis excavating on the periphery of drum 1. Photograph by Don Frey.

2006 SEASON

The second excavation season proved more fruitful in terms of recovering hull remains. Excavation of the upslope portion of the site revealed more cupreous fasteners and small sections of thin planking. At the time it was unclear if this was ceiling planking, hull planking, or other planking due to the degraded nature of the wood and lack of other identifiable wood remains or nails clearly associated with the planking in this section. Further complicating the task of assigning function to these timbers in the field was the fact that a large iron anchor-shaped concretion rested directly atop some of the timbers, initially suggesting that the timbers were deck planking.[30]

Other finds from the upslope area of the site included a sounding weight[31] along with a large lead anchor stock and associated lead anchor collar. These finds suggested the orientation of the ship as it lay on the seafloor, with the bow upslope, on the northern shallower end of the site, situated between two large boulders.

During the final weeks of the 2006 excavation season, four of the eight column drums (nos. 5, 6, 7, 8) (Figure 1.5) were rigged with large-capacity lifting balloons and removed off the wreck site, allowing for excavation of an area approximately 9 m^2 beneath the drums. The delicate procedure of repositioning the drums off site was accomplished with little disturbance of the fragile wooden hull remains that lay directly beneath the drums, although not without incident (discussed below). The area beneath drum 5 (designated area U5) proved the most lucrative in terms of wood remains. Numerous fragments of longitudinal planking were recovered along with four distinct frame fragments. These frame fragments have proven to be the most diagnostic and well-preserved timbers from the vessel.

---

[30] For example, see the story of Saint Paul's shipwreck (Acts 27:29-30) for a description of anchors on deck and ready for use. Also see Hirschfeld (1990, 27) and Sottas (1921, 260) for analysis of this story with references to the anchors and their positions aboard the ship.

[31] This is the only sounding weight clearly from a datable context recovered from Turkish waters. Oleson (2008, 131) reports four sounding weights found in Turkish waters, including the example from Kızılburun. Of these examples, he claims one to be doubtful as a sounding weight (from the Bronze Age Uluburun shipwreck) with the remaining two from non-provenienced sites.

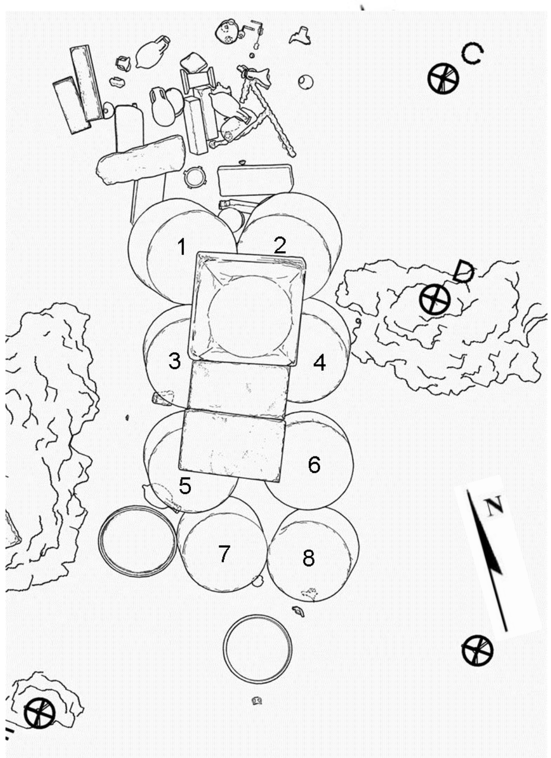


Figure 1.5. Site plan showing drum numbering system. Image by Sheila Matthews.

Additionally, a section of a longitudinal timber, initially thought to be a stringer or keelson-like timber due to its modest dimensions, was exposed between drums 7 and 8 (areas U7 and U8 respectively) when digging a small test pit. This timber was approximately 3 m in length as found but suffered damage during the rigging and lifting of adjacent drums. The damage to the timber was extensive and irreparable as a 1 m long section was broken into dozens of tiny fragments. The remaining 2 m of the damaged timber indicated that it had yet to be fully uncovered and was thus left in situ for the following season.

2007 SEASON

With much of the upslope area of the site excavated in 2006 and the removal of four column drums (5 – 8) to an off-site location, the focus of the 2007 season was to continue excavation in the areas under the repositioned drums as well as to remove the remaining drums, capital, and two large marble blocks to the same off-site location and open up these areas for excavation. After the repositioning of the drums, the corresponding areas beneath them were renamed with respect to the drum that was removed from that space (e.g., the space beneath drum 1 became area U1, the area beneath drum 5 became area U5, etc.)

Areas U7 and U8 were nearly devoid of any hull wood, with the exception of the long longitudinal timber discovered in 2006. Further excavation in 2007 revealed that this timber continued along a path roughly bisecting these two excavation units, further continuing upslope between areas U5 and U6. Again in 2007, this timber had not been fully exposed and consequently, not recovered from the site. It was covered with sand for protection and left in situ for the next excavation season.

Sections of frame fragments discovered in 2006 were found to be outboard portions of frame pieces uncovered in 2007. In area U5 both pieces of frames, as well as small amounts of longitudinal hull planking were revealed. Area U6 produced the best preserved and largest amount of wood in 2007. Distinct layers of ceiling planking, frame pieces, and hull planking were identified.

In early July of 2007, the remaining four drums (nos. 1, 2, 3 and 4) and capital were transferred off site, exposing more timber fragments below them. Excavation in areas U1 and U3 revealed transverse timbers atop badly broken hull planking sections, clearly identifiable by several examples of preserved pegged mortise-and-tenon joinery, while areas U2 and U4, as with areas U7 and U8, were almost devoid of wood.

2008 SEASON

After three seasons of excavation, hundreds of wood fragments and thousands of other excavated artifacts awaited cataloging in INA's Bodrum Research Center (BRC).

Therefore, 2008 was designated a study season in lieu of an excavation season. This marked the beginning of the author's involvement with the Kızılburun shipwreck project.
Over the course of two months during the summer of 2008, I catalogued more than 165 hull fragments and timbers in detail. This process involved making for each fragment a sketch, usually at 1:1 scale, measuring in three dimensions, photographing, and writing a description of any distinguishing features. In addition, dozens more fragments were examined and photographed, but not cataloged due to their diminutive size or loss of context. However, even when provenience was unclear, any timber or fragment with discernible, distinguishing features was cataloged. Wood samples were also collected for many of the timbers and fragments for wood species identification.

2009 SEASON

The 2007 field season ended with one large, looming question. Had all or most of the hull remains been revealed, or was there a more substantial, well-preserved portion of hull awaiting discovery? The only known timber left in situ was the longitudinal timber stretching centrally from the top of area U3/U5 downslope through areas U7 and U8, but this timber had yet to be positively identified and it was unclear if other hull remains lay in the substrate awaiting excavation. Probing of the surrounding seafloor produced (generally) inconclusive results.

Three main goals dictated the course of the 2009 excavation season: 1) the final mapping and raising of any remaining artifacts and hull fragments, including the central longitudinal timber left in situ from the 2007 excavation season, 2) raising some of the architectural components for further study, and 3) covering the column drums left on the seafloor with a layer of polyester sheeting to protect their surfaces until they could be retrieved at a later date.

With few new hull remains discovered, attention was focused on the central longitudinal timber. The discovery of a longitudinal groove or rabbet along its uppermost edge indicated this was, in fact, the ship's keel and not a stringer as previously thought. At this point it became clear that more timbers were not likely to be discovered in the lower strata. However, while uncovering the keel, a 62 cm long section of the disarticulated port-side garboard strake was discovered and excavated.[32] With the exception of a few small non-diagnostic fragments, the garboard section proved to be the only new hull remains revealed in 2009.

Consequently, during post-excavation recording of the timbers in the Nixon Griffis Wood Laboratory of the BRC, attention was directed to the nearly 3 m long keel fragment and the small garboard section. Although the keel fragment is the most substantial timber recovered from the wreck, it is fragile and in fragmentary condition due in part to the damage it sustained in the 2006 season during the removal of the drums. The keel section is in nearly 30 pieces, requiring slight modifications to the otherwise standardized recording process. Instead of recording the timber as a unit, it was recorded in smaller reconstructed sections. Much of the post-excavation work of 2009 was spent in a trial-and-error process of assembling the pieces in order to record the timber accurately. Cataloguing the ship's metal fasteners also comprised a large portion of the 2009 laboratory work.

2010 SEASON

As the study of the hull remains progressed from season to season, construction features became better understood. For fear that important information had been overlooked in the early stages of recording due to my own inexperience, many of the hull remains catalogued in 2008, and some from 2009, were revisited and given a second and often a third examination. As suspected, information was missed that came to light with renewed investigation. For instance, while no plug-treenails were observed in 2008, they were noted in 2009, albeit not conclusively, due to the poor condition of the wood. Additionally, the focus of study was on the keel and garboard, which do not hold any

[32] Neither the stem nor stern post survives. Therefore, port-side identification is presumed by the location of the iron anchor, lead anchor stocks and sounding weight that would have been stowed at the ship's bow.

preserved plug-treenails. Thus, definitive evidence for plug-treenails was finally observed in frame timbers documented in 2010.

Regretfully, the hull was not as well preserved as was hoped in the first months of the excavation. Although none of the upper hull components of the ship survives, key elements such as hull planks, ceiling planks, numerous frame fragments, and fasteners do survive, and allow for discussion of the construction of the vessel. This, in turn, will offer comparative material for future discussions pertaining to stone transport vessels of antiquity. Information has been gained from the study of the ship's fasteners that both support and amend the data gathered in the examination of the wood remains.

OBJECTIVES

The longest established and most highly developed approach to examining the past is the historical approach, in which documentary evidence is scrutinized to answer the enquiries with which anthropologists are concerned and applied to supplement information derived from the objects that archaeologists recover.[33] As Yentsch and Beaudry express, "… there is truth in the statement that the fullest range of layered meaning is obtained when one can consult an informant using her words and deeds to inform the analysis of material culture."[34] Regrettably, there is a dearth of documentary evidence concerning Hellenistic shipbuilding and stone transport, thus leaving the discovery of such information to maritime archaeologists through the implementation of a near purely materialistic approach. This examination of the objects and ship remains is not simply a matter of data collection from the artifacts themselves, but should offer a glimpse of the people responsible for their production.[35] As Creasman expresses, "…ship timbers are individual artifacts that can [and should] be studied to expose the cultural information they contain; not just their origin, species, date, or preference in construction."[36] Similarly and equally valid is Throckmorton's statement:

---

[33] Muckelroy 1998a, 24.

[34] Yentsch and Beaudry 2001, 214.

[35] Wheeler 1954, 13.

[36] Creasman (2010, 2-3), further states that ship timbers, as material culture, can offer more than information on the ship's final voyage or trade routes and outlines the need and methods for more thorough timber studies

> "A sailing ship, seen as an artifact, is one of the most interesting and beautiful of human creations. In it is concentrated the cumulative knowledge of half a dozen crafts through many generations. Like public buildings, ships are expressions of the societies that created them."[37]

The Kızılburun hull remains are sparse at best, yet information has been gleaned that both challenges and affirms current, admittedly minimal, knowledge of Hellenistic and early Roman shipbuilding, specifically in terms of stone carriers. Through the treatment of the ship itself as a diagnostic artifact, one can offer comparative insights into the historical and technological contexts in which the ship was produced.

This thesis is a record of the cataloging, recording, analyses and interpretation of the preserved elements of the Kızılburun column wreck's wooden hull, including its fasteners. My focus is recording aspects of hull construction to compare them with those of contemporaneous vessels in historical, as well as technological terms, in order to facilitate future discussion of both shipbuilding and transport of stone in the late Hellenistic period. As stated by Muckelroy,

> "It is only by this steady accretion of data within a systematic framework that any real advances in knowledge or understanding can be made; without it, each worker is essentially starting from scratch, and it is as if all previous workers had not existed, the same basic questions being considered over and over again."[38]

This seems to be much the case with respect to stone-carrying ships of antiquity as some researchers have conjectured about their construction in lieu of solid

---

to extract cultural information from ship timbers; methods that have been employed in this thesis whenever possible.

37 Throckmorton 1970, 31.

38 Muckelroy 1998a, 25.

archaeological evidence. Therefore, it is the desire of the author that this work be built upon and expanded by future investigators, with a clearer understanding of ancient stone transport as a point of departure.

CHAPTER II
METHODOLOGIES[39]

With wrecked ships, the environment in which artifacts are deposited has a direct bearing on the quality of the material preservation.[40] This environment is dynamic and studies addressing these factors are becoming more prevalent,[41] yet more research is certainly needed. As noted, "one material that is commonly encountered on underwater sites is wood, and the processes of its deterioration serves as a good example to highlight the complex interactions of chemical and biological processes in the underwater and marine environment."[42] Factors of deterioration, at least those that can be discerned, must be addressed in order to gain a better understanding of a vessel's remains. Therefore, a brief discussion of the nature of the Kızılburun shipwreck site is necessary in order to understand the state of preservation of components of the ship and, consequently, the methodologies employed to record the site in general, as well as individual timbers or fragments of the hull, both in the field and in the laboratory.

SITE DESCRIPTION

After the ship sank, it came to rest on a moderately sloping, coarse-sandy seafloor at a depth of 42-45 m, grounded between outcrops of rocks (Figure 2.1).[43] Although site formation processes have not been formally addressed, evidence suggests the hull was not immediately buried in the seafloor sediments. Rather, the hull likely came to rest on the seabed and slowly became structurally weak by the effects of seawater saturation, bacterial

---

[39] A brief discussion of methodological modifications appears in Littlefield 2011b.
[40] Muckelroy 1998a, 27; Muckelroy 1998b, 270-4. Also see Dumas 1972 for a thorough explanation of the effects of differing Mediterranean Sea bottom types on the preservation of hull remains.
[41] For example, a replica of the Bronze Age Uluburun ship (Uluburun III) was intentionally sunk in order to provide a training ground for archaeological methods, to share what are normally restricted archaeological dives with recreational divers, and to observe the process of the vessel's decay (Varinlioğlu pers. comm. 2012)
[42] Bowens 2009, 30. It is noted that wood exposed to sea-water is colonized by biological agents rather than chemical agents . However, in the case of the Kızılburun ship it is possible that the marble cargo influenced the pH level of the wood that it rested on, making the wood less appealing to biological agents.
[43] Two major outcrops of rocks were situated on the site, but it is unclear if these calcareous concretions existed at the time of the ship's demise or if they were formed at a later time.

consumption, wood-boring molluscsand crustacean damage, along with the weight of the cargo.[44] Throckmorton describes the effects of teredo worms very well:

> "Unfortunately for students of Greek and Roman ships, the Mediterranean is not a very good place for conservation of ships, compared to the Baltic or Black Sea. The worst enemy of a wooden ship, sunk or afloat, is the teredo worm, tiny, efficient, voracious, which in the Mediterranean will in a very few years tunnel so effectively through a piece of wood that it looks as if it has been riddled by buckshot. Its small pincer beak, less brittle than bone, tougher and stronger than a human fingernail, bites slowly through the wood, digesting whole ships with the quiet speed known to anyone who ever left so much as a dinghy afloat too long in dirty harbor waters."[45]

The Kızılburun ship was likely originally resting on, or in, shallow seafloor sediments, particularly in the upslope portion of the site. This is demonstrated by the fact that a large percentage of the surviving wooden hull remains were heavily damaged by teredo worms, which exist in the water column and in aerobic, shallow substrates,[46] and suggest the hull was exposed for a number of years.[47] Of the surviving hull remains, extremely little of the original outer surface is preserved; while a fair amount of inner surfaces- those protected by the column drums- does survive, suggesting the outer faces of the hull timbers were exposed to biological agents for a prolonged period. Second, as teredo damage was also observed on interior portions of the hull, the exterior worm damage was not solely that of an older vessel. Over time, however, the weight of the cargo forced a portion of the ship

---

[44] Sen et al. (personal communication, 2011) show that at least five shipworm species are present along the Turkish coastline, as tested at six distinct coastal sites. In tests conducted at Çesme, very close to the Kızılburun wreck site, *Teredo navalis* and *Lyrodus pedicellatus* were both found.
[45] Throckmorton 1970, 16.
[46] See Müller (2010) for a description of the life and habitat of *Teredinidae* (shipworms). It has been shown that factors such as specific water salinity, temperature, depth, and available dissolved oxygen all contribute to the survival of wood-borers (shipworms and gribble), however, available oxygen is reportedly the single most important factor for their survival (Bowens 2009, 30-1).
[47] Müller (2010, 107) references a study by Sen et al. which demonstrates how *Pinus nigra* samples were "more or less infested and destroyed by shipworms within about a year" in tests conducted along the Turkish coast. The Nautical Archaeology Society (NAS) suggests that the complete destruction of a wooden vessel can occur within a decade (Bowens 2009, 31).

into the seabed, where the hull remains found a less favorable environment for bacteria and shipworms and this in turn helped preserve a small fraction of the ship.[48]

Figure 2.1. Column drum positioning as found and their assigned numbering. Photomosaic by Sheila Matthews.

[48] This is a well-understood scenario in underwater Mediterranean sites. For a theoretical explanation of this and other marine site formation processes as well as further examples see Muckelroy 1998b, 278-9. For a discussion of general archaeological site formation processes see Schiffer 1987.

STATE OF WOOD PRESERVATION

The Kızılburun wood remains are poorly preserved, the drums and their point load are likely contributors to the preservation of the extant wood; the bottom of the drums served to protect the wood from biological agents in the water column above and the weight of the drums drove portions of the hull deeper into the seabed as the upper structure deteriorated over time beyond the perimeter of the drums. Although these factors can help explain how wooden hull remains did survive, they do not explain the differential preservation of the extant wood. At the Kızılburun site, wood preservation levels varied greatly, even between areas of close proximity. While the weight and size of each drum is similar, there is no pattern to the level of preservation. For example, drum 4 (6.31-6.96 tons) and drum 6 (5.82-6.97 tons) are the heaviest drums and are of very close volumetric size, both having a maximum volume of 2.55 m^3.[49] These drums were adjacent to each other on the ship, have very similar sizes and weights, yet the level of preservation of the hull remains beneath shows the most variation (among remains that survive directly beneath the drums). One likely explanation for the differential state of preservation is the variable topography beneath the ship. Presuming it was grounded on the seafloor relatively intact some sections of the hull would have been more exposed than others in relation to the contour of the wreck site. Therefore, one must presume differentially prolonged exposure to biological factors prior to the ultimate deposition in anaerobic or reduced oxygen sediments.

In addition to biological and chemical processes that affected the state of material preservation, there is a mechanical process that also contributed to the heavy deterioration of the vessel; that being severe compression and distortion suffered by many of the wood fragments due to the concentrated weight of the column drums. The combination of natural deterioration processes coupled with mechanical processes created numerous problems including, but not limited to, loss of original dimensions, poor definition or loss of timber edges, loss of evidence as to how the timbers were cut, and loss of tool marks.

[49] For dimensions, volumetric calculations and tonnage figures of the column drums see Carlson and Aylward 2010, 150 table 2.

The crushing and distorting of timbers under the weight of the column drums is not fully understood. In some cases where planking appears flattened or crushed, the manner is very clear, but in the case of distortion the processes are less so. The results of these mechanical processes are wood remains that are fragmentary, fragile, and friable. Simply handling a fragment for recording, whether on the seafloor or in the conservation laboratory, often resulted in breakage. Excavation and mapping methodologies were employed to minimize the time timbers and fragments were exposed and handled on the seafloor.

It should be noted that several timbers are fragmented, yet contiguous, suggesting they were broken upon impact with the seafloor or shortly afterwards as the ship's structural integrity failed. Given that Kızılburun is a promontory and given the presence of at least four other shipwrecks in the immediate area, one may presume these ships collided with the land mass, in the dark of night, as a consequence of a lodos (southerly) storm, or some other indiscernible reason. Regardless, it remains unclear if the impact causing the evident damage was a single event at the time of the ship's wrecking, or multiple events as the structure of the ship failed over time. Most likely the fragmentary nature of the remains is due to a combination of the two factors, yet individual breakage events cannot be directly attributed to either. Although evidence of impact is not particularly surprising, these data do help one begin to understand the nature of the remains.

EXCAVATION AND MAPPING METHODOLOGY

In 2006, drums 5, 6, 7, and 8 were relocated to the eastern side of the site to allow exploration below them for hull remains. Several transverse timbers were discovered under drum 5 (area U5). Additional timbers, both transverse and longitudinal, were discovered in area U6. These timbers were left in situ due to the end of the excavation season.[50] However, during the 2007 season, these remains were recovered, alongside newly exposed timbers from area U1 and area U3, which were found after off-site repositioning of drums 1, 2, 3, and 4 due to the realization that exposed timbers were immediately at risk of being lost to the current.

[50] Carlson 2007, 8.

The mechanics of excavation were executed using a combination of airlifts and hand-fanning. Excavation of the site was done by area, with individual excavators working stratigraphically in each unit (e.g. U1, U2, etc.), as opposed to working as a group excavating stratigraphically over the entire site. Consequently, timbers were exposed in different units at differing times. As the wood remains were exceptionally fragmentary and friable, extreme care had to be taken to assure that fragments remained in position until they could be photographically documented. This was a product of necessity as often fine silt was the only thing holding wood fragments in place and removing the silt instantly put fragments at risk of being swept away in the current. Therefore, most wood pieces were immediately raised to the surface after being photographed, while more substantial fragments were left in situ for short periods to allow other timbers from the same area to be exposed simultaneously. However, at no point were all, or even most, of the wood remains exposed concurrently.

The keel was exceptional in that it was partially uncovered in 2006, although it was thought to be a stringer or keelson at the time due to its (seemingly) diminutive size. It was further uncovered and remained exposed for several weeks in 2007; once again it was exposed for most of the duration of the 2009 season. Researchers did not have the luxury or good fortune to have an exposed hull laid out on the seafloor for inspection and relative measurements. Therefore, instead of direct measurement techniques used for many years on excavations throughout the world, an adaptive form of photogrammetry was employed, not only for the wood remains but for all artifactual material.

All artifacts were assigned a sequential "Lot Number" by the on-site conservation team when raised. Those artifacts in association with each other were given sub-Lot numbers. For example, an amphora may be given Lot number 100, but any associated artifacts raised with the amphora may be given numbers like 100.01, 100.02, etc. Therefore each nail, group of nail fragments, wood fragments, etc. referenced in this work all received Lot Numbers.

In 2007 a secondary numbering system, Wood Number, was put into place to aid the mapping of hull timbers. Wood numbers were assigned to all timbers, dependent upon the area where they were excavated, either in situ or after a fragment was raised to the surface. For example, the first timber discovered in Area U1 received the wood number 1000. As with Lot Numbers, Wood Numbers also received a secondary division for fragments that were clearly of the same timber (e.g. 1000.01, 1000.02, etc.) Wood Numbers have no meaning other than letting the reader immediately know from which area the timber was excavated and allow a system of reference. The wood catalog in Appendix I uses Wood Numbers for reference.

Mapping of hull timbers and fragments was accomplished using a combination of fixed datums or control points, photographs, *Site Surveyor* software, *Photo Modeler* software and *Rhinoceros* 4.0 three-dimensional imaging software, along with direct measurements.[51] Each day numerous general artifact and site photographs were taken. Hundreds of close-up images of wood remains were also produced. Thus, in hull analyses I relied on computer software and in situ, as well as laboratory photographs, along with divers' logs, close inspection and recording of the wood remains as they were excavated. Additional, more thorough study was carried out in the laboratory during post-excavation periods.

LABORATORY RECORDING METHODOLOGY

J. Richard Steffy penned an article entitled "Maximum Results from Minimum Remains," in which he emphasized the need for close examination of even the most scant ship remains where large questions loom over construction techniques or general design.[52] Large questions certainly loom over the construction of ancient stone carriers. The thesis of Steffy's article has become a sort of mantra during the recording and interpretation of the scant hull remains of the Kızılburun vessel.

[51] For a description of the mapping procedures used at the Kızılburun site see Higgins (2007). For a more general description of the methods see Green et al. (2002).
[52] Steffy 1978.

Between 2008 and 2011, approximately 800 fragments of the Kızılburun ship were photographed and/or drawn (Appendix A)[53] in the Heathea Nye Wood Conservation Laboratory at the Institute of Nautical Archaeology's Bodrum Research Center. Many are of miniscule size and are non-diagnostic in terms of the ship's construction. Such pieces were photographed, but many were not recorded otherwise. However, if a fragment, no matter how small, showed any construction feature or distinguishing marks, the fragment and feature were photographed, sketched, measured and described on a catalog sheet.

Photographs

Each fragment was digitally photographed with and without a centimeter scale against a white background. This allows for easier manipulation of photographs for analysis and publication, as well as overcoming problems created by artificial lighting. Profile photographs were taken where useful information could be obtained, such as original shape or dimensions. However, diagnostic features, such as mortises, pegs, or tool marks were photographed with a macro lens to show details as clearly as possible.

Catalog sheets

Two separate catalog sheets were utilized in recording of the wood remains (Figures 2.2 and 2.3). The first was the general catalog sheet (Figure 2.2) used for all recovered artifacts. Information included a Lot Number and a mapping number that had been assigned in the field, along with basic description, measurements, and a sketch, either in 1:1 or 1:2 scale that was later added in the laboratory. In addition, the area from which the fragment was excavated, the registry date, and the identity of the excavator were also recorded to aid in the location of in situ photographs and diver's notes for later use.

[53] Appendix A lists every wood fragment by Wood Number, Lot Number, and notes those that were cataloged and photographed versus photographed only.

Some timbers, often made up of many fragments, could be temporarily reassembled and recorded as a unit (Figure 2.4).Therefore, in addition to recording each individual fragment, a second catalog sheet was created solely for laboratory use (Figure 2.3) to record each distinct timber.

Drawings

In another publication, *Wooden Ship Building and the Interpretation of Shipwrecks,* Steffy provides guidelines for recording ships' hulls, both as complete vessels and as individual timbers.[54] In short, Steffy's methodology for drawing timbers involves tracing each face of a timber on acetate sheets, either placed directly on the timber or placed on sheet glass supported on the ends and raised slightly above the timber.[55] Tracings are done in black waterproof ink, with timber features color-coded.[56] Due to the diminutive nature of the individual Kızılburun wood fragments, and in order to save precious budgetary resources, small fragments were recorded on overhead transparency sheets, while larger fragments and reconstructed timbers were recorded on more expensive 40 inch-wide acetate cut to appropriate sizes.

---

54 Steffy 1994.
55 Steffy 1994, 200-3. This technique was reportedly first used with the Skuldelev ships in 1962 (Crumlin-Pedersen 1977) and has been enhanced and better defined by Steffy. Other modifications are described by Harpster (2005, 53-61).
56 Steffy (1994, 202) suggests color-coding features, however, Harpster (2005, 57) discourages the use of colored inks as they tend to fade over time.

Kizilburun Roman Column Wreck **Artifact Catalog Sheet**

Lot number ______________ **KZ number** ______________ **Map number** ______________

Cataloged By ____________________________________ **Date Cataloged** ________________

Description (material, damage, corrosion, diagnostic features such as stamps, graffiti, tool marks):

Measurements (may include: length [L], height [H] or preserved height [PH], diameter [D] (often expressed as a minimum-maximum range), and thickness [TH] of toes, handles, necks, rims):

Sketch (include measurements):

Page _____ **of** _____

Figure 2.2. Artifact catalog sheet.

Kizilburun Roman Column Wreck--- Timber Summary Sheet

Mapping Number ____________

Reconstructed Drawing _____ Drawing Scanned _____ Added to Site Plan_____

Reconstructed Photo ______

Sampled _____ Genus/Species ID ________________________________

Function (if known) ________________________________

Orientation on Site ________________________________

Lot Numbers ________________________________

____

____

Max Dimensions

Length ________ Width (Sided) ________ Thickness (Molded) ___________

Features

Nails N Y #_____ Spacing _____ Other __________________

Mortise(s) N Y #_____ Spacing _____ Other __________________

Tenon(s) N Y # _____ Spacing _____ Other __________________

Other Features ____

____

____

____

____

____

____

____

____

____

____

Figure 2.3. Laboratory catalog sheet for hull wood.

Figure 2.4. Planking section 3007 being reassembled. Photograph by the author.

Steffy's method was adopted to record the wooden remains of the Kızılburun timbers and fragments. Proper alignment of the marker over the wood was maintained through the use of variously sized right-angle triangles with a small block of wood fastened to the lower edge for vertical and horizontal stability (Figure 2.5). By using the vertical edge of the triangle I was able to create a line of sight between the eye, the acetate, and the edge of the fragment, the goal being to keep the point of the marker directly over the edge of the timber being drawn in order to reduce the margin of error.[57]

[57] Alternative methods for maintaining proper alignment are described by Harpster 2005, 53-61.

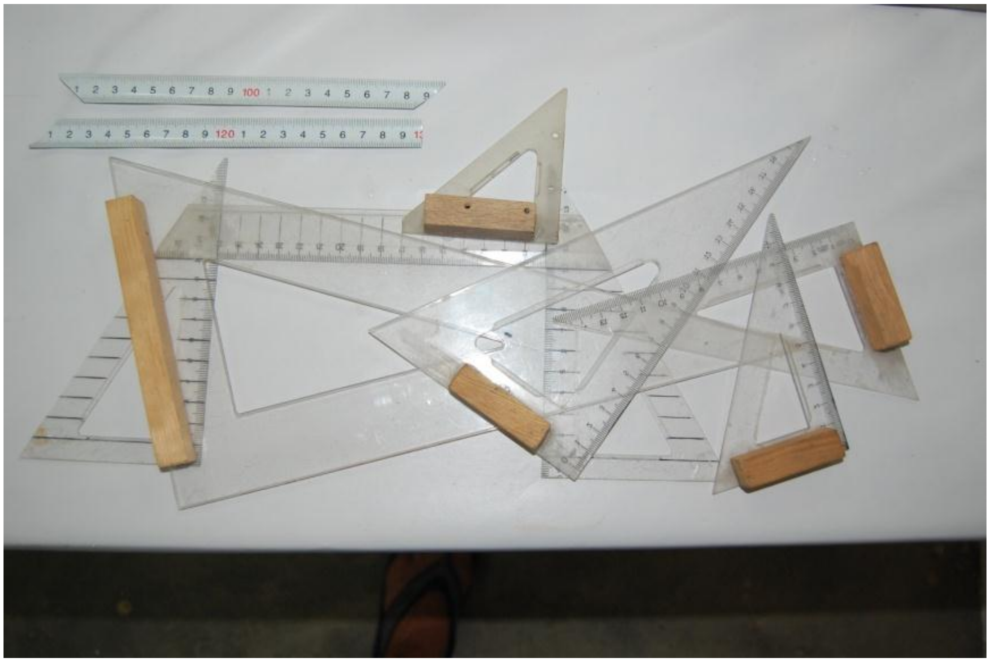


Figure 2.5. Tools adapted for recording timbers. Photograph by the author.

Colored, waterproof inks were used to record features such as fasteners, pegs, treenails, mortises, tenons, and drilled holes; alterations were made to the suggested color code provided by Steffy. Features are color-coded as follows: red for fasteners (both wooden and metal); blue for tenons/mortises; brown for original surface; green for pitch or tar. Pegs are defined by a red circled "X", while peg holes and peg hole remnants are defined by a red circle. Likewise, nails are defined by solid red lines where they are visible and broken red lines indicate the path of a nail through a timber as accurately as possible. This method was employed for recording individual fragments as well as reconstructed whole or partial timbers.

Recording re-assembled timbers

In some cases, especially with the nearly three-meter-long keel section and a number of frame pieces, individual fragments could be temporarily reassembled into more substantial timbers by utilizing a combination of notes, sketches, and in situ photographs.

The process of gathering these data for the reconstruction of a single timber often took days to locate, collect and evaluate before attempting to reassemble a timber section for final recording. In some cases, even with the best of notes and photographs, reassembly was impossible due to the fragmentary and discontiguous nature of the fragments, obscured or distant photographs, non-joining edges, or shortcomings of diver's notes.

The method described by Steffy works sufficiently well on complete or near complete timbers, even when they are broken. However, the Kızılburun remains are fragmented and discontinuous. Fragments are seldom more than 20 cm in length, but reconstructed timbers, although few in number, are often significantly greater in length. In order to facilitate the correct temporary 3-D reassembly of these fragments into a more complete timber, creative methods had to be utilized.

A long, shallow plastic container filled with tiny marble chips was used to support and align the timber fragments so that they could be recorded as a unit (Figure 2.4). These marble chips were chosen as they were easily form fitted under and around the fragments and offered more support than sand, which was also experimentally used. Further, the marble chips were more easily rinsed off the wood. This was a minor, albeit essential, adaptation that allowed accurate drawings and measurements to be produced. It further allowed for features such as nail spacing and mortise spacing to be measured or estimated more accurately. An illustrated catalog of reconstructed timbers follows in Appendix I.

Recording the keel

In the case of recording the vessel's keel, even with the aforementioned adaptive measures, initial results were less than satisfactory. Several attempts were made, but after recording one face and moving to another, timber fragments proved less stable and resulted in non-matching drawings between the different views of the keel. The lack of stability when turning or rotating the reconstructed keel timber was not only a product of it's fragmentary nature, but also its poor state of preservation. The keel does, however, have a relatively well-preserved, flat inner face. Consequently, recording methods were adapted once more by placing the timber's inner face on the glass to give the best alignment of the fragments in all three dimensions. This modification necessitated lying on the floor and recording the timber from below (Figure 2.6), while the molded face(s) was recorded by using an additional plate of glass mounted to 90˚ shelving brackets (Figure 2.7). In this manner the keel fragments were less susceptible to movement or misalignment, which resulted in a more accurate drawing.

The recording of the keel's profile also presented problems in that little of the original surfaces survive. At no point along the length of the keel does a distinguishable outer surface survive. Both molded surfaces of the keel section were also heavily deteriorated with very little of the original surfaces intact. The rabbets were partially preserved on each side of the keel, but in no single place do the rabbets survive on both sides simultaneously, making a keel profile very difficult to obtain. Profiles were produced with a device created using 30/60/90 degree triangles and a ruler to establish points of reference for measurements (Figure 2.8). Measurements were made at 5 mm intervals and plotted on millimetric graph paper.[58] In the end, 21 profiles were taken from the three-meter-long keel section, although most were concentrated in a section of approximately 125 cm long, and a composite profile was produced.

[58] More detailed areas were recorded at intervals of 1 or 2 mm as necessary.

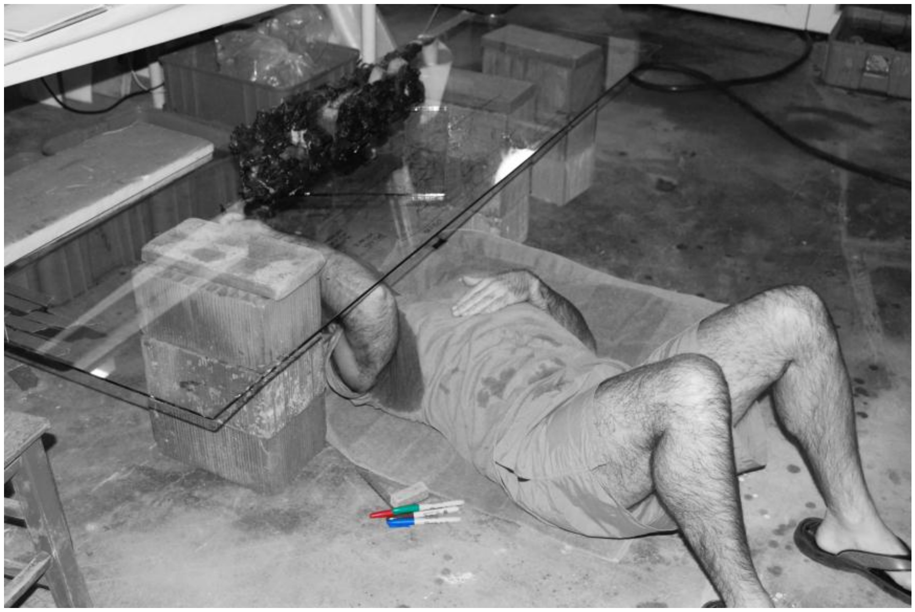


Figure 2.6. Recording the keel fragments. Photograph by Kimberly Rash.

Figure 2.7. Recording keel fragments using plate glass and 90˚ brackets. Photograph by Kimberly Rash.

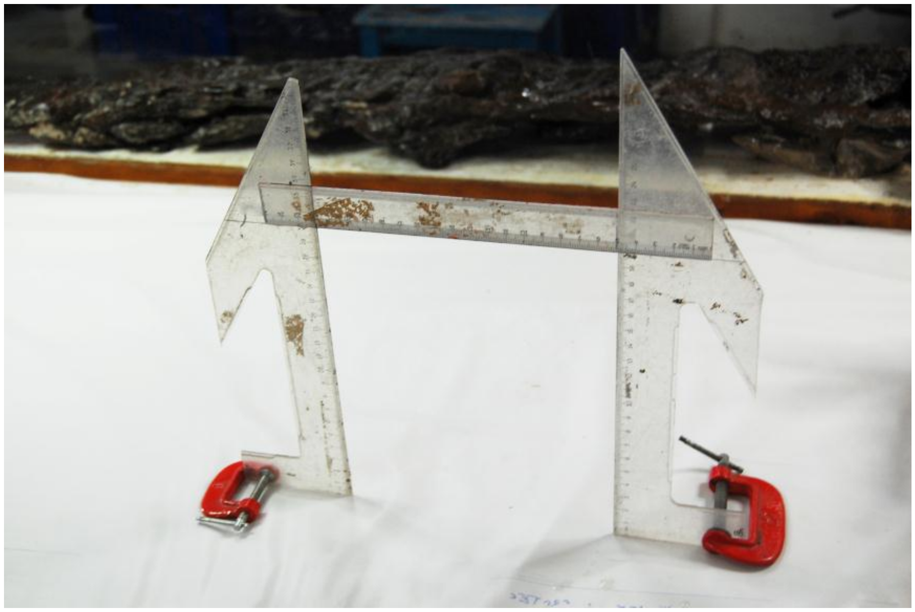


Figure 2.8. Tool for measuring timber profiles. Photograph by the author.

Three-dimensional modeling

For the sake of reconstruction and comparison, a three-dimensional (3-D) model of the keel was produced using *Rhinoceros 4.0* software. As Steffy explains, "your ship is a three-dimensional structure, so why not research it in three dimensions whenever possible."[59] If the 3-D reconstruction is a mold-and-batten model, or is computer generated, the ability to examine and disseminate data pertaining to the ship, in whole or in part, is a powerful tool in hull analysis. Often, incomplete components or features can be realistically recreated or re-constructed through the use of models. This was certainly true of several components of the Kızılburun ship.

By marrying extant dimensions of the keel sections, the keel's composite profile and rabbet angle measurements, minimum original dimensions of the keel were projected. This was necessary as the original molded surfaces of the keel do not survive at the same point

[59] Steffy 1994, 221.

anywhere along the three meter-long section, nor does the original outer face survive at any point. To further complicate the matter, the rabbet lines are eroded along most of its length making points of reference for projecting dimensions all the more difficult. Therefore, 3-D modeling was necessary in order to project or hypothetically reconstruct the original dimensions of the keel timber.

Both two-dimensional drawings and 3-D modeling were also employed to reconstruct the garboard strake using extant dimensions. The outer face of the garboard is completely devoid of original surface. Using the mortise depths and garboard width, the timber's minimum size was modeled. With both the keel and garboard digitally modeled, it was possible to place a drawing of a reconstructed frame over these elements to offer a hypothetical bottom hull shape. Three dimensional modeling is illustrated and discussed further in Chapter V.

CONCLUSION

In order to obtain as much information as possible from fragmentary hull remains, modifications to methodologies must be employed for the recording of timbers both in situ as well as in the laboratory. Limited remains do not necessarily mean all is lost when attempting to record a ship's construction features. Scant fragments do not negate the constructional and cultural information that can survive and be gleaned from close examination. By employing a variety of methods, modifying some standard methods and utilizing computer technologies, one can garner maximum data from minimal remains. Such is the goal of my examination of the wooden hull remains and fasteners of the Kızılburun vessel.

CHAPTER III
THE WOODEN HULL REMAINS

The wooden hull remains of the Kızılburun ship[60] are sparse, yet as Steffy noted, "The value of excavated hull remains has nothing to do with the extent of survival; it is the amount of information gleaned from each fragment which is important."[61] The paucity of hull remains and their level of preservation present countless enigmatic questions, some that remain unanswered, but others answered both in field and laboratory analysis. In the laboratory portion of the documentation process, approximately 800, mostly tiny wooden fragments from the wooden hull were recorded. Fragments of hull planking, ceiling planking, sections of frames, as well as a disjointed but contiguous segment of the keel have been positively identified among the extant timbers. No evidence for the mast step, assuming its existence, or portions of the vessel above the turn of the bilge has come to light. This is not particularly surprising as seldom are these portions of an ancient ship preserved.[62] The extant remains have suffered heavily from compression by the weighty cargo, two millennia of decomposition, consumption by marine organisms and disturbance by fishermen's nets and anchors. These facts do not negate the importance of detailed study of the remains. At the very least, this study confirms the continuation of many of the standard shipbuilding practices and designs used in the Aegean region from the Classical Period through the Hellenistic and early Roman Imperial Periods. At best, the study of this ship's remains offers a late Hellenistic example of a marble transporting ship for future comparison to Hellenistic and Roman marble carriers, presuming future discoveries of such, in a quest to define, or identify, the elusive *navis lapidaria.*

---

[60] A preliminary report on the Kızılburun hull remains was given at the International Symposium on Boat and Ship Archaeology (ISBSA 12) in November 2009, with a summary of that report published in 2012 (Littlefield 2012). Also see Littlefield 2011b.

[61] Steffy 1978, 53.

[62] Casson 1971, 210; Parker (1992a, 26) notes that at the time of publication hull remains of 189 Graeco-Roman vessels had been discovered. Of these, only 37 (less than 20%) retain at least some portion of a side of the hull.

Almost all of the wood that survives was located under or between the eight column drums, concentrated in four areas (U1, U3, U5, and U6) with a few sporadic fragments coming from areas U7 and U8 (Figures 3.1 and 3.2) (Table 3.1). There was little continuity of individual timbers, even among those that were presumably adjoined (e.g. a floor timber that crossed the keel may have had fragments on both sides of the keel, yet had no physical connection). In instances where elements such as framing or planking were contiguous, they were still broken such that individual pieces are seldom more than 20 cm in length. The most substantial timber excavated was the keel, retrieved in three relatively large sections, with at least 30 additional smaller fragments. Often, recording the timber fragments was only feasible in two dimensions and not always in the same two dimensions, further complicating the interpretation of a constructional puzzle with most of the pieces missing.

AREA U1	**AREA U2**
hull planking, fragments of frames	non-diagnostic frame fragments
AREA U3	**AREA U4**
hull planking, 3 frame fragments	non-diagnostic frame fragments
AREA U5	**AREA U6**
ceiling planking, frame fragments, hull planking	ceiling planking, frame fragments, hull planking
AREA U7	**AREA U8**
frame fragments	ceiling planking, frame fragment

Table 3.1. Surviving timbers by area.

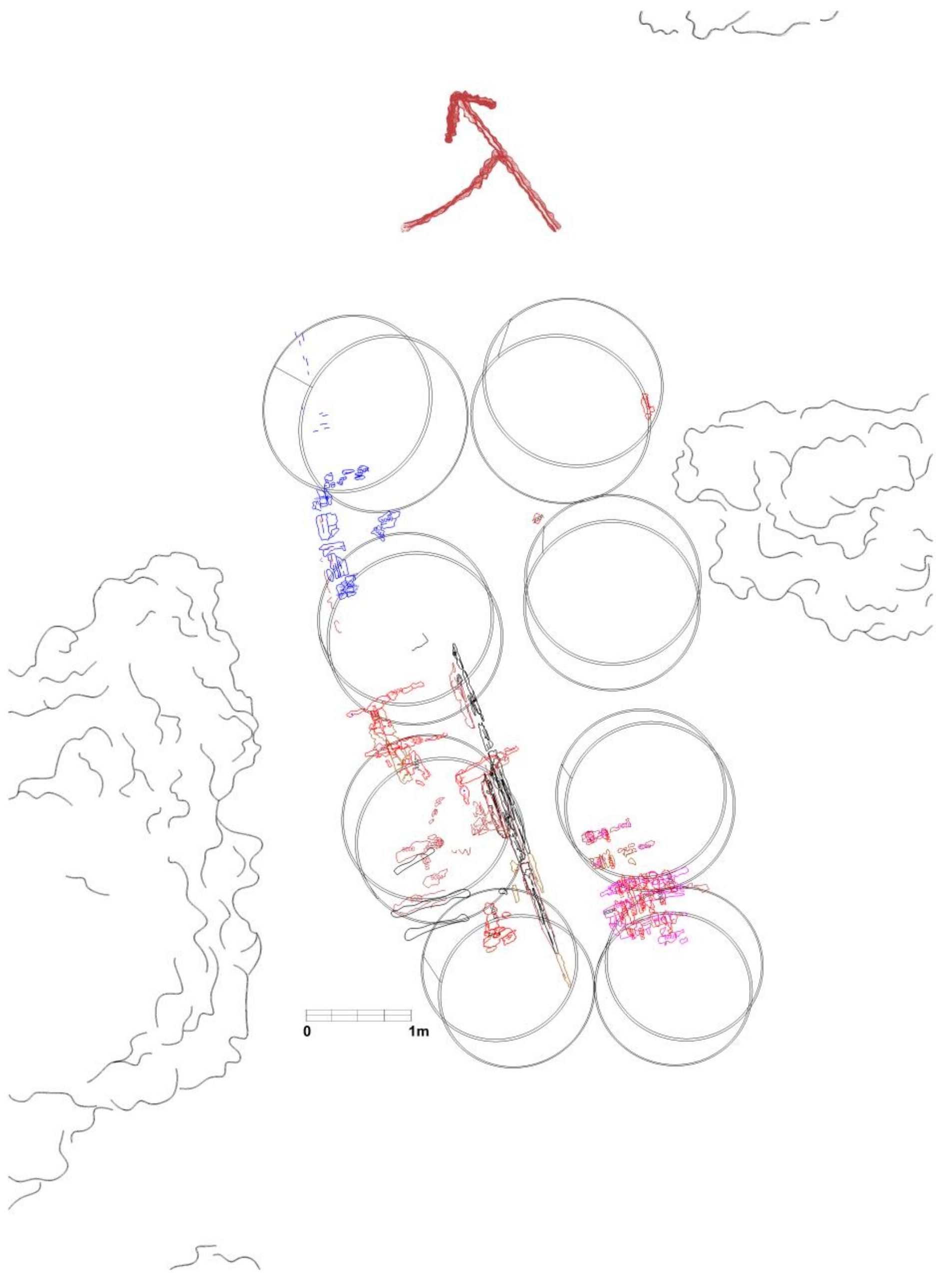


Figure 3.1. Timber fragments and iron anchor from Kızılburun with column drums superimposed. Site plan by Sheila Matthews and the author.

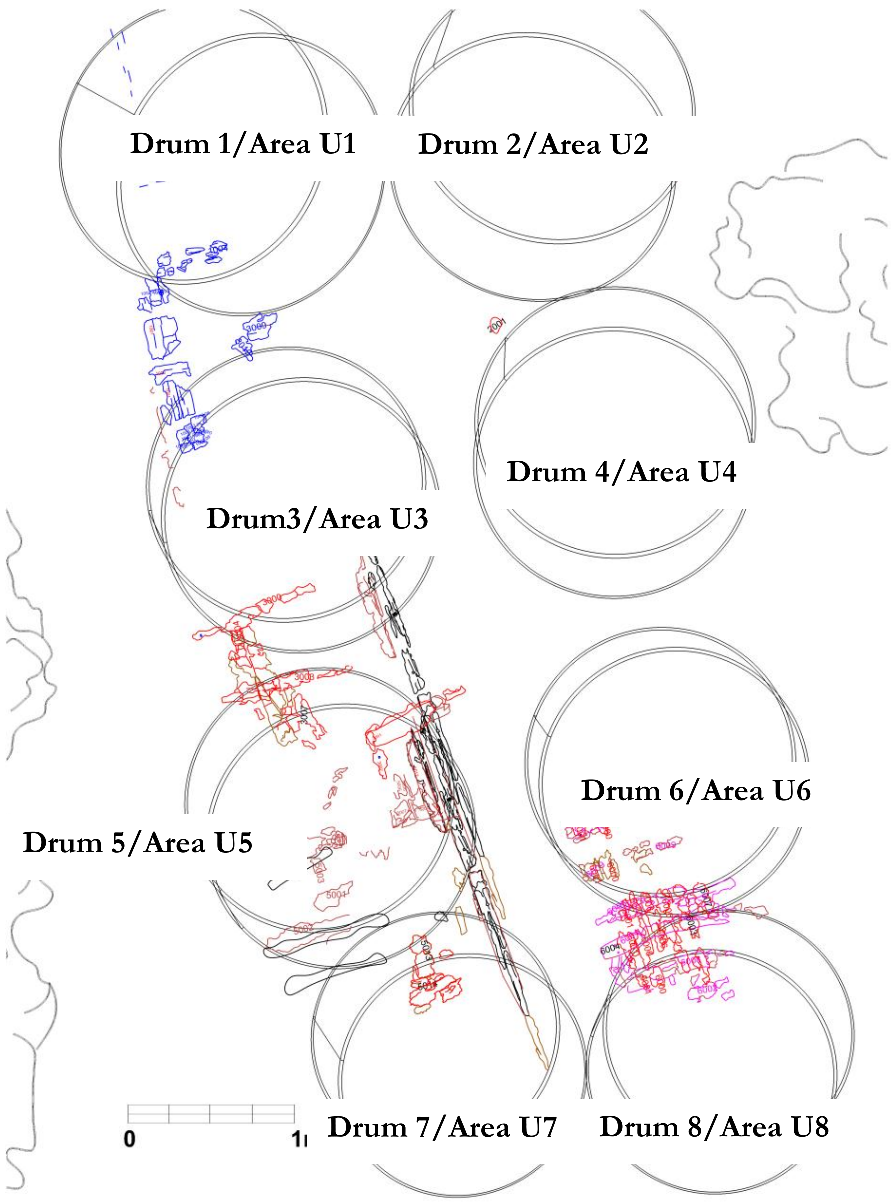


Figure 3.2. Detail of Figure 3.1. showing main concentrations of wood remains with column drums included for reference. Areas under the drums were named according to the corresponding drum after it was re-positioned off-site. Image by Sheila Matthews and the author.

Little of the hull's planking survives and almost all of the extant planking has been compressed by the concentrated weight of the marble cargo to the point that thickness measurements are skewed or invalid. Frame fragments have little extant original outer surface, making measurement of both molded and sided dimensions problematic. Despite these difficulties, each fragment was recorded individually and used in the reconstruction of more complete, but still partial timbers whenever possible. Measurements obtained from fasteners (discussed in Chapter IV) were helpful in determining or confirming minimum thickness of planking as well as frames.

In addition to hull components (i.e. hull and ceiling planking, a section of one garboard strake, frame pieces, and a section of the keel), diagnostic construction features were identified and as Steffy notes, these "lesser details all contribute to the study of a very important hull feature: the methods used by the shipwright."[63] Among these are a diagonal planking scarf, numerous pegged mortise-and-tenon joints, tool marks, and evidence to suggest a repair at some point in the life of the vessel. Additionally, species-level wood identification has been achieved allowing for a more thorough understanding of the choices made by the shipbuilder(s) in the construction process.

Analysis of the hull remains has demonstrated that the ship was constructed with shell-based methods using closely spaced, pegged, mortise-and-tenon joinery. Features such as planking thickness, frame spacing, and keel dimensions all appear small, but are relatively common when compared to contemporaneous vessels of similar size (see Chapter VI). This information corroborates many established features and methods of the period, lending credence to and adding to the collective corpus of data. On the other hand, several features or attributes have been discovered that help refine our understanding of shipbuilding and shipbuilders' personal choices. Wood type selection may prove to be one of these attributes, not only for contemporaneous vessels, but for vessels throughout antiquity. Taken together, these data give a clearer, if still incomplete picture of the ship that once transported a

[63] Steffy 1999, 165.

monumental marble cargo of the first century B.C.E.

KEEL

A longitudinal timber discovered in 2006 was initially thought to be a stringer due to its small transverse dimensions. In 2009 this timber was positively identified in situ as the keel owing to the presence of a rabbet. Only a portion of the overall keel survives; less than 3 m in three fragmentary, but contiguous sections along with numerous small disarticulated fragments (Figure 3.3).[64] Although this surviving keel section is relatively small when the potential overall length of the ship is considered, it is the single most substantial surviving timber. There is no evidence of a scarf in the extant keel and no remains of the stem or sternpost. It is also unclear if the keel was rockered, but no rockering is present in the extant timber. Evidence, in the form of three partial nails, suggests the use of a false keel or shoe attached to the bottom of the keel, although the actual timber does not survive.[65] The nail fragments literally disintegrated upon lifting the timber from the seafloor and reassembly of the fasteners was impossible. Consequently, it is not possible to comment on the thickness of the false keel beyond that it was at least 1-3 centimeters thick, presuming its existence.

[64] A fourth section survives (L952) that was accidentally broken from the main timber in 2006 and being heavily damaged could not be definitively joined to the other sections. This section is 39.4 cm in length and lacks any diagnostic features with the exception of a consecutive pair of degraded tenon peg holes, each 1.0 cm in diameter and with center-to-center spacing of 10.4 cm.

[65] False keels are seen on the Ma'agan Mikhael ship (Kahanov 2003, 58-63, figs. 13, 17, 19, 20, 21), the Kyrenia merchantman (Steffy 1994, 43, 54) and the Herculaneum boat (Steffy 1985a, 520). Theophrastus, writing in the late fourth to the early third century B.C.E., describes the wood types used for false keels (5.7.2-3; 5.8.3) suggesting their use was common for merchant ships. Pollux, writing in the second century C.E., defines the term (1.86), "That which is nailed to the underside of the keel as a finishing piece so that the keel will not get rubbed is called the false keel (*chelysma*)."

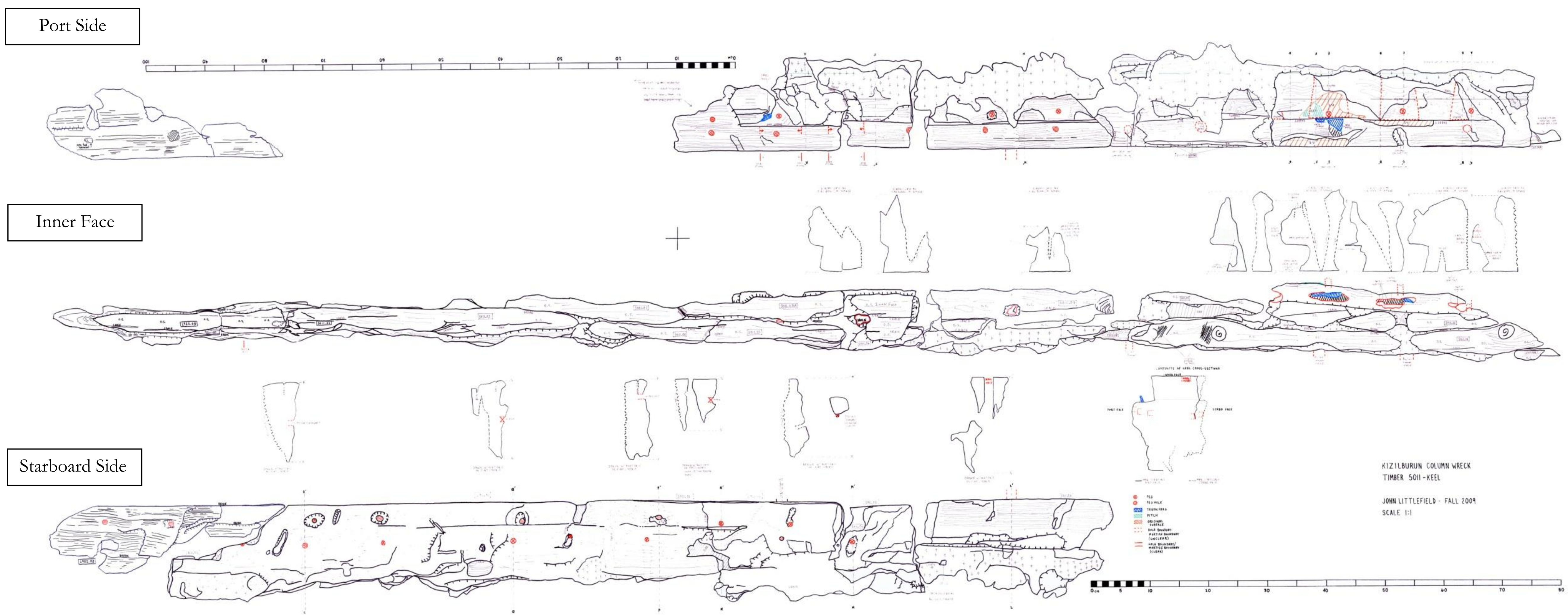


Figure 3.3. Extant keel section. Drawing by the author.

The lower portions of the keel, below the bearding lines, are heavily deteriorated, worm riddled and retain virtually no original surface. The upper portion survives in a better, albeit still degraded, condition. The garboard strakes had mostly disintegrated. A 62 cm-long section does survive (discussed below) on the presumed port side of the keel, yet was disarticulated as all the mortise-and-tenon joinery had been consumed, leaving the rabbets open to deterioration processes as well. Along most of the length of the extant keel the two rabbets are preserved in various states, with a small section (5011.05/05A/25) of presumably *nearly* complete rabbets surviving simultaneously. However, at no point do the two rabbets survive simultaneously and completely. In fact, at no point is either rabbet complete. There is always a degraded section, whether in the rabbet surface or the back rabbet surface.

Rabbets and cross-sectional profile

From the aforementioned keel fragment the first cross section was taken and found to be lacking sufficient preservation to produce an accurate profile. Due to its incomplete and degraded nature, particularly below the bearding lines, a series of 21 cross sections were taken from various stations along the length of the timber and a composite profile was created (Figure 3.4). This was aided by a score mark (Figure 3.5) that was observed in the port-side rabbet of a keel fragment (5011.09) approximately 17 cm in length and protected by a small fragment of the garboard that was still in place. In order to ascertain the accuracy of the dimensions, this score mark was utilized as a point of reference to produce composite measurements where direct measurement was not possible and subsequently transposed to other sections for measurement as possible.

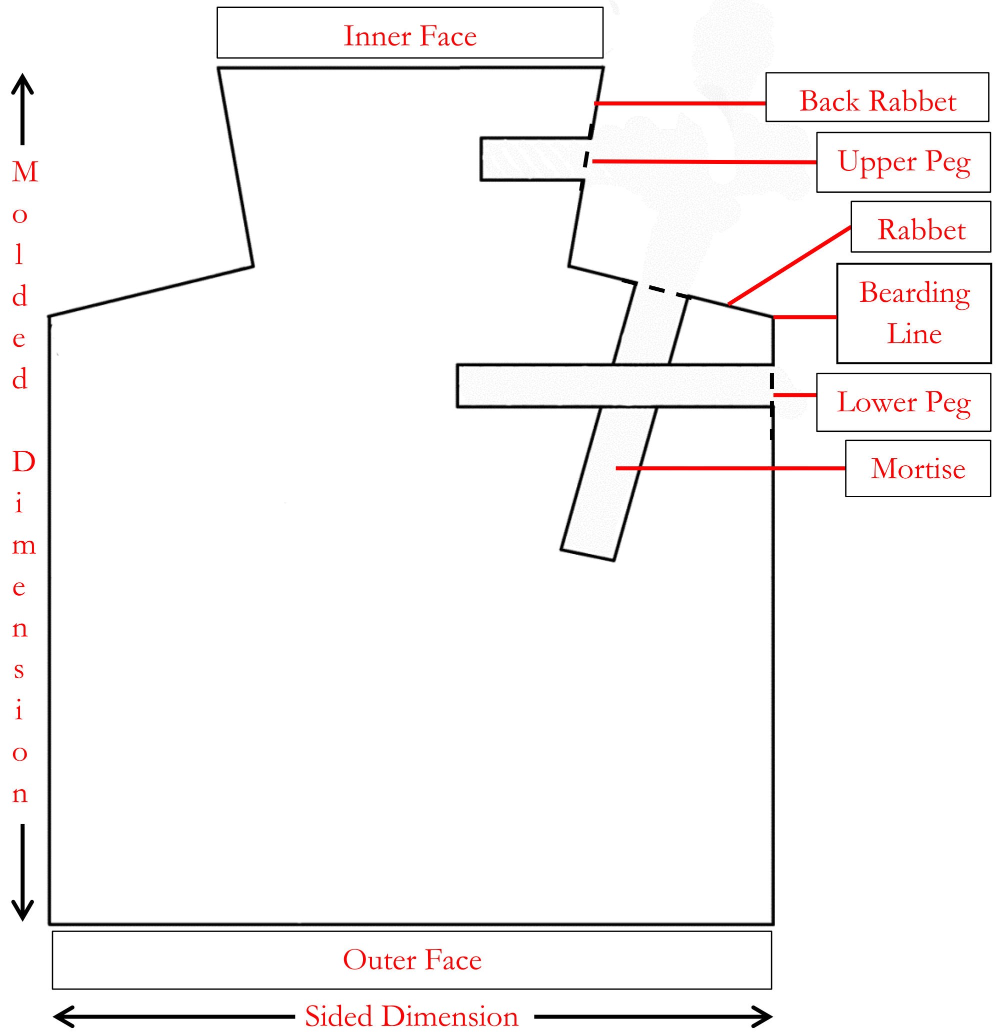


Figure 3.4. Keel features, in profile view. Image by the author.

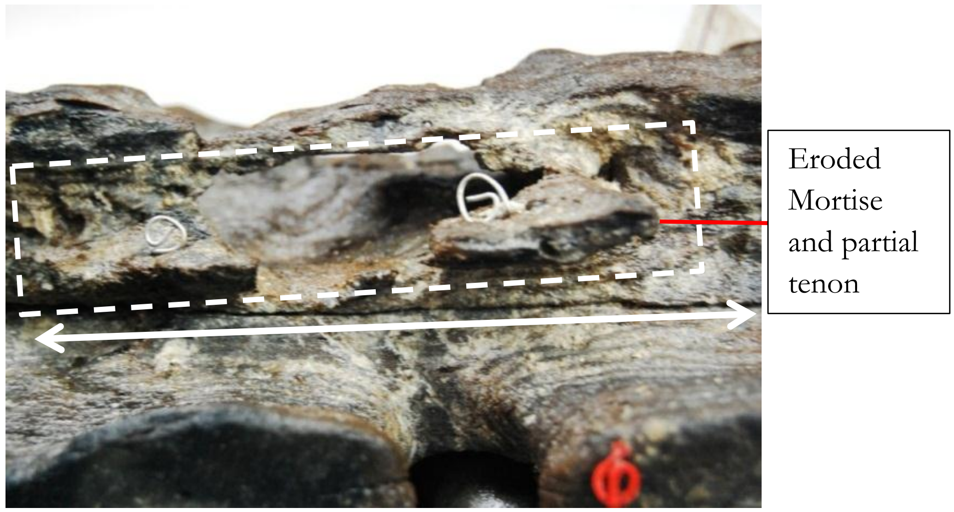


Figure 3.5. Score mark in rabbet of keel. Photograph by the author.

At multiple points along the length of the extant keel it was possible to determine both the shape and angles of the rabbets in relation to the keel's flat inner face. In several places it was also possible to record the back rabbet height, which ranges from 4.3-5.0 cm. The rabbet surface dimension has been more challenging to determine due to the erosion of the surface along most of length of the keel sections at or below the bearding line. In fact, only a tiny amount of original surface from the keel below the bearding line survives on the presumed port side. However, several valid measurements of the rabbet width range between 4.0 and 4.5 cm. One of these measurements, 4.5 cm, was obtained from the rabbet line to a drafting triangle extending the surface of the lower portion of the keel where a small spot of pitch is retained, which established original surface on the keel's molded face. These figures correspond well with the nail breakage pattern (discussed in Chapter IV), thus substantiating a rabbet width and garboard thickness measurement of 4-5 cm.

Dimensions

At various points along the length of the keel, the inner face appears complete or near complete, having a width of 8.3 cm. The inner face dimension does not reflect the total sided dimension of the timber due to the removal of some wood to form the rabbets. The maximum surviving sided dimension (width) is 12.1 cm and the maximum extant molded dimension (height) is 18.3 cm.

Using the measured angles of the rabbets and back rabbets, the surviving dimensions of the flat inner face and the incised rabbet line as references, along with the maximum extant dimensions, I was able to extrapolate the minimum original sided dimension of the keel as 14.9 cm at the bearding line (the widest point of the keel) using a combination of hand-drawings and *Rhinoceros* 4.0 software. It was not possible to determine anything more than the maximum surviving molded dimension of 18.3 cm due to the lack of any existing original surface of the outer face (Figure 3.6).

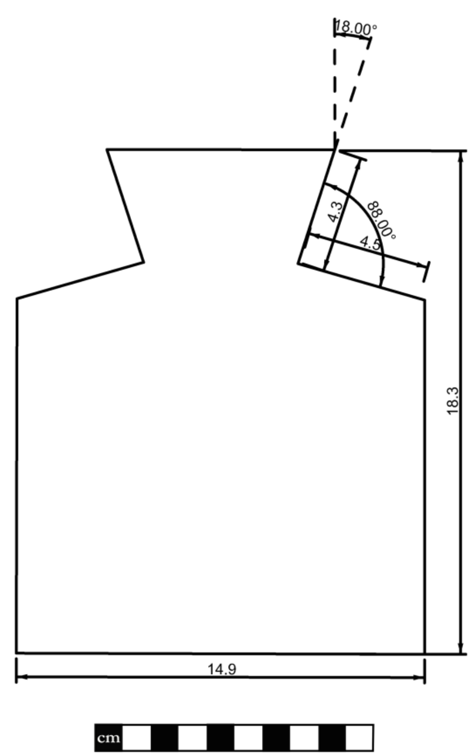


Figure 3.6. Keel profile. Image by the author.

Mortise-and-tenon joints of the keel

Mortises were placed centrally in the rabbet surface, with no horizontal staggering. Ten whole or partial mortises survive in the preserved portion of the keel, along with several partial tenons. Mortise widths were recorded in five places and average 5.8 cm. A depth of 5.1 cm was obtainable from only one mortise. In all mortises, the original edges have worn away so the smallest measurement was used. Three mortises retained usable thickness dimensions of 0.6, 0.7, and 0.75 cm, with tightly fitted tenon fragments surviving in two of these three mortises. Tenon fragments also survived in two other mortises that were much more decayed. These had an average thickness of 0.7 cm.

Tenons were held in place by tapered pegs (Figure 3.7); 17 surviving examples have an average peg diameter of 0.91 cm (Table 3.2). These pegs are not round, but faceted, having been shaped with a knife or similar tool.[66] In addition to the 17 extant pegs or peg fragments, 10 peg holes were identified that no longer retain pegs. Using the information from the pegs and peg holes, 17 tenon spacing measurements were collected, ranging from 11.2 to 12.6 cm with an average of 11.7 cm. Dimensions and measurements of mortises, tenons, and pegs taken from the keel are compared to those obtained from the planking in the *Mortise-and-tenon joints in the planking* section.

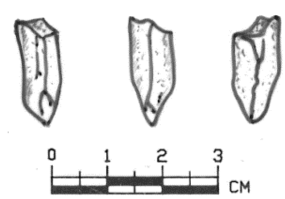


Figure 3.7. Tapered peg fragment from keel section 5011.06. Drawing by the author.

[66] For example, the use of faceted tapering pegs was definitively shown in the earlier Kyrenia ship (Steffy 1985b, 72; 1994, 46) as well as in the Laurons 2 vessel (Gassend et al. 1984, 91).

Keel Fragment	Diameter (cm)	Distance to Seam (cm)
5011.05A/25	1.0	
5011.05A/25	0.9	
5011.05A/25	0.9	
5011.05A/25	0.9	
5011.05A/25	0.8	0.8
5011.05A/25	0.8	0.8
5011.05A/25	0.8	2.1
5011.05	1.0	1.1
5011.05	0.9	1.2
5011.05	0.9	1.9
5011.05	0.9	1.7
5011.06		
5011.07	1.0	1.1
5011.07	0.9	1.3
5011.07	1.0	1.5
5011.07	0.9	1.2
5011.08	0.9	
5011.08	0.9	
5011.08	1.0	
5011.09		
avg.	0.91	1.3

Table 3.2. Keel tenon-peg data.

In all cases where pegs or peg holes were discernible in the keel, the upper pegs were driven into the back rabbets parallel to the inner face of the keel. The lower pegs were likewise driven into the keel's molded faces at an angle parallel to its inner face. An unusual and possibly unique feature is observed in the placement of the tenon pegs; they are consistently staggered along the vertical central axis of each tenon when viewed from the molded faces. This occurs in over 90% of mortise stations that have discernible pegs or peg holes, and always in the same orientation regardless of which side of the keel is viewed. The upper peg is always placed to the right of the central axis (Figure 3.8). This feature may have been employed to prevent possible splitting of the tenon, but may simply be the habit of a particular shipwright with no functional purpose. Staggered placement of tenon pegs is seen in at least one other ship, the fifth century C.E. Dramont E wreck, yet there the pegs are staggered randomly.[67]

Figure 3.8. Staggered peg holes in the keel. Photograph by the author.

[67] Santamaria 1995, 140 figs. 137- 138, 141 figs. 139, 142, 145.

FRAMES

As Steffy mentions, "Frames are the most important group of timbers to be recorded for most ships. They describe the curvature of the hull and are the primary indicators of a vessel's strength, design and technological status."[68] At least 12 partial frames have been identified, but even this information is tentative as several fragments are clearly extensions of the same frame, but lack physical connection owing to poor preservation on the seafloor. Many of these associated sections were located on the same side of the keel, but were disjointed and separated by missing sections. This may have been due to breakage of a timber caused by the cargo, blunt trauma sustained since the wrecking, or biological degradation. Frame identification was based on two features; the retention of clenched nail fragments and the orientation of the timber on the seafloor (e.g., east-west or transverse timbers). In almost every case this identification was supported by the nearly homogenous use of a single wood type for framing components (discussed in Appendix III).

Framing pattern

In Graeco-Roman shipbuilding, the standard framing pattern is a combination of floor timbers alternating with half frames.[69] However, it is unclear if the shipwright used full frames (ribs), floors alternating with half-frame, or some unprecedented design, as only sporadic sections and fragments of the lowermost portions of the hull survive. It may still be possible to comment on the framing system based on two bits of information suggestive of a floor alternating with paired half-frames pattern. First, three frame sections; 3001 (Figure 3.9), 5000 (Figure 3.10), and 8000 (Figure 3.11) are likely floor timbers as evidenced by the widening of their molded dimension as they approach or reach the keel. However, none of these timbers extend beyond the middle of the keel in their current preserved state and therefore cannot be definitively labeled as floors. Secondly, frame 6004 terminates in a clean cut edge on its inboard end, suggesting it is a futtock. If 6004 is a futtock, its position in the hull is unusual as its inboard end is much too close to the keel for a standard futtock and its method of fastening to a presumed floor is suspect as well. However, it is not

[68] Steffy 1994, 210.
[69] Fitzgerald 1995, 33; Steffy 1994, 65, 67, 72.

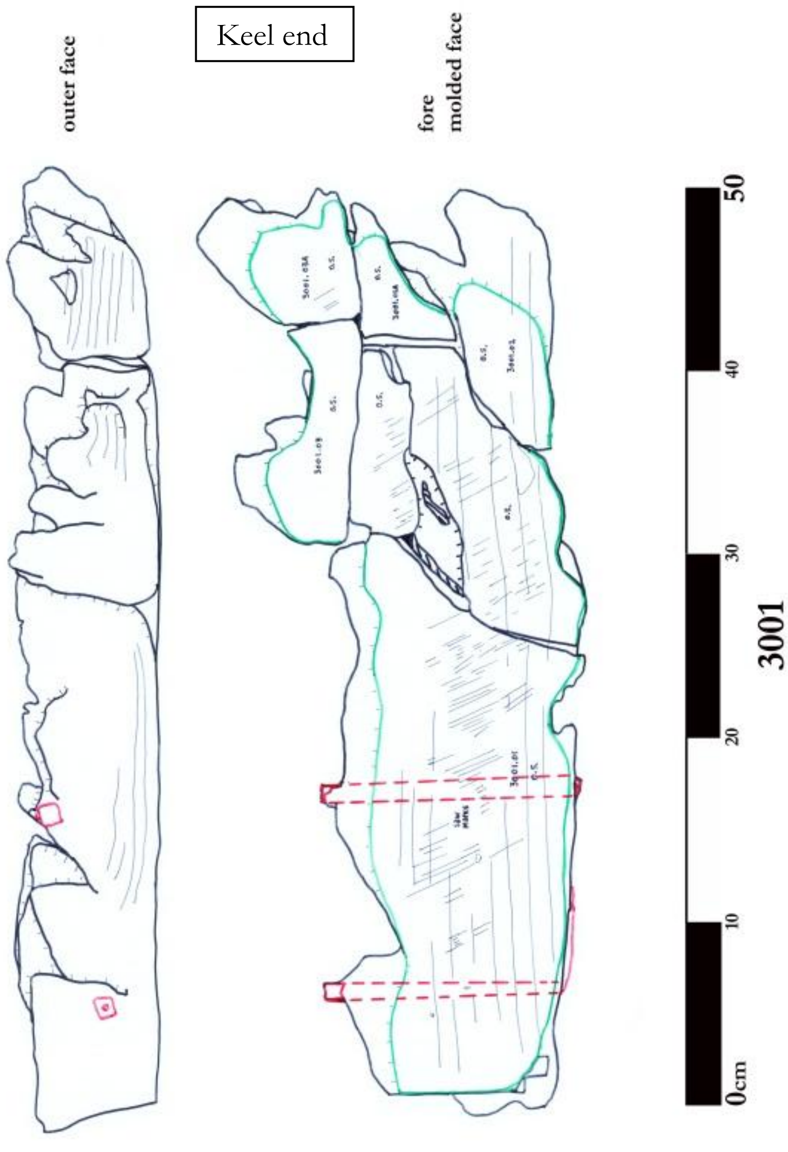


Figure 3.9. Frame 3001 showing sculpted shape. All frame drawings were made as the timber was found with the forward molded face up. Often not all pieces could be placed correctly for drawing and had to be omitted from some views. Drawing by the author.

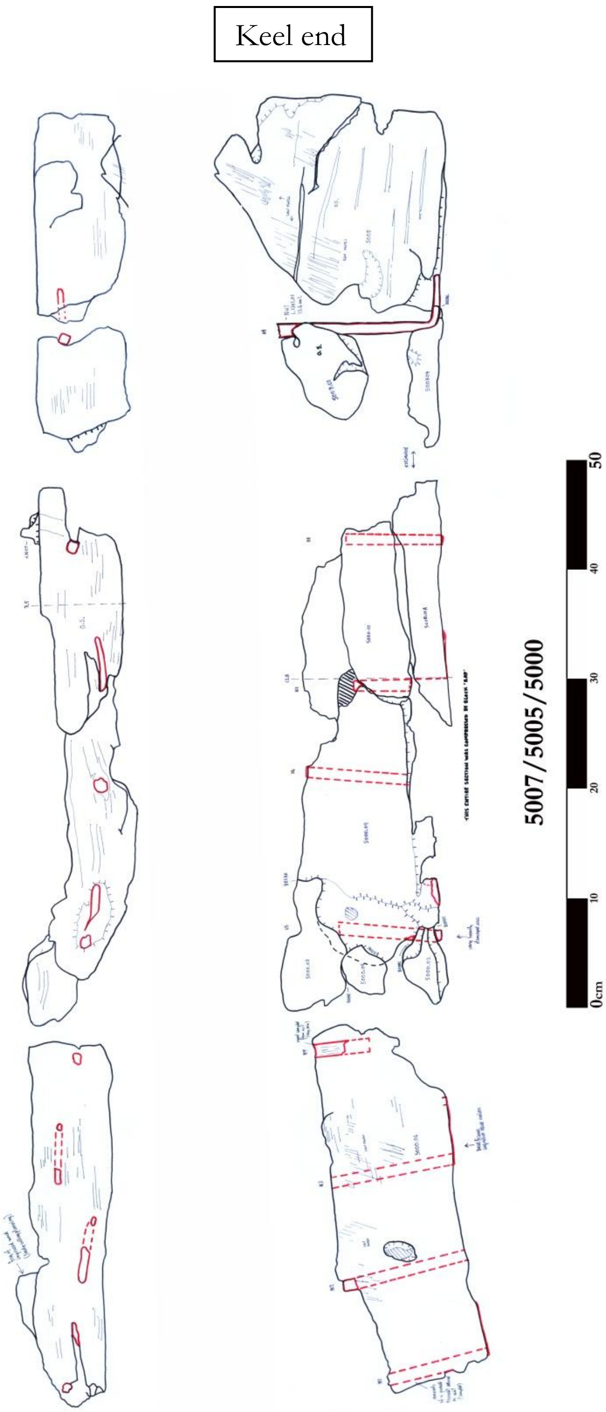
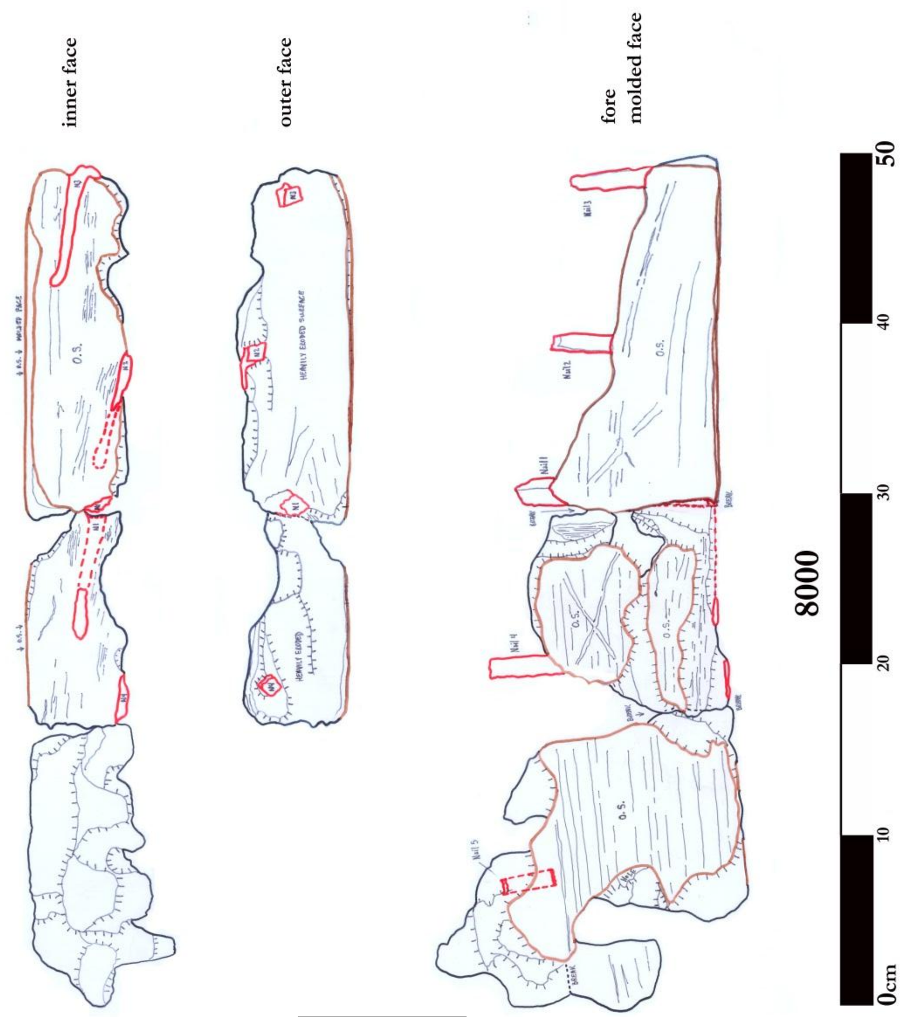


Figure 3.10. Frame 5000/5005/5007 showing sculpted shape towards the keel. Drawing by the author.



Keel end

Figure 3.11. Frame 8000 showing increased molded dimension towards the keel. Drawing by the author.

unprecedented to have futtocks that are not attached to floors, yet this timber has two vertical holes at its inboard end that suggests it was attached to something. These holes retain no cupreous fastener or their corrosion products, nor do they retain any fragment of a treenail or dowel. Vertically placed fasteners for connecting futtocks to floors would be an unprecedented method of joining the two, since no known examples for this seems to occur on other ships. Additionally, no joining floor timber or half-frame was present, making the identification of this timber as a futtock questionable. For now, although somewhat problematic, identifying this timber as a futtock seems to be the best explanation.

Displacement of frames from planking

During excavation, all frames were found with their forward molded side up, strongly suggesting that the frames broke away from the planking and toppled 90º onto their aft molded faces in a downslope direction (Figure 3.12) as suggested by several factors. First, at the time of discovery, all transverse timbers that retained clenched nails were found with the clenched portions oriented downslope. This orientation suggested these transverse timbers may have served some unusual purpose, and thus were something other than frames, possibly a pallet system for supporting the column drums.[70] However, the widths of the preserved frame impressions on the planking do not match the width of the transverse timbers as found, but do correspond to their widths if these timbers are oriented with their nail clenches in an inboard orientation.

Second, the pattern of nail breakage (discussed in Chapter IV) corresponds to the thickness of the planking, which suggests that the frames sheared off from the planking. This breakage most likely occurred at the time of the ship's impact with the seafloor, but the frames may have been displaced at some later date when the deteriorating hull gave way under the substantial weight of the cargo. The sequence of this breakage is illustrated in Figure 3.13.

---

[70] This idea was suggested by Carlson and Atkins (2008, 25) as one possible explanation for the orientation of the timbers on the seafloor, and was subsequently reported as such by Richardson (2007, 76).

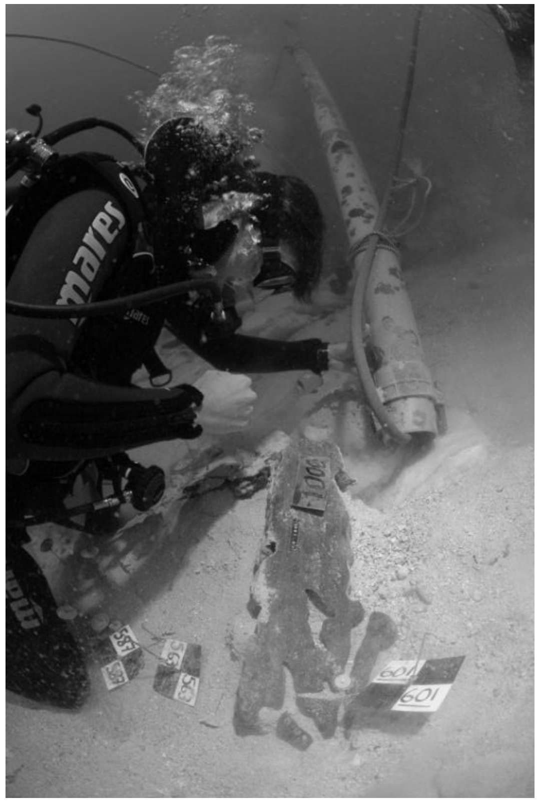


Figure 3.12. Deborah Carlson excavating timber 3001. Tag 601 marks the keel end of the timber. Photograph by Don Frey.

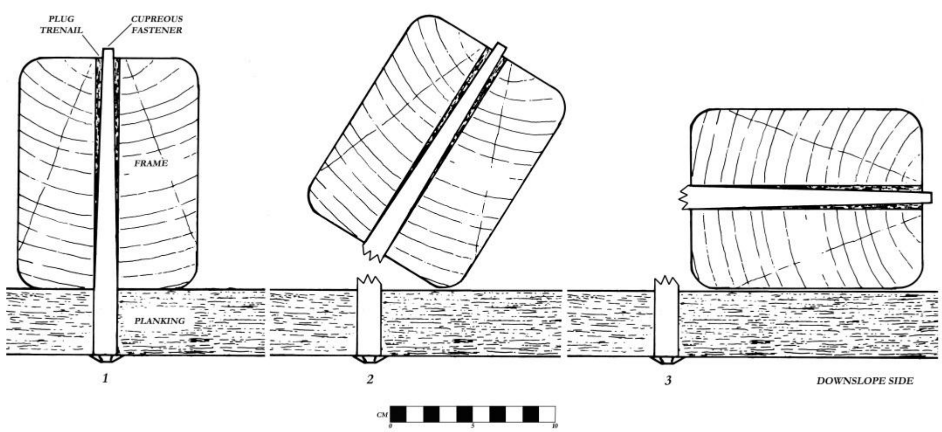


Figure 3.13. Sequence of frame/planking separation. Image by the author.

Dimensions

There are several aspects to keep in mind when trying to determine original molded and sided dimensions of the frames. The edges of the inner face appear to have been slightly rounded, making their now deteriorated edges more difficult to define. The purpose of rounding the edges is not easily explained as the effort would be more labor intensive, yet doesn't seem to serve an obvious function. If the edges were rounded it was not the result of using halved or quartered timbers as the frame fragments exhibit more squared surfaces. It is possible that the edge rounding is the product of some unintentional process or processes such as biodegradation, but from my observation, the rounded edges appear to have been deliberate, likely to prevent splintering.

Next, few fragments retain their full dimensions due to biological consumption and degradation. Therefore, the sided dimensions of the frames have been taken from impressions on planking. The measurement obtained was 8.9 cm. This may not be representative of the full dimension due to the possibility of rounded edges on the outboard face of the frames. If the outer face edges were rounded, one would expect the full sided dimension to be greater by as much as 1-2 cm. Therefore, one consider the maximum surviving dimensions of individual fragments and compare those to the impressed frame dimension of 8.9 cm. By considering all these factors a reasonably accurate average sided dimension of 9.9- 10.9 cm is obtained for testing against other evidence.

Other factors that need to be considered are deformations caused by compression and torsion. At this point I cannot offer a proper explanation, but many of the frames do not appear to have been compressed in the same manner as most of the planking. When frame pieces are viewed in cross-section and tree-rings are discernible, the rings do not exhibit signs of obvious compression, although it is possible that minor compressions are not always visibly evident. In some cases, some deformation due to torsion was visible, particularly in timbers 5001/5002 and 6008, which made most measurements from these timbers less useful, save for those involving nail spacing.

Seven frame timbers offer sided dimensions that may be compared with the 8.9 cm figure taken from the planking impressions; those frames are 3000, 3001, 5000, 6002, 6004, 8000, and 5017 (Table 3.3). The sided dimensions range between 6.7 and 9.2 cm depending upon the level of frame preservation. The maximum surviving sided dimension of the frames is 9.2 cm, yet no obvious original surface of the aft molded face survives. Presuming that a frame had a somewhat consistent original sided dimension, the original dimension is likely to be slightly greater. Given the frame impression of 8.9 cm and accounting for the possibility of added width due to rounded edges of the frame, an original sided dimension of 10-11 cm for the frames seems feasible. Therefore, evidence suggests frame widths range between the 9.2 cm figure obtained directly from surviving frame fragments and the projected figure of 11 cm.

Molded dimensions are somewhat more difficult to define as at least some of the frames (presumably floors) were sculpted to become wider at or over the keel. Here we are forced to rely on maximum surviving dimensions. Timber 6004, which *may* represent a futtock, has a maximum width at the cut inboard end of 10.0 cm (Figure 3.14), while timbers 3000, 3001, and 5000 have maximum outboard dimensions of 10.5, 12.3 and 13.6 cm, respectively. The most telling, however, may be timber 5017, which is a disjointed outboard fragment of timber 5000 on the presumed port side of the keel. Measurements obtained from this 63 cm-long fragment are 12.6 cm on the inboard side and 13.1 cm on the outboard end. If timber 5000 is a floor, then the combination and reconstruction of 5000, joined with 5017, is a representative frame from the vessel (discussed in Chapter V).

To summarize what can concluded about the dimensions of the ship's frames, the sided dimensions originally average 9.2-11 cm, while the molded dimension on presumed floors increases from outboard to inboard, starting at 10-13 cm and widens to more than 21 cm at or over the keel, while molded dimension on presumed half-frames range between 10 and 13 cm.

Figure 3.14. Frame 6004 showing cut end. Photograph by the author.

Frame spacing

Two frame impressions left in a small section of planking (3007) suggest a center-to-center frame spacing of approximately 25 cm. The measured distance between the frame edges of the impressions is 14.6 cm. When this figure is added to the sided dimension of the frames (1/2 width [9.2-11 cm] x two frames), we arrive at a figure of 23.8 to 25.6 cm. This figure is supported by evidence of rows of in situ nail heads (discussed in Chapter IV) and should be representative of the greatest portion of the vessel as the in situ nails heads were grouped across areas 19/20, just forward of Area U1 where the planking section with frame impressions was uncovered. Additionally, separate rows of nails, although fewer in number, were found in Areas U7/U8; several meters downslope from the other groups and also support the average frame spacing of 25 cm.

Frames						
Timber	**Sided (w)**	**Molded (h)**	**Nail sp. inner**	**Nail sp. outer**	**Wood species**	**Notes**
1000	3.8	10.0	6.0	7.3	*Fraxinus excelsior*	2 nails
3000	6.8	10.5	9.3	9.2	*Fraxinus excelsior*	8 nails
3001	8.1	12.3-19.4	11.0	10.4	*Fraxinus excelsior*	2 nails
3003	6.6	15.9	9.0	7.5	*Fraxinus excelsior*	6 nails
3009	4.3	11.2	5.7	n/a	*Fraxinus excelsior*	4 nails
3013	3.6	2.8	n/a	n/a	*Fraxinus excelsior*	1 nail
4000	4.6	2.6	n/a	n/a	*Fraxinus excelsior*	0 nails
4002	4.0	5.5	n/a	n/a	*Fraxinus excelsior*	1 nail
4003	5.7	4.1	n/a	n/a	*Fraxinus excelsior*	1 nail
5000/5003/ 5005/5007	8.6	13.6-21.4	10.9	11.2	*Fraxinus excelsior*	10 nails
5001/5002	9.8	16.1	8.2	7.8	*Fraxinus excelsior*	6 nails
5009	8.6	7.2	n/a	n/a	*Fraxinus excelsior*	4 nails
5010	5.9	3.4	n/a	n/a	*Fraxinus excelsior*	0 nails
5014	5.1	17.6	10.2	n/a	*Fraxinus excelsior*	4 nails
5017	9.2	12.8	10.0	11.2	*Fraxinus excelsior*	7 nails
5018	10.0	8.1	10.0	n/a	*Fraxinus excelsior*	2 nails
5020	7.9	13.9	8.3	8.8	*Ulmus campestris*	7 nails
6002	6.7	10.2	7.1	9.6	*Fraxinus excelsior*	2 nails
6004	6.9	13.0	9.1	8.4	*Ulmus campestris/ Fraxinus excelsior*	7 nails
6005	5.9	14.6	9.6	9.2	*Fraxinus excelsior*	8 nails
6008	5.5	12.4	8.4	9	*Fraxinus excelsior*	6 nails
6009	n/a	10.3	10.9	11		5 nails
6010	6.1	11.0	n/a	n/a	*Fraxinus excelsior*	2 nails
6018	7.6	8.0	n/a	n/a	*Fraxinus excelsior*	1 nail hole
7001	4.3	5.1	n/a	n/a	not sampled	1 nail
8000	8.6	18.0	9.5	9.5	*Fraxinus excelsior*	5 nails
		avg	9.20	9.29		

Table 3.3. Frame data.

Frame-to-keel fastening

No frame impressions are discernible on the inner face of the surviving keel sections, suggesting that frames did not touch the keel and were not regularly affixed to it. This may be significant as comparanda suggests that this is the trend in Graeco-Roman ships from the fifth century B.C.E through the first century B.C.E.[71] After the first century B.C.E. frames begin to be sporadically or occasionally fastened to the keel with nails and/or bolts.[72]

However, there is one clear nail hole of 1.5 cm square section preserved in keel fragment 5011.07 (Figure 3.15). This fragment of the keel was located in the area from which presumed floor 5000 was excavated. Due to heavy decomposition of keel fragment 5011.07, the nail hole is indefinable below the surface of the inner face, making it impossible to discern with certainty the direction from which it was originally driven. However, given the size of the nail hole in comparison to extant large nails from the wreck (discussed in Chapter IV), it was likely driven from the inner face of the keel. No nail head or shank fragment(s) could be positively associated with the nail hole. There are possibly at least two other nail holes with poorly defined edges in the keel, One of these non-diagnostic nail holes is in section 5011.08, which *may* be associated with frame 3001; the second is in section 5011.05 and *may* be associated with frame 5001. Additionally, there are several breaks in the preserved portion of the keel that could have accommodated nails. When viewed as a whole from the keel's inner face, these possible nail holes and potential nail stations do not seem to form a recognizable pattern (Figure 3.16) such as one might see if floor timbers were regularly nailed to the keel.

---

71 Other wrecks in which frames were not connected to the keel include the fifth century B.C.E. wreck at Ma'agan Mikhael (Kahanov 2003, 54), the fourth century B.C.E. wreck at Kyrenia (Steffy 1985b, 85; 1994, 43, 52, 54), the third century B.C.E. wreck at Marsala (Frost 1981, 249), and the second century wreck at La Roche Fouras (Joncheray 1976, 112). The wreck at Cavalière also shared this trait (Charlin et al. 1978, 72, 73 fig. 50) and is contemporaneous with the Kızılburun vessel.

72 The Kinneret (Steffy 1990, 35) boat and the St. Gervais 3 vessel (Pomey et al. 1988, 13), both of the first century C.E., as well as the second century C.E. Laurons 2 (Gassend et al. 1984, 98) ship each had some frames fastened to the keel with nails, while the large first century B.C.E. ship at Madrague de Giens (Tchernia et al. 1978, 80-1) had frames bolted to the keel as did the first-century Alexandria A vessel (Steffy, unpublished) and the fourth century C.E. vessels of Fiumicino 1 (Bonino 1989, 43) and Yassı Ada (van Doorninck 1976, 124).

Figure 3.15. Nail hole in keel. Photograph by the author.

Floor timber 5000 has nails spaced at regular intervals as it widens approaching the keel. It is devoid of any fasteners in its widest portion, showing a break in the nailing pattern that otherwise averages 9.3 cm from center-to-center on the inner face. This suggests the lack of regularly placed fasteners between the frames and the keel. Therefore, the function of the square-sectioned nail hole, as well as several other possible nail holes in the keel, remain undefined.

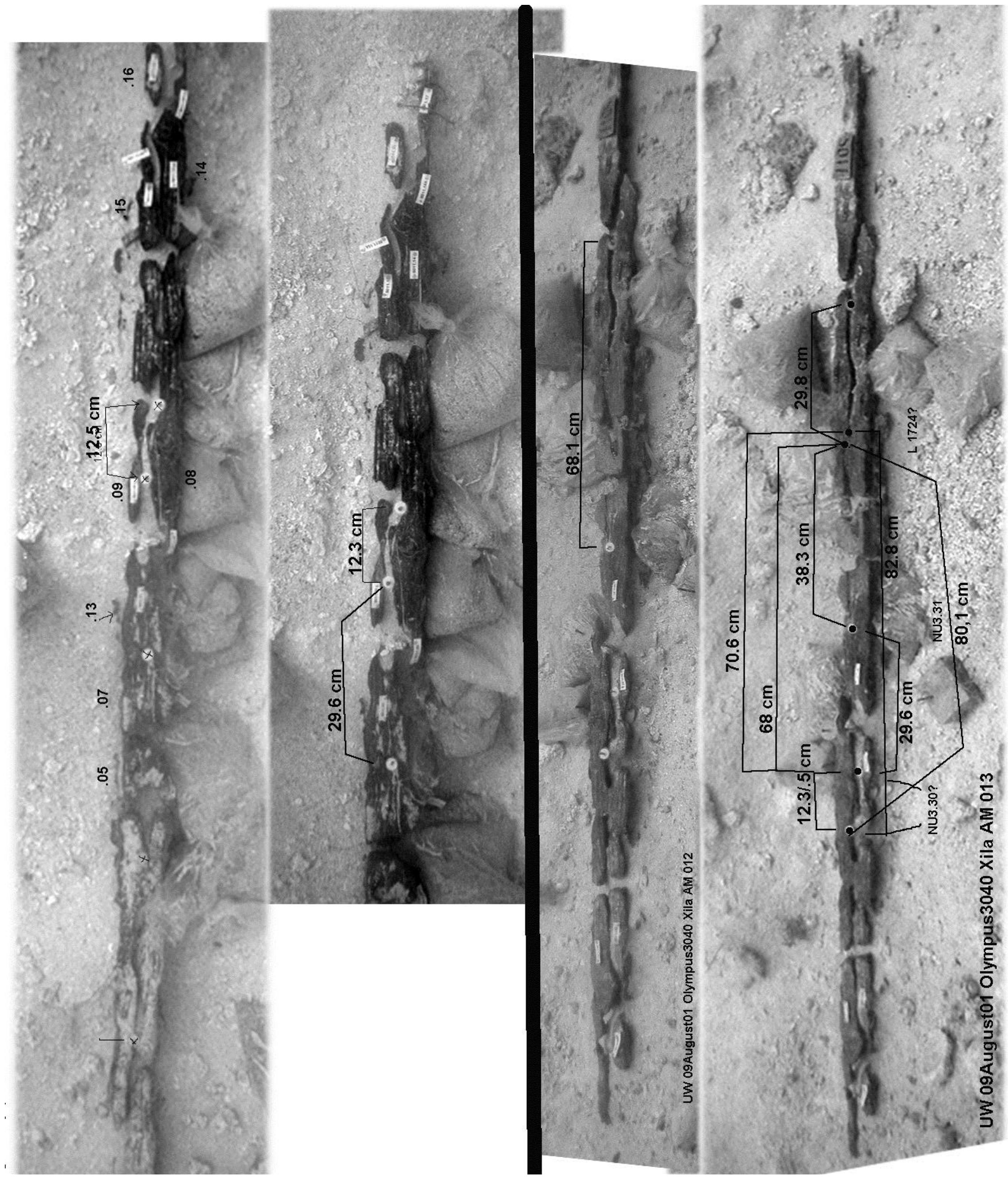


Figure 3.16. Potential nail stations for frames in the keel. Image by Sheila Matthews.

Planking-to-frame nail spacing

Most frame fragments retain multiple nail fragments and many clenched portions of nails. From these timbers, the spacing between nails was measured on both the inner and outer faces whenever possible. Measurements showed that planking-to-framing nails were rather regularly spaced, averaging 9.2 cm on the inner face of frames and 9.3 cm on the outer face. The Kyrenia ship was noted to have pairs of nails in each plank of less than 20 cm width in the lower portion of the hull and three in those of greater than 20 cm width.[73] This does not appear to be the case with the Kızılburun ship, at least in the lower-most portion of the vessel. The regularly spaced nails in the Kızılburun frames suggest the nail spacing was of greater importance than the number of nails per plank. In order to have utilized a pattern of two nails per plank, each plank would have to average 18.6 cm in width. As there are few timbers from which plank widths can be taken, it is impossible to say if planks were of uniform width, however, in section 3007, plank width is estimated to have been 24 cm. Even if plank widths were uniform, there would not be a consistent number of nails per plank.

The fact that we are dealing with the lowest portions of the vessel and a somewhat flat profile section is reflected in the average center-to-center nail spacing, as the inner face nail spacing is virtually equal to the outer face nail spacing. With more acute curvature, the inner face nail spacing should be tighter, assuming nails were driven relatively perpendicular to the surface of the planking. For example, fragment 5017 (Figure 3.17) is an extension of frame 5000 (Figure 3.18) and is from the turn of the bilge area of the frame. As the timber starts to curve upward the nails on the outer face of the timber have a greater center-to-center distance than those on the inner face due to the curvature of the timber. In addition to being applied to the frame sections, this reasoning may also be applied to planking section 3007. In the frame impression here, two nails are present with a center-to-center distance of 8.9 cm. The frame associated with these nails does not survive; however, the dimension is remarkably similar to that of frame 3003, the adjacent frame towards the presumed bow, where the spacing between nails was 8.8 cm on the outer surface abutting the planking.

[73] Steffy 1994, 49. Similarly, Steffy (1985a, 520) reports two nails per 16 cm plank in the Herculaneum boat.

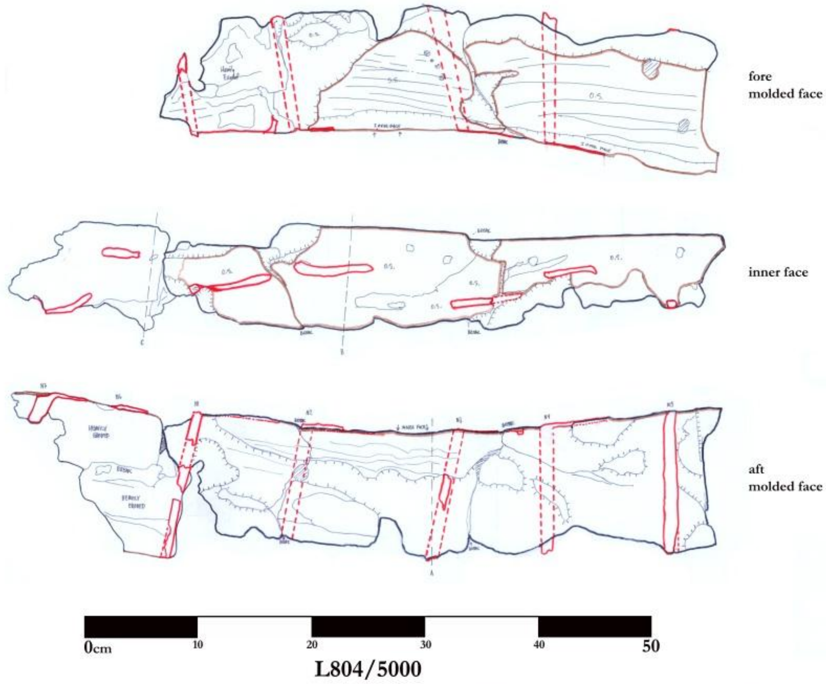


Figure 3.17. Frame fragment 5017. Drawing by the author.

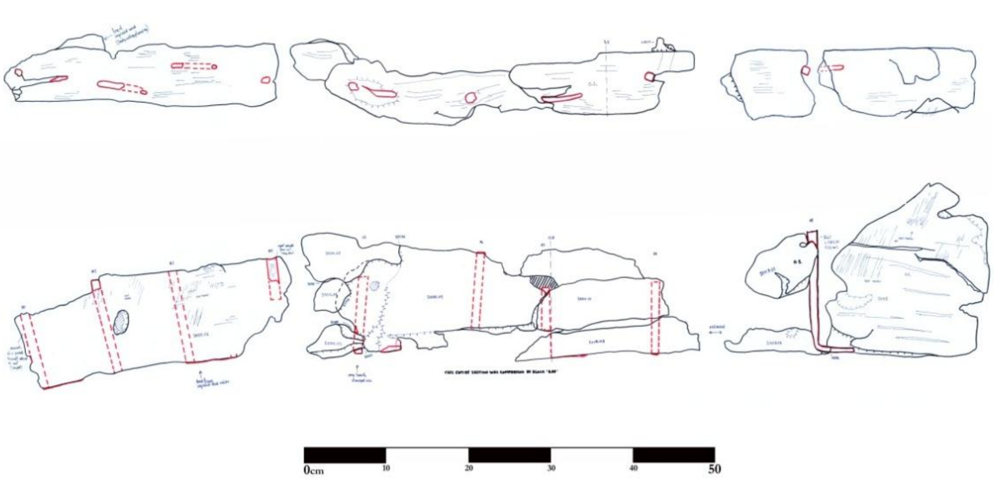


Figure 3.18. Floor fragments 5007/5005/5000. Drawing by the author.

All nails preserved in frame components are broken and none retain a nail head as nail heads were either severed completely or were retained in hull planking when the frames separated from the planking. Many frame fragments, therefore, preserve the full length of the nail shank minus the portion that remained in the planking. The nail head and a portion of the nail shank roughly equal to the thickness of planking were retained in the planks when the frames were sheared off during the wrecking or in subsequent deterioration of the hull. This topic will be revisited in Chapter IV.

Watercourses

With regard to the lack of frame impressions on the keel's inner face, it is likely that the gap between the frames and keel served as a watercourse and provided a means for bilge water to flow to a presumed pump sump or, at the very least, prevented water from pooling in one area.[74] No further evidence for watercourses or limber holes was found.

HULL PLANKING

Eighteen distinct timber sections have been identified as pieces of hull planking. Due to the decomposition of the wood, these vary in width, thickness, and length. Few edge seams are detectable. Although most of the extant planking sections or fragments are heavily compressed from the weight of the cargo, thickness dimensions were obtained from 20 fragments within the 18 sections preserved (Table 3.4). Thickness measurements ranged from 2.0 to 4.8 cm; the former is clearly from a compressed fragment and the latter is from the garboard strake, which is often slightly greater in thickness than other pieces of planking. With these outliers removed, the 18 remaining measurements give an average of 3.6 cm, and a mode of 4.1 cm occurring five times. Plank fragment 3005.01 (Figure 3.19) retained a nail fragment with a head and partial shank broken at 4.0 cm below the head. Another small fragment of planking from area U4 (plank fragment 6009.04) retained a

[74] This style of watercourse is seen in the Marsala Punic ship (Frost 1981, 249; Steffy 1994, 59), Chrétienne C (Joncheray 1975, 52), and Madrague de Giens vessel (Steffy 1994, 63 Fig. 3-49 a-c).

partial nail with head, broken at 4.1 cm below the head.[75] It also retained small portions of original surface from the plank's outer and inner faces (Figure 3.20) This fragment was located on the seafloor over one meter away from the keel and it's thickness is representative of the planking strakes as opposed to the garboard strake that is often of greater thickness (4.8 cm in this case). These figures correspond well with those obtained from examination of the nails discussed in Chapter IV, as well as figures obtained from the examination of the keel rabbets (4.0-5.0 cm). It should be noted that some variation in planking thickness is to be expected, as thicknesses often vary depending on a plank's position on the vessel.[76]

Planking width should also vary along the length of the vessel, with the widest portions being amidships. Due to the scanty hull remains, the Kızılburun vessel's amidships cannot be located precisely. However, as the stone cargo was presumably centrally located in the ship, and all of the extant wood survives under the cargo, some of the preserved planking should represent the widest planks used on the ship, or those within approximately 2 m of midships.[77]

---

[75] Timber 6009 is a frame fragment. Fragment 6009.04 was attached or associated with this group, but is a plank fragment.
[76] Steffy 1994, 212; van Duivenvoorde (forthcoming).
[77] Excavation has shown a slight, but as yet undetermined amount of downslope movement of the column drums.

Wood Number	Width (cm)	Thickness (cm)	Wood type
1001.01	19.1	2.5	*Pinus brutia*
1002.00	8.5	2.0	*Pinus nigra*
1003.00	9.6	3.1	*Pinus nigra*
1004.00	8.5	2.9	*Pinus nigra*
1005.00	8.5	2.8	*Pinus nigra*
3004.00	14.1	3.8	*Pinus nigra*
3004.01	14.2		*Pinus nigra*
3005.01	14.9	3.9	*Pinus nigra*
3006.00	7.5	3.0	*Pinus brutia*
3007.00	24.0	3.9	*Pinus nigra*
3007.11	11.8		n/a
3007.16	13.9		*Pinus nigra*
3007.25	12.8		*Pinus brutia*
3007.26	12.4		*Pinus brutia*
3011.00	11.9	4.1	*Pinus nigra*
5010.00	5.9	3.4	*Pinus nigra*
5012.00		4.8	*Pinus nigra*
6000.00	9.8	4.1	*Pinus brutia*
6000.02		4.1	*Pinus brutia*
6001.02	9.3	3.8	*Pinus brutia*
6003.00	15.8	3.8	*Pinus brutia*
6006.04	11.6	4.1	*Pinus brutia*
6006.06		4.3	*Pinus brutia*
6009.04		4.1	*Pinus nigra*
L490	14.8	3.1	n/a
avg.		3.6	

Table 3.4. Planking data. Wood identification by Nili Liphschitz.

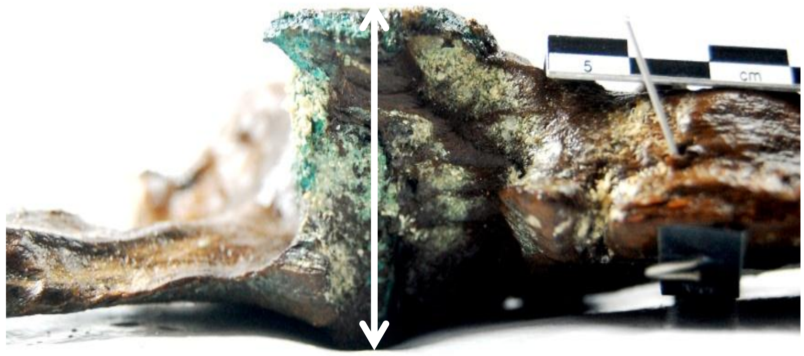


Figure 3.19. Plank fragment 3005.01 with partial nail (highlighted by the arrow) corresponding to original plank thickness. Photograph by the author.

Figure 3.20. Planking fragment 6009.04 with broken nail (highlighted by the arrow) corresponding to original plank thickness. Photograph by the author.

Several planking seams have survived. Most of the planks that retain a seam, however, lack an opposing plank seam. In these cases, maximum surviving plank widths range from 7.5 to 19.1 cm. Planking section 3007 (Figure 3.21) is a scarfed section of planking and is the most diagnostic of the planking fragments. Both planks on either side of the scarf survive, making it possible to reconstruct a strake with a width of approximately 24 cm. This was obtained by projecting the opposing plank seams and measuring the perpendicular distance between them. A small fragment of this planking section has a thickness of 3.9 cm. This section also contains fragments of framing nails, and multiple mortise-and-tenon joints. One light frame impression and a second more pronounced impression are also retained and offer information about frame spacing. These impressions indicate the distance between frame edges to be 14.6 cm. This figure was used to calculate the center-to-center distance between frames (discussed above in the frame spacing section).

Garboard

A 62 cm-long section of the disarticulated port side garboard strake was excavated from under Drums 3 and 5 (areas U3 and U5) (Figure 3.22). This area corresponds to approximately the longitudinal central point of the cargo. Comparing the location of the keel, to that of the cargo's central axis, one can see some shifting toward the starboard side. This may simply be a result of the ship listing to starboard before the collapse of the hull. The downslope movement of the heavy load cannot be stated with certainty, although I do not believe the shift to have been substantial.[78] Regardless, the garboard fragment should be representative of its shape from, or within relatively close proximity to, amidships.

[78] Downslope movement could have been as much as 2 m based on the positioning of marble blocks that were under the column drums, but the exact amount of downslope movement cannot be stated with certainty.

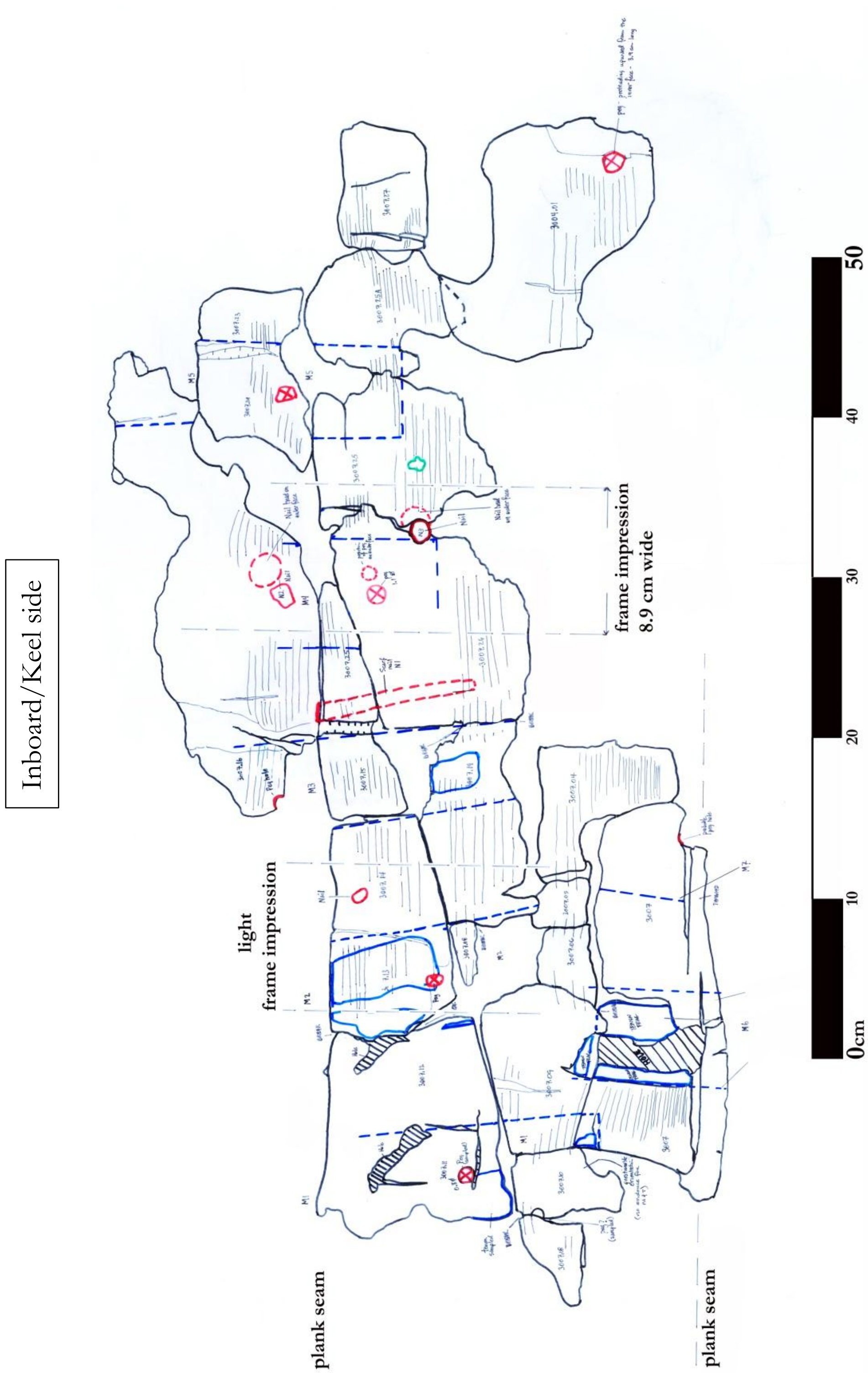


Figure 3.21. Plank section 3007 with diagonal scarf. Drawing by the author.

Figure 3.22. Garboard fragment- timber 5012. Photograph by the author.

The lower portion of the garboard's inner face is so eroded and deteriorated that no original surface is discernible and none of the mortise-and-tenon joinery that once connected the garboard to the keel survives in the garboard fragment. Although separated completely from the keel, the garboard was only slightly removed from its rabbet (Figure 3.23).

Figure 3.23. Garboard strake in situ. Photograph by Eric T. Kemp.

The upper half of the garboard's inner face is better preserved than the lower half and retains some of its original surface as well as one complete, albeit distorted, mortise, a partial second mortise, and a small fragment of a tenon. No exterior surface survives. The wood has suffered from compression. However, three knots that have survived in the garboard helped to establish the original shape, thickness, and the curved shape of the garboard.

The garboard is not rectangular in section, but sculpted to form a two-part angled inner surface,[79] with the upper portion of the garboard angling away from the lower portion at an angle of approximately 35 degrees, thereby creating a five-faced or pentagonal-shaped timber (Figure 3.24). The upper portion of the garboard is just deep enough to

[79] The wreck of La Roche Fouras has a similarly shaped garboard, but more sharply carved into an "L" shape with only a few centimeters adjoining the garboard to keel (Joncheray 1976, fig. 4, 112). Likewise the Laurons 2 shipwreck also had a five-faceted garboard of 4.5 cm thickness (Gassend et al. 1984, 91), and the wreck at Ladispoli shared a pentagonal garboard of 4-4.5 cm thickness (Carre 1993, 14). Although double planked, the outer garboard of the Cavalière wreck is pentagonal in shape (Charlin et al. 1978, 73).

accommodate the plank-to-garboard mortises before the garboard angles downward towards the rabbet of the keel. Although the upper mortised face of the garboard is eroded, its width can be estimated based on the more complete surviving mortise and an empty peg hole. The average tenon peg-to-plank seam distance in the keel is 1.3 cm, and this figure can be used to estimate the original mortise depth at 6.8 cm. The width of the lower section of the garboard is unclear. However, if the lower portion of the garboard is at least equal to the upper portion in width (6.8 cm), as seems likely since it has to accommodate the garboard-to-keel tenons, then these dimensions can be used to reconstruct the original garboard size from an area near amidships. This will be discussed in detail in Chapter V.

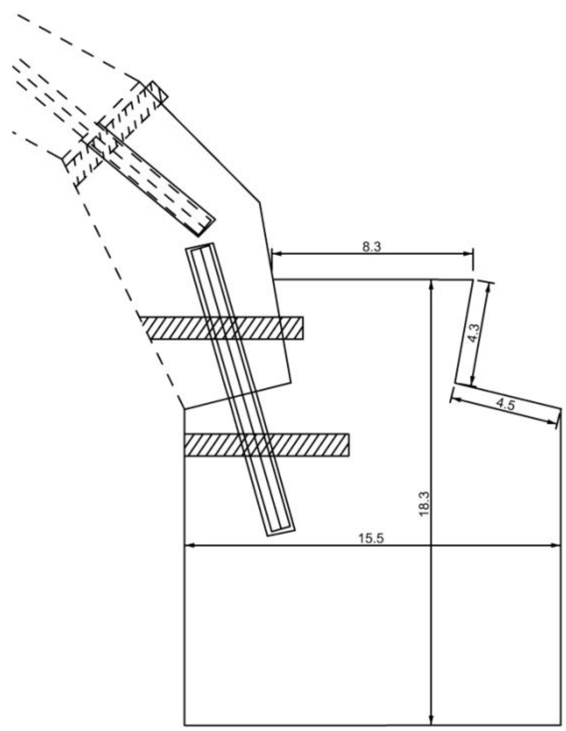


Figure 3.24. Keel profile with reconstructed garboard. Image by the author.

One of the two mortises in the upper edge of the garboard is complete and is 6.2 cm wide and 0.7 cm thick. These dimensions conform with the average measurements taken from the mortises on the keel. Since the second mortise is incomplete and only 5.2 cm of its width survives, spacing between the mortises must be approximated. Using a mortise width of 6.2 cm and an edge-to-edge mortise spacing of 6.1 cm, center-to-center mortise spacing can be calculated at approximately 12.1 cm, matching the mode of mortise spacing of the keel, but is just slightly greater than the average mortise spacing of 11.7 cm.

Mortise-and-tenon joints in the planking

Planking strakes were fastened to one another using closely-spaced pegged mortise-and-tenon joinery. Peg placement of planking tenons were not vertically staggered as they were on the keel, suggesting that the staggering of tenon pegs is more stylistic in their application than one of function. Planking tenon pegs taper from the outer face toward the inner face, revealing the direction in which they were driven. Only two full examples survive intact and both taper from 1.1 cm to 0.7 cm. However, 14 compressed pegs have diameters that range from 0.9 to 1.2 cm, with an average diameter of 1.0 cm. This figure compares well with the average peg diameter of 0.95 cm on the keel. As most original plank seams are lost, the distance between a peg center to its plank seam is based almost exclusively on surviving dimensions rather than actual dimensions. These figures average 1.9 cm, which is slightly greater than the average of 1.3 cm found in the examination of the keel. Planking tenon pegs are summarized in Table 3.5.

When obtaining the minimum sizes of tenons and mortises, I used measurements only from plank fragments that were not damaged in the dimension being measured. Most plank fragments suffer from severe compression and the thickness measurements from such examples were not used in the analysis. In total, 28 partial tenons survive from the hull planking and are summarized in Table 3.6.

Wood #	Diameter (cm)	Dist. To Seam (cm)	Wood type	Notes
3003.01	1.0	---	*Fraxinus excelsior*	---
3003.04	0.9	2.1	*Pinus brutia*	---
3004.01	1.1	2.6	*Quercus* sp.	peg tapers to 0.7
3004.01	1.1	1.7	---	---
3004.01	1.1	1.7	---	---
3007.10	1.0	---	*Quercus* sp.	L1412.20
3007.10	0.9	---	*Pinus* sp.	---
3007.11	0.8	2.5	*Fraxinus excelsior*	---
3007.13	0.9	1.6	*Fraxinus excelsior*	---
3007.16	1.1	2.5	---	---
3007.24	1.0	1.2	*Fraxinus excelsior*	---
3007.26	1.1	2.0	*Fraxinus excelsior*	---
3007.29	1.1	---	---	---
5010.03	1.0	---	*Fraxinus excelsior*	---
Lot 200	1.3*	1.4	---	partial peg hole
anchor con.	1.2	1.2	---	best preserved

Table 3.5. Pegs in planking. (* denotes partial peg.).

Wood #	Width (cm)	Length (cm)	Thickness (cm)	Wood type	Notes
1000.01	6.63	7.85	1.1	*Quercus cerris*	attached to frame 1000
1001.01	2.0*	7.2	0.3*	---	---
1001.05	5.3*	7.2	0.75	---	---
1002.02	1.9*	n/a	0.3*	---	---
1003.02	6.1	4.2*	1.1	*Quercus cerris*	tapered fragment
1003.08	---	---	---	*Quercus* sp.	compressed fragment
1003.10	3.4*	3.4*	0.3*	*Quercus cerris*	---
1004.04	4.0*	3.4*	0.9	---	tapered fragment
3003.01	6	6	1.1	---	partial tenon attached to 3003
3003.04	5.8	8.4	1.2	---	partial tenon attached to 3003
3004.01	1.6*	6.4	0.6*	*Quercus cerris*	---
3004.01	3.2*	3.5*	0.6*	---	---
3004.01	1.4*	5.6*	0.6*	---	---
3005.01	3.4*	2.9	0.8	---	---
3007.00	5.2*	2.6*	0.4*	*Quercus cerris*	---
3007.00	6.1	1.0*	0.4*	*Quercus cerris*	---
3007.09	1.5*	0.8*	0.3*	*Quercus cerris*	same tenon as 3007.11
3007.11	2.7*	3.1*	0.3*	*Quercus* sp.	same tenon as 3007.09
3007.12	2.0*	0.4*	0.2*	---	same tenon as 3007.13
3007.13	6.6	7.2	0.2*	*Quercus* sp.	same tenon as 3007.12
3007.19	2.9*	2.3*	0.3*	*Quercus cerris*	---
3007.29	5.5*	5.7*	0.2*	---	---
3011.01	6.2	7.2	0.4*	---	tapered fragment
6000.04	3.5*	6.4	0.8	*Quercus cerris*	---
6008.01	2.6*	3.1*	0.4*	*Quercus* sp.	attached to frame 6008
Lot 200	2.2*	6.2	1.1	---	---
Lot 213	7.4	4.3*	0.71	*Quercus* sp.	---
Lot 213	2.6*	2.4*	0.5*	---	---

Table 3.6. Tenons in planking. (* denotes incomplete or distorted measurement.)

Tenon widths range from a minimum of 5.8 cm to a maximum of 7.4 cm in eight examples that were recovered. The average width is 6.38 cm, with a mode of 6.1 cm occurring twice. Surviving tenon lengths, which are only approximately half the length of the original tenons as they were generally broken in half at the planking seams, range from 6.0 to 8.4 cm giving an average of 6.6 cm, with a mode of 7.2 cm occurring four times. Therefore, the overall tenon length would have ranged between 12.0 and 16.8 cm. None of these measurements is definitive, but they are presented here to establish minimum tenon size of the Kızılburun ship. Thickness measurements range from 0.7 to 1.2 cm, with an average of 1.0 cm and a mode of 1.1 cm occurring four times. Thus, the planking tenons on average are 6.4 cm wide, 13.1 cm long and 1.0 cm thick.

It may be more informative to discuss mortise sizes and see how they compare with the tenon dimensions. There are fewer surviving mortises than tenon fragments from which dimensions can be taken. These are summarized in Table 3.7. The average mortise width is 6.5 cm and that of a tenon is 6.4 cm. Depth of mortises average 6.8 cm as compared to the average half-tenon length of 6.6 cm, thus demonstrating that tenons were tightly fitted in the mortises.

Although original edges are poorly defined and often difficult to discern on both tenons and mortises, these average figures correspond well to one another and suggest they are indicative of their original dimensions. In several examples, mortise edges are better defined and clearly show distinct tapering (Figures 3.25 and 3.26), as do several tenon fragments.

Mortise spacing is inferred from the center-to-center distance between pegs of adjacent mortise-and-tenon joints. Unlike the pegs of the keel, the planking tenon pegs are positioned centrally along the horizontal axis of the tenon. The five spacings that could be measured range from 11.5 to 13.6 cm with an average of 12.5 cm. This compares well with the average mortise spacing of 11.7 cm taken from the keel. A slight increase in size can be seen when the planking mortise (6.5 w. x 6.8 l. x 0.9 th.) and tenon dimensions (6.4 w. x 6.6 l. x 1.0 th.) are compared with those of the keel (5.8 w. x 5.1 l. x 0.7 th.).

Timber	Width (cm)	Depth (cm)	Thickness (cm)	Distance	Notes
1001.01	---	8.7	---	---	---
1001.05	---	7.8	0.8	---	---
1002.02	6.5	6.8	---	---	---
1003.02	6.4	---	1.1	---	---
1004.04	---	---	0.9	---	---
3004.01	6.4	6.4	---	---	projected from peg center
3007.00	6.1	5.4	---	---	---
3007.09/.11	6.1	5.8	---	12.2	to 3007.13
3007.13	6.5	7.1	---	12.8	to 3007.15 projected
3007.15/.19	5.7	---	---	11.5	to 3007.26 projected
3007.24/.25	6.0	---	---	13.6	to 3007.26
3007.25/.26	6.7	---	---	---	---
3007.29	8.8	---	---	---	tapering shape, 1/4 mortise
3011.01	6.4	7.4	---	---	good shape, half mortise
5012.05	6.2	6.0	0.7	12.3	---

Table 3.7. Mortises in planking.

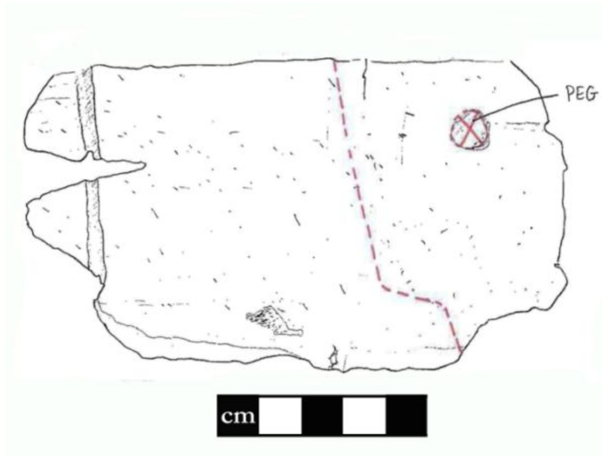


Figure 3.25. Planking fragment 3007.29 illustrating a partial tapered mortise. Drawing by the author.

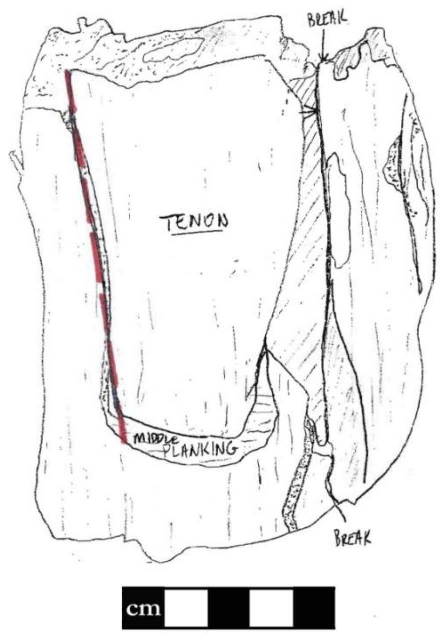


Figure 3.26. Planking fragment 3011.01 illustrating a partial, tapered mortise. Drawing by the author.

Scarf

The single, partially extant planking scarf is of the common diagonal version.[80] Although its full length has not survived, it can be reconstructed as having a length of 80 cm in a strake that is estimated to have been 24 cm wide.[81] Pegged mortise-and-tenon joints aided by a single nail secured the two planks of the scarf. The nail, used to secure the scarf tip, was driven from the lower plank into the upper one (Figure 3.27). Strengthening scarfs with nails is a common feature of Graeco-Roman shipbuilding and lasted well into the seventh century C.E.[82]

The position of nails in scarf tips is somewhat indicative of the assembly sequence. A nail driven downward from the top is less telling, as the strake may have been assembled prior to attachment to lower strakes, or planks of the upper strake may have been laid down individually, then nailed together. However, a nail driven from the lower plank up through the upper plank shows that planks were first assembled into a strake, then fastened to the lower strake. Additional information about the assembly sequence is revealed by examining the mortise-and-tenon joints. Three joints survive in the scarf, albeit four mortises likely fortified the scarf originally. Pegs secure the three tenons in place, with the tenon of mortise 3 (M3) continuing through the plank seam and into the next lower strake, where it was secured by a peg. No peg was used in the lower plank of the scarf in this case. This suggests that mortise 3 was cut at the time this strake was being joined to the lower strake.

[80] Fitzgerald 1995, 137; Steffy 1999, 166-7.
[81] These figures are similar to those of three scarfs from near amidships on the third century C.E. Pommègues A vessel (Gassend 1978, 102 fig. 2). The length of scarf is not given but a scaled drawing is provided.
[82] Fitzgerald (1995, 136) reports nailed scarf tips as common from the fourth century B.C.E. through the seventh century C.E. For examples see the Nemi barges (Ucelli 1950, 153, fig. 153), the Sea of Galilee boat (Steffy 1990, 32, 33 fig. 5.7; 1995, 144-6), Madrague de Giens (Tchernia et al. 1978, 79 fig. 11, 80), and several examples in Bass (1972, 70-1).

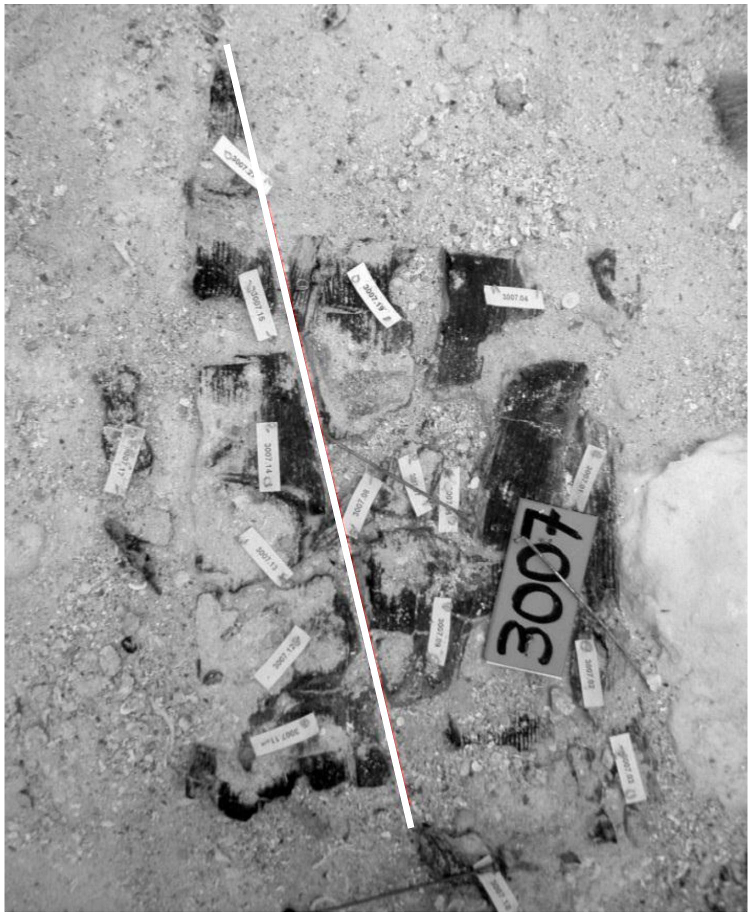


Figure 3.27. Diagonal scarf on plank section 3007 shown in situ, with the scarf marked by line. Photograph by Deborah N. Carlson. Also see Figure 3.22 for drawn version.

Edges of the three surviving mortises are not clearly defined due to heavy compression, distortion, and the degraded nature of the wood, but it is possible to see that tenons were placed in a perpendicular orientation to the plank seam rather than perpendicularly to the scarf seam. This further supports the idea that the two planks were pre-assembled into a strake prior to securing them to the strake below.[83] The ship excavated at Kyrenia also exhibits diagonal scarfs. In fact, four of its scarfs have nailed tips, and there is evidence of both strake-by-strake and plank-by-plank assembly in the same ship, illustrating that these

83 Steffy 1999, 167.

are features of ship construction that were established centuries prior to the construction of the Kızılburun ship.

The diagonal scarf in planking section 3007 is the only scarf that has survived among the Kızılburun planking. However, there is evidence for the presence of a second planking scarf. Plank fragments 1001 and 1002 were found in line and were presumably parts of the same strake. Both fragments have been identified as pine but of differing species; 1001 is of *Pinus brutia* and was found upslope of 1002, which is of *Pinus nigra*. These timber fragments likely represent a continuation of strake section 3007, which was also sampled on either side of the scarf for wood identification purposes. In 3007, the same situation was discovered, with the plank on the upslope side (fragment 1002) being of *Pinus nigra*, and thus matching the wood species of plank fragment 1002. The plank lying on the downslope side of the scarf in section 3007 is of *Pinus brutia*. (Figure 3.28)

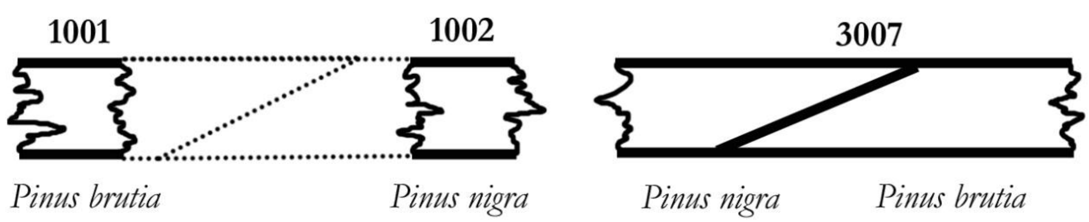


Figure 3.28. Wood identification of planks in scarf 3007 and location of possible scarf between plank fragments 1001 and 1002. Image by the author. Wood identification by Nili Liphschitz. Image not to scale.

CEILING PLANKING

Ceiling planking is seldom discussed as constructional components in shipwreck publications,[84] and often overlooked as an inconsequential feature of a vessel. Yet, these longitudinal timbers can offer torsional strength and longitudinal stiffness to a craft,[85] as well as helping to distribute point loads. In shell-based ships, this can be especially important as the strength of the vessel exists predominantly in the planking. For a ship carrying a cargo of heavy marble column drums, the distribution of point loads is of even greater importance.

The remains of an iron anchor, with its disassembled stock lying next to it, were located just forward of Drum 2 on the starboard side of the keel. Although the original iron anchor itself does not survive, its shape is preserved in the form of a natural concretion mold composed mostly of calcium carbonate.[86] The anchor shaped concretion preserved the impression of a plank that included one of its seams (Figure 3.29). Measuring perpendicularly from the seam to the widest point of the impression yielded a width of 19.2 cm. As the anchor could not have been resting directly on hull planking due to the presence of frames, the plank impression most likely represents of ceiling planking.[87] Although fragments of ceiling planks were identified elsewhere in the hull, the impression left on the iron anchor concretion provides the widest preserved piece from which a minimum width is obtained for the ship's ceiling planking.

---

[84] Steffy 1994, 213.

[85] Gassend et al. 1984, 98.

[86] Kimberly Rash (forthcoming; 2010, 31-3) employing the anchor concretion as a natural mold and using an epoxy compound produced a cast likeness of the anchor, which is a Haldane Type A iron anchor (Haldane 1990, 22).

[87] The possibility exists that the impression represents deck planking, with the anchor lying on the fore deck. If such were the case, a bulwark would have been placed between the column drums and the fore deck. No evidence survives to substantiate such a structure, however and, the identification as ceiling planking remains tenuous.

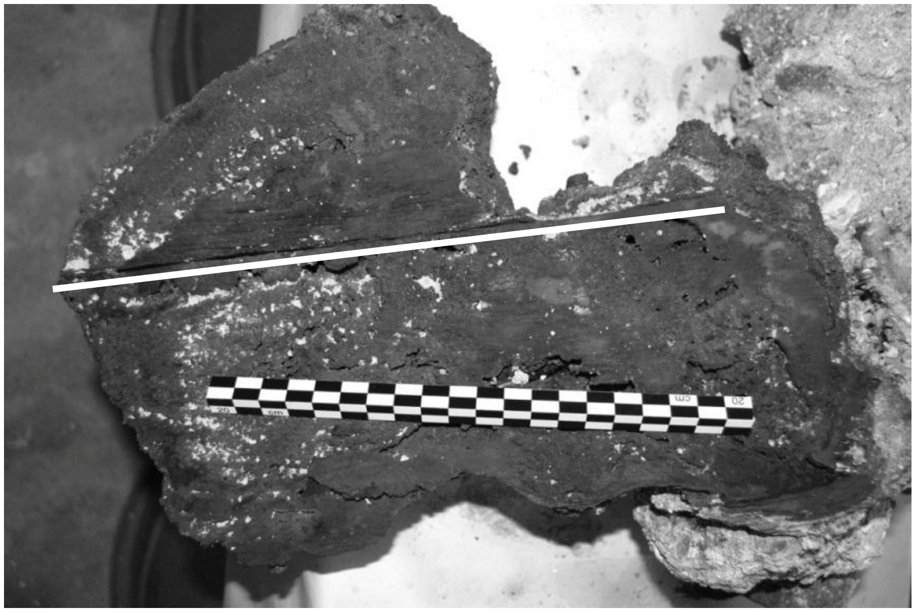


Figure 3.29. Ceiling plank seam impression preserved in iron anchor concretion. Photograph by the author.

Among the hull remains, six wood fragments, representing as many as five distinct ceiling planks, have been identified (Table 3.8).[88] No single fragment retains original opposing edges to measure planking width thus making the minimum width obtained from the anchor concretion vital. Measurements of surviving ceiling plank fragments range from a minimum of 7.0 (6023) to 12.4 cm (5013) and may denote several original plank widths, as ceiling planks are seldom of uniform dimensions.[89] Ceiling plank thickness also shows variation, albeit to a lesser extent, ranging between 2.8 and 3.9 cm (3.28 cm average) and as with the frames, do not show the same level of compression seen in the hull planking. The average ceiling plank thickness is comparable to those of the Kyrenia,[90] the Madrague de Giens,[91] and the Anse de Laurons 2 ships.[92]

88 Wood fragment 3002 is likely an extension of fragment 5006. Fragments 6003 and 6006 are likely extensions of fragment 6007.
89 Steffy 1994, 213.
90 Steffy 1994, 52.
91 Tchernia et al.(1978, 84) reports thicknesses ranging from 2.5 to 4 cm.
92 Gassend et al. 1984, 98; Steffy, 1994, 72.

Timber	Area	Width (cm)	Thickness (cm)	Wood Type
3002	U3	7.5	3.7	*Pinus brutia*
5006	U5	10.5	3.9	*Pinus nigra*
5008	U5	10	2.8	*Pinus nigra*
5013	U5	12.4	3.1	*Pinus nigra*
6007	U6	11.3	broken	*Pinus nigra*
6023	U6	7.0	2.9	---

Table 3.8. Ceiling planking data. Wood identification by Nili Liphschitz.

UNIDENTIFIED WOOD FRAGMENTS

There are many unidentified and/or unprovenienced fragments among the wood remains. These are generally referred to as UMs (unidentified members). By definition, either the function or provenience of these pieces is unclear, yet in some cases assumptions may be made. For example, Lot 1238 has no identifying features or wood identification from which a function could be inferred. However, the fragment has a thickness of 4.4 cm and the appearance of pine. It also retains what appears to be an impression of a frame measuring 10.1 cm in width. These measurements are similar to those obtained from identifiable hull planking fragments and frames. It is almost certain, therefore, that Lot 1238 is a piece of hull planking.

Some UMs are more diagnostic than others and can be used to define features. For example fragment 8000 was clearly a frame piece from Area U8, as evidenced by several clenched framing nails, but could not be placed with certainty on the wreck plan. However, it provided several framing nail spacing measurements as well as a suggestive frame/floor shape. Further, frame fragment 5017 was excavated from under drum 5 in 2006 when attempting to rig and move the 5-6 ton drum in the closing days of the excavation season.

As a consequence, the exact provenience of timber 5017 was lost. Through examination of diver's notes, sketches, and interviews with excavators, I determined the piece was an extension of floor timber 5000, thus giving proper provenience to 5017. These fragments, in turn, were used to reconstruct the shape of a more complete frame and a subsequent model for a representative floor timber.

UNEXPLAINED FEATURES

Timber 6004 is a frame fragment, possibly from a futtock, and has a cut inboard end with two vertical holes of small diameter (2.0, 1.8 cm) (Figure 3.30). Given the vertical placement of the two holes in relation to each other, they were likely drilled from the foreword face as this relationship is not shared on the aft face. Each hole is drilled at slightly different angles with respect to the forward face of the timber. The upper hole is drilled at 105˚ while the lower hole is drilled at 95˚.

One possible function of the two holes is to secure its end to a floor or other similar member. However, no extant floor survives from the area in which 6004 was excavated. Further, no dowel, nail or treenail remnants survive to suggest that the holes were in use at the time of the ship's demise. Examples of this type of joinery have eluded the author thus far and their function remains unknown.

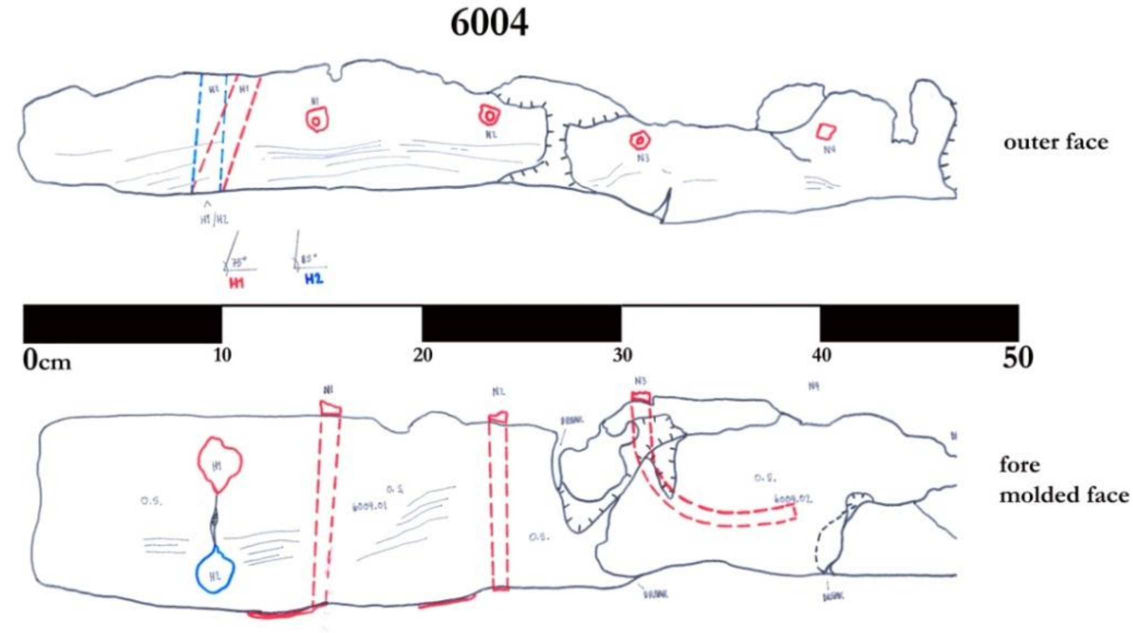


Figure 3.30. Frame fragment 6004 showing vertical holes of unknown purpose at its finished end. Drawing by the author.

TIMBER RE-USE

A second possibility to explain the two holes in frame piece 6004 is that the timber was reused, either from an earlier construction or from another vessel. This idea is supported by two nails serving no apparent function (Figure 3.31). They are spaced appropriately to serve as clenched planking-to-frame nails, but instead of penetrating through the inner face of the frame for clenching, they are embedded within the timber. There are no treenails on the inner face of the timber to guide these nails through the thickness of the timber. However, it is also possible that these nails were simply mis-driven and left in place. No other instances of mis-driven nails or those of dubious purpose were observed in the other timbers.

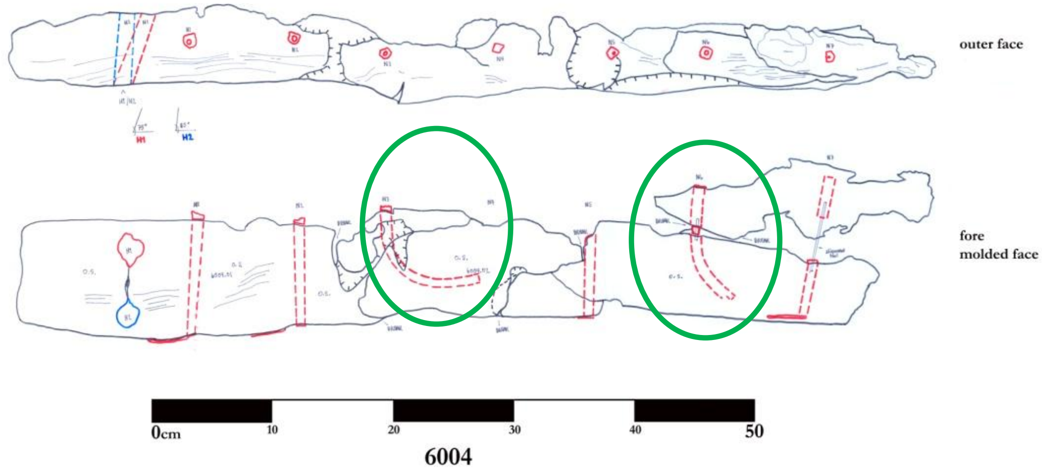


Figure 3.31. Timber 6004 with bent nails of unknown purpose. Drawing by the author.

TOOL MARKS

There are a limited number of tool marks preserved on the hull remains, including the already discussed score mark on the port side rabbet of the keel. A small area with saw marks has also been found on the inner face of the keel, illustrating the manner in which the keel was shaped. Saw marks were also found on other timbers from the ship. Ceiling planking fragments 3002 and 5006 also exhibit saw marks on their inner faces, but saw marks are most clearly seen on frame fragments 3001 (Figure 3.32) and 5000 (Figure 3.33). These were made by a fine-toothed finishing saw with teeth spaced approximately 1 mm apart. No clear evidence of a coarse-toothed saw was discovered, nor was there any direct evidence for the use of an adze to shape or finish the timbers. Absence of evidence does not constitute evidence of absence; therefore, it is only possible to say that the timbers of this ship were at least finely shaped with the use of finishing saws.

Figure 3.32. Saw marks on frame fragment 3001. Photograph by the author.

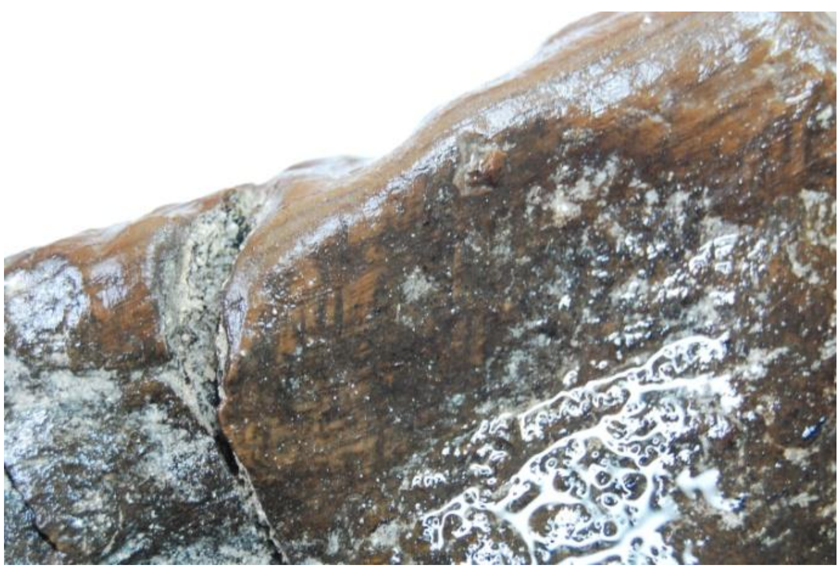


Figure 3.33. Saw marks on frame fragment 5000. Photograph by the author.

SURFACE TREATMENT

Pitch was observed in small amounts on all identified components of the vessel (i.e. keel, hull planking, ceiling planking, and frame pieces) as well as on their interior and exterior surfaces. Planking fragments 6001 and 6003 each retain pitch in small amounts on the outer face. A very small amount of pitch survives on the port side molded face of the exterior portion of the keel, no pitch was found on the keel's inner face. However, pitch was found on the interior surfaces of other timbers. Therefore, the lack of pitch on the keel's inner face may be a product of deterioration rather than lack of application. As for other interior surfaces, pitch was observed on the inner faces of both the hull planking (3007, 6000, 6001, 6003, and 6006) and ceiling planking (6007), as well as on frame fragments (4002, 5000). As pitch is easily lost by degradation processes and marine organisms, only traces now remain, but presumably the entirety of the interior was protected by pitch treatment.

Polzer suggests that pitch was used only on interior surfaces of early Greek laced vessels and only on exterior surfaces of vessels built using mortise-and-tenon joinery.[93] However, numerous ancient references point to the use of pitch, wax, or a combination of the two as surface treatments on both the interior and exterior of seagoing ships.[94] Furthermore, a number of wrecked vessels have been recovered with pitch on both interior and exterior surfaces.[95] Surface treatment samples have been taken from the keel, frame 4002, and UM L705 for future analysis.

RADIOCARBON DATING

Two wood samples were subjected to ^{14}C dating. One sample was collected from the keel, taken at its inner face, the farthest point from the pith of the timber and thus more desirable in terms of gaining an accurate felling date for the tree, and the other was a two-cm long broken tenon peg. The peg was selected for dating purposes because it was made from a small branch or twig with only a few years of growth rings represented and this

---

93 Polzer 2009, 149-50.
94 Casson (1971, 211-2) details ancient authors that write of ship's surface treatments.
95 Harpster 2005, 68; Kahanov 2003, 54; Steffy 1990, 67; van Doorninck 1982, 59-60.

yields a date closest to its actual felling. Radiocarbon dating was performed by private company, Beta Analytic of Miami, Florida. The results from both samples were consistent, but unfortunately not very decisive. The dates obtained are; 350-290 B.C.E., 230-220 B.C.E., 210-110 B.C.E. (2 sigma or confidence range or 95% probability). When applied to a calibration curve the date returned is 195 B.C.E. Dating based on the ceramics of the vessel suggests a date for the last voyage in the first three quarters of the first century B.C.E. and are likely be more precise than the ^{14}C analyses.

CHAPTER IV

THE FASTENERS[96]

Nails are common artifacts found on terrestrial sites as well as in shipwrecks,[97] yet detailed analyses of them in ancient archaeological contexts are often overlooked. Seldom are fasteners given more attention than an illustration plate in excavation publications.[98] A few researchers have attempted to create typologies from individual collections of Roman iron nails,[99] yet a standardized typology of ancient square nails remains elusive. No typology of copper or copper-alloy nails is known to this author.

Attributes of existing iron fastener typologies are: head shape, head diameter, shank shape, shank width, and length (Figure 4.1). Head shape can be indicative of function,[100] and is therefore a diagnostic typological attribute. Head size is variable, but generally it is another good attribute to consider. Most ancient nails have a maximum shank width just below the nail head. The head is adjoined to a square-sectioned shank that tapers towards the distal end. However, cylindrically shanks are not unprecedented, so one must also distinguish shank shape for typological analysis. As ancient nails were hand-forged, variation in length is inevitable.[101] Therefore, length is of limited utility in categorizing fasteners.

---

[96] A brief and preliminary discussion of the ships fasteners is presented in Littlefield 2011a; 2012.
[97] Angus et al. 1962, 957; Sim 1998, 61.
[98] Angus et al. 1962, 957.
[99] See Cleere et al. 1958 and Angus et al. 1962, for attempts at categorizing iron nails. A more recent attempt is in press (Galili 2010, 130, 131) using an assemblage of nails from a Roman shipwreck discovered off the North Carmel coast of Israel.
[100] Angus et al. 1962, 957.
[101] Angus et al. 1962, 957; Blandford (1980, 39 Fig 202 caption) describes the nail heading process and the "guessed" nail length that blacksmiths tried to achieve.

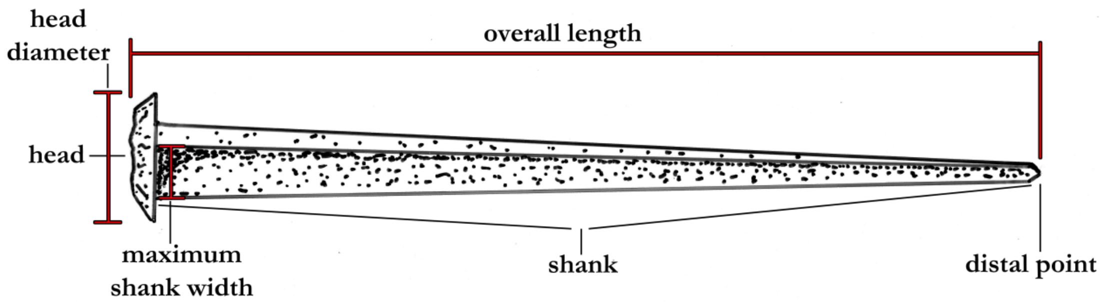


Figure 4.1. Anatomy of a nail and measurement points. Image by the author.

Shank width may be the most consistent attribute of a hand-forged nail, at least within individual assemblages.[102] With forged nails, the blacksmith forms the nail head by driving the fastener through a square hole in an anvil,[103] swage block,[104] or nail header[105] (Figure 4.2) until the width of the shank fits snugly in the hole and so that a short length of the nail protrudes above the anvil or swage block. The smith then hammers the remaining metal into the desired shape of a head[106] (Figure 4.3). As the maximum shank width of a nail is dictated by the size of the hole in the swage block/anvil/heading tool, the finished nails will have a uniform maximum width and therefore may be more easily compared and categorized, at least within a single assemblage (assuming a single source of production). However, shank widths will likely vary only slightly between independent smiths having different sized slots cut into their swage blocks, anvils, or nail headers. As there may be a correlation between nail shank width and length, these two variables are generally functions

102 For example, Angus et al. (1962, 957) show that among the nails in the small category, all had exactly 1/8" shank widths.
103 Illustrated and described in Mercer (1960, fig. 205, 243).
104 A swage block is described by Blandford as a rectangular block that has an assortment of hollows of differing sizes and shapes placed around its circumference and within the body itself (Blandford 1980, 23). The caption for fig. 202 in (Mercer 1960, 239) describes the process of nail forging in some detail.
105 Mercer 1960, 242, fig. 204; Sim 1998, 61.
106 McCarthy (2005, 87) offers a concise summary of the forging process and the use of a swage block to produce nail heads. Sim (1998, 61-3) reports production procedures for replicating Roman iron nails. Also see Blandford 1980, 39, 79-81; Mercer 1960, 241-44, figs. 204-205; Steffy 1994, 49; Tylecote 1976, 241.

of each other, as are nail head size and length.[107] Experiments in replicating Roman nails have shown that un-headed nail blanks could, and likely were, often produced by a blacksmith's apprentice(s), women, or even children. These experiments further demonstrated that considerable variation in length can exist in nail blanks produced by multiple workers, while the shank width remains more uniform.[108]

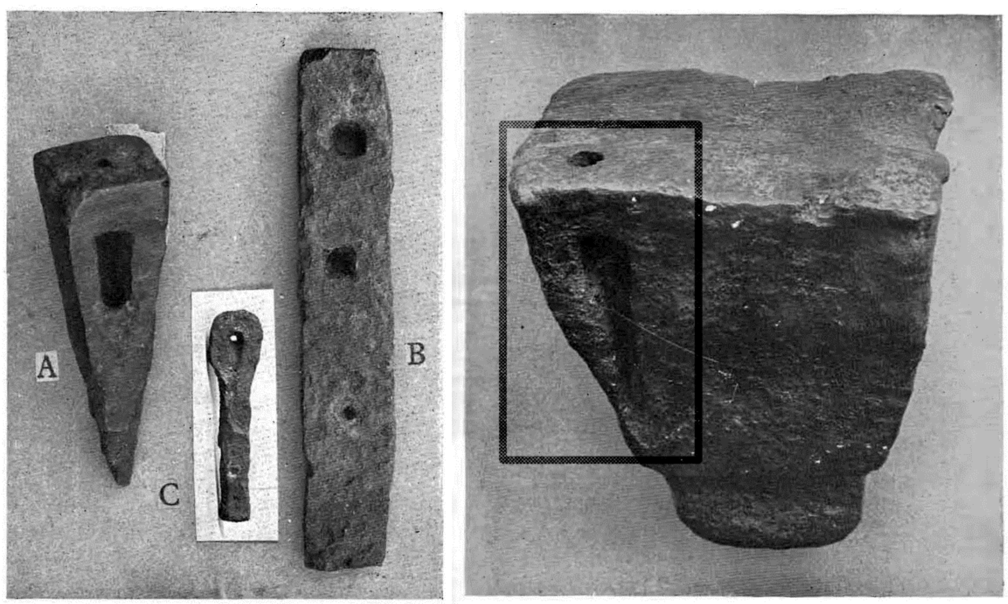


Figure 4.2. Roman nail headers and anvil. Reprinted with permission from *Ancient Carpenter's Tools*, by Mercer, Mercer Museum/Bucks County Historical Society, Doylestown, PA. 1960.

[107] Galili et al. 2010, 131.
[108] Sim 1998, 61-4. Sim further demonstrated that nail heads, particularly of larger nails, required a skilled smith to manufacture as opposed to assistants.

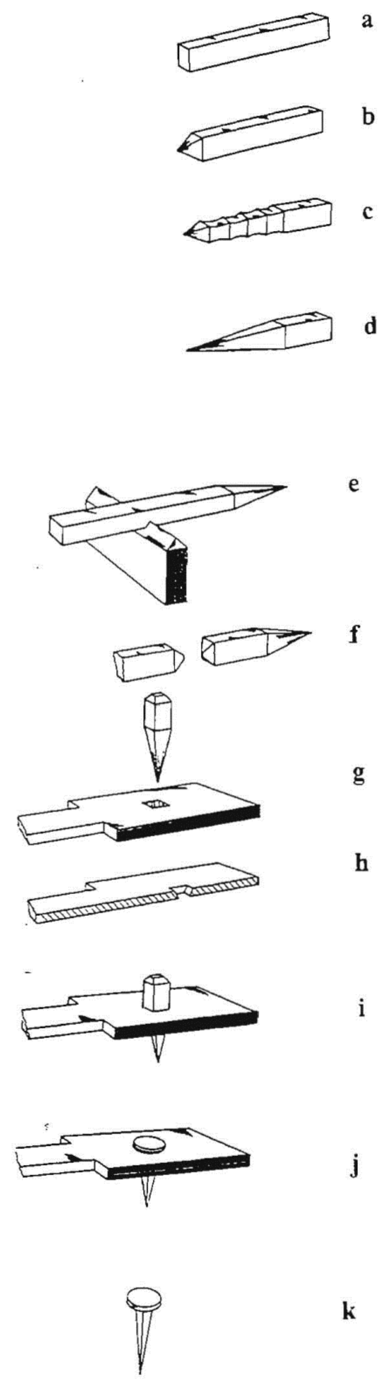


Figure 4.3. Nail production process. Reprinted with permission from *Beyond the Bloom: Bloom Refining and Iron Artifact Production in the Roman World,* by Sim, 1998.

One major problem one must face when attempting to classify or categorize ancient copper or copper-alloy (cupreous hereafter) nails is that the only existing typologies, are based on iron nails. After smelting, the manufacturing or shaping processes of iron nails and cupreous nails are very similar, which may allow for cupreous nails to be similarly categorized or classified based on iron nail typologies. Copper can be cold hammered or forged into shape. The most dramatic difference in the forging processes between copper and iron is the greater temperatures needed to forge iron nails, as iron is not malleable enough to be cold hammered. Whether the cupreous nails were cold hammered or forged, the hammering or shaping techniques remain unchanged and both technologies were available during the serviceable life of the Kızılburun ship.[109] The nails from Ma'agan Mikhael,[110] Kyrenia,[111] and Tektaş Burnu shipwrecks[112] are all reported to have been cupreous, cold hammered, and annealed.

Writing in the second century C.E., Athenaeus repeats the now lost text of Moschion, of copper spikes used in the construction of *Syracusia* during the time of Hiero II in the late fourth or third century B.C.E.[113] Writing contemporaneously with Athenaeus, Tacitus notes that the boats used in ancient Pontus[114] were constructed without fasteners of iron or bronze, suggesting that these materials were the norm.[115] Since iron, copper, and copper alloys such as bronze, are noted in ancient written sources, and distinguishing the material visually can be problematic, if not impossible, elemental analyses of metal fasteners are necessary to determine the metal(s) they are made of.

Archaeological material recovered from the sixth century B.C.E. provides the earliest evidence found to date of cupreous nails used in shipbuilding.[116] The advantageous

[109] Lucas and Harris 1962, 211-4.
[110] Kahanov et al. 1999, 282; Yovel 2004, 83-104.
[111] van Duivenvoorde 2011, personal communication.
[112] van Duivenvoorde, in press.
[113] Ath. 5.207.
[114] Pontus was a Greek province on the southeastern coast of the Black Sea in modern-day Turkey.
[115] Tac.*Hist*.3.47.
[116] The Gela wreck of the late sixth century B.C.E. reportedly used a combination of lacing, iron and copper nails (Freschi 1991, 207). Cupreous nails were also used in the late sixth century B.C.E. the Place

corrosion resistance of cupreous metals over iron in shipbuilding is a quality known to the ancient shipbuilders as expressed by Vegetius (fourth century C.E.) who suggested the use of bronze over iron fasteners.[117] Copper and copper alloy remained the predominant materials for fasteners in seagoing Graeco-Roman ships before the Late Roman period.[118]

According to Blackman, marine cupreous nails were once generally assumed to be made of bronze.[119] However, actual analyses are rare and this had led to problems; particularly when identifications are made visually. Subsequently, in recent years, researchers have focused more on elemental analyses of fasteners, particularly fasteners from marine environments to qualitatively and quantitatively establish the metals used for fasteners.[120]

The fasteners of the fifth century B.C.E. Ma'agan Mikhael ship were originally visually identified as iron due to the black, powdery corrosion that is typical of iron from marine contexts.[121] In fact, many of the fasteners in the Kızılburun assemblage have a similar corrosion product (Figure 4.4). However, after more than five years in storage the Ma'agan Mikhael nails were re-examined due to a blue-green patina that had formed; a patina that

---

Jules Verne 7 hull (Pomey 1995, 478)**.** The Porticello (Eiseman and Ridgway 1987, 11-6) and Tektaş Burnu (Jurgens et al. 2003, 400); van Duivenvoorde (in press)] wrecks of the fifth century B.C.E. had clenched cupreous nails used in their construction. Also of note concerning early non-ferrous fasteners are the fifth century B.C.E. shipwreck at Ma'agan Mikhael (Yovel 2004, 83-104), and the late fourth/early third century B.C.E. shipwrecks at Kyrenia (Foerster-Laures 1990, 175), and Capistello (Frey et al. 1978, 245).

117 Vegetius (4.34) recommends the use of bronze nails over iron to the military due to the decreased corrosion qualities of bronze. "As when building houses the quality of the sand or stone of the foundations is important, so the more carefully should all materials be obtained when building ships, because it is more dangerous for a ship to be faulty than a house. So the warship is constructed principally from cypress, domestic or wild pine, larch, and fir. It is better to fasten it with bronze nails than iron; for although the cost seems somewhat heavier, it is proved to be worthwhile because it lasts longer, since iron nails are quickly corroded by rust in warm, moist conditions, whereas bronze preserve their own substance even below the water-line."

118 Parker 1992, 27; Fitzgerald 1995, 156.

119 Blackman 1972, 117-9. Blackman must have been either unaware of Benoit's (1961, 189-95) analysis of the nails from Grand Congloué or thought Benoit's findings anomalous, as Benoit showed the fasteners to be of copper and suggested copper to be more commonly used. However, Benoit's idea was not commonly shared at this point.

120 Shipwreck nail analyses from Kyrenia (Kahanov et al. 1999, 277, 286), Marsala (Frost 1975, 228, n. 3), Ma'agan Mikhael (Kahanov et al. 1999; Shalev et al.1999, 18), and Tektaş Burnu (van Duivenvoorde, in press) are notable.

121 Linder 1989, 6; Kahanov et al. 1999, 277; Shalev et al. 1999, 16.

suggests copper or bronze was more likely the production metal. The re-examination of these fasteners has produced one of the most comprehensive studies on ancient cupreous nail deterioration processes, albeit a non-comparative study of cupreous fasteners from an anaerobic environment. More than 50 years ago Benoit published on ancient nails from an aerobic environment like that at Kızılburun, although this early analysis lacks the detail achieved by the Ma'agan Mikhael study.[122]

Figure 4.4. Cupreous nail (Lot 019) from Kızılburun. Photograph by the author.

Although marine cupreous nails were commonly believed to be made of bronze, analyses have shown that most ancient nails from a maritime context, at least those that have been subjected to qualitative and quantitative elemental analyses, were made of nearly pure copper.[123] This is illustrated by several examples. The non-ferrous nails from the fifth-

[122] Benoit 1961. Also see North and MacLeod, 80-8.
[123] Lang et al. 1990, 48.

century B.C.E. Ma'agan Mikhael shipwreck were 98.5 % copper, [124] as were those of the second-century B.C.E. wreck from Grand Congloué,[125] while those of the late fourth- early third- century B.C.E. Kyrenia shipwreck[126] and the first century C.E. Nemi barges were 99% copper.[127] Additionally, four fasteners analyzed from the fifth-century B.C.E. Tektaş shipwreck also consist of more than 98% copper.[128] However, the non-ferrous nails of the third century B.C.E. Punic wreck at Marsala were of bronze containing only 80% copper (12.3% lead, 7.1% tin, 0.6% zinc) illustrating that both bronze and copper were utilized for ship's fastenings in antiquity.[129] For those hulls with bronze fasteners, further problems of metal identification exist. Corrosion by-products of bronze that has reacted with seawater can yield misleading results.[130] It is known that bronze is generally made up of 90% copper and 10% tin, although impurities in the metals may alter the constituents slightly. Tin has a tendency to breakdown or dissolve in seawater over time, even when it is alloyed with another metal.[131] The result of this tendency in analyses can lead to questionable or inaccurate identification of the original composition.[132]

CATEGORIZING THE KIZILBURUN FASTENER ASSEMBLAGE

The following analysis of the fasteners from the Kızılburun vessel is based on the examination and cataloging of over 1000 nail Lot numbers (See Appendix II). The inventory includes a few complete nails, but the vast majority of the assemblage consists of fragmentary fasteners, wholly or partially encased in concretions of calcium carbonate

[124] Kahanov et al. (1999, 286) note that there is a discrepancy between this figure and that published by Steffy (1985, 84 note 5), which cites the percentage of copper as 88.22-91.0 %.
[125] Benoit 1961, 193.
[126] Lang et al.1990, 47.
[127] Ucelli 1950, 272.
[128] van Duivenvoorde (in press).
[129] Frost 1975, 227-8, n. 3.
[130] Frost (1975, 228 n. 3). The identification of the metal of the Marsala Punic ship had come into question, so formal analyses were performed to establish more concrete evidence that the nails were indeed made of bronze. In her 1975 article Frost clarifies an earlier statement that the nails were of copper and presents analytical data supporting the conclusion that the fasteners were of bronze. Lang et al, however, have brought questioned this analysis as well, stating that the at least one tack "was found to be essentially copper not bronze" (Lang et al. 1990, 47). For other identification problems see Tylecote 1987, 275; Frost 1981, 120-125; North and MacLeod 1987, 89-90; Kahanov et al. 1999; McCarthy 2005, 140.
[131] North and MacLeod 1987, 86, 89-90.
[132] Frost 1975, 227-8; Frost 1981, 120-25; McCarthy 2005, 139-42.

and/or by products of corroding metal, often in a matrix of metal impregnated wood that survives on the shank of the nail.[133] The fasteners are made almost exclusively of cupreous metals. The majority of the nail fragments are heavily eroded and deteriorated. Many are hollow and show evidence of outward dissolution of metal ions.[134] All metal fasteners have been negatively affected by two millennia of immersion in high-salinity sea water. The majority of the nails that have been preserved were in a reductive, aerobic environment, but survived due to their inclusion in the matrix of the ship's wooden components or slow burial in the sediments of the seafloor.

State of preservation

Copper and its alloys from a submerged shipwreck site will corrode at a rate dependent upon the chemical composition of the object, its microstructure, and the amount of oxygen in the water.[135] Dramatic differences can be found in cupreous nails that have been subjected to varying states of oxygenation, even within a single fastener.[136] This is exemplified by the Kızılburun fastener assemblage as there is great variation in the state of preservation of the mostly fragmentary fasteners.

Many of the fasteners are covered by varying amounts of concretion. Unlike iron, generally, copper or copper alloy prohibits biological growth and concretion. This in turn helps preserve wood with a cupreous nail embedded in it or in close proximity.[137] As the wood decays, however, acetic acids, ammonia, and amine are released which cause the copper or copper-alloy fastener to break down.[138] Eventually the wood disintegrates completely, the fastener breaks down into copper by-products (oxides and sulfates in an aerobic

[133] For an explanation of copper metal transformation into copper oxides and copper sulfates, and the subsequent impregnation of the surrounding wood see Benoit 1961, 191-94.
[134] The same processes were documented by Tylecote in his examination of the Marsala Punic ship fasteners (Frost 1981, 297).
[135] MacLeod 1985, 12-3; 1994, 269.
[136] McCarthy 2005, 140 cites an unpublished report by Vicki Richards 1996.
[137] Kahanov et al. 1999, 281.
[138] North and MacLeod 1987, 80-1. For a thorough explanation of copper and copper alloy by-products in both aerobic and anoxic marine and terrestrial environments, also see Tylecote 1987, 80-8.

environment), allowing the biological process to advance and concretion to form.[139]. This process is seen in the Kızılburun nails.

A second process that can cause copper to become concreted normally results in higher amounts of concretion. A cathodic protection, induced upon the cupreous metal by adjacent iron artifact(s), spurs an increased amount of calcareous accumulation on the cupreous fastener.[140] This, in turn, has two effects to help reduce, albeit not halt, corrosion of the cupreous metal. First, it reduces the amount of oxygen available to the surfaces of the metal, thus creating an reduced oxygen, if not completely anaerobic, environment. This new environment explains the black powdery surface on several of the fasteners after their removal from the concretion.[141] This covering is by-product of the devolution of the metal and gives the fastener an appearance much like that of iron. Second, the calcareous matrix reduces the normal pH of the seawater (8.0 ± 0.2) by as much as two full points.[142] Fresh water is the defining point for pH neutrality at 7.0. By reducing the pH to a level closer to 7.0 or a neutral pH figure, the metal fastener is provided more protection. This process can also be seen within the Kızılburun nail assemblage (Figure 4.5). One specific example of the process involves nail Lot numbers 655.03 (cupreous) and 655.04 (ferrous). These were found side by side, with the cupreous fastener having substantial amounts of concretion protecting a relatively well preserved small nail.[143]

---

[139] North and MacLeod 1987, 83-4. Concretion from aerobic environments is made up of a combination of inorganic calcite (calcium carbonate), organic calcareous materials deposited by mollusks such as toredo worms, and foraminifera, and suspended grains of sand and detritus.
[140] See MacLeod (1985, 10-3) for a thorough coverage of cupreous metal corrosion processes.
[141] MacLeod 1985, 11-2.
[142] MacLeod (1985,11-2) showed that pH in aerobically formed concretion was reduced to 6.17 ± 0.08.
[143] Nail Lot 758 was found directly beneath the iron anchor stock and also had significant amounts of concretion.

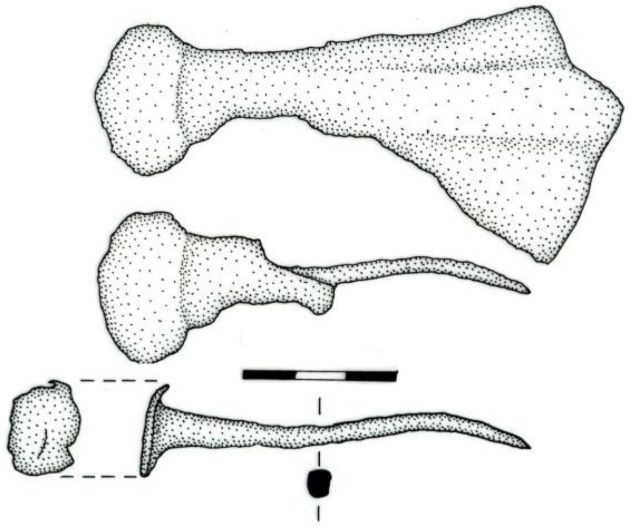


Figure 4.5. Lot 655.03- stages of concretion buildup. Drawing by Mustafa Korkmaz.

In addition to chemically produced concretion, other materials exist on the fasteners in the form of a patina. Cupreous patinas, usually bluish in color, are left by degrading cupreous metals and are a clear indicator of the base material, yet not always evident or developed. Therefore, each fastener, or fastener fragment, was tested with a small rare-earth magnet to distinguish ferrous from non-ferrous content. In almost all cases, it was possible to determine that the fasteners were non-ferrous. All but four fasteners examined are of non-ferrous metal, the remaining four being the concreted iron fasteners that were completely corroded and replicated by casting with epoxy resin. There are, however, several examples that exhibit ferro-magnetic qualities (discussed below).

Fasteners have been categorized according to nail-head shape and a set of dimensions including maximum shank width (although these were originally square in section, many examples have lost edge definition), maximum head diameter and maximum length, when available. Only fasteners that included a nail head were used to distinguish categories, as this ensured a distinct nail and not a section of a broken fastener. Nail heads completely clear of concretion were rare in the assemblage and nail-head size was also a limited diagnostic characteristic as the outer edges are thinner and more susceptible to deterioration processes. Maximum shank width was measured below the nail head (where it existed) at a point where concretion and deterioration by-products were non-existent or minimal in order to get maximum preserved dimensions. Length was taken for each broken fragment and if joins could be identified overall lengths were calculated and recorded. As most fasteners are fragmentary, original dimensions were seldom obtainable. Complete nails, particularly large nails, are rare and the length dimension therefore, was of limited utility in sorting/categorizing the fasteners.

In addition to the small group of iron nails, three groups of cupreous fasteners have been designated and assigned to one of three categories; "large", "small", and "other." Categories were assigned by the researcher and are not necessarily indicative of the shipbuilder's intended purpose or function. All nails in the "large" and "small" categories with a discernible cross section have square shanks (Figure 4.6) and taper from head to distal end. "Other" fasteners include a group of 46 fasteners with a unique, conical shape with similar maximum diameter and length, as well as other anomalous fastener forms.

Comparanda

Ancient nail typologies from shipwrecks that one can use for comparative material are rare. The nails from the Kyrenia ship have been studied in depth,[144] yet offer little for comparative data as they are morphologically different in both style and manufacture method. The nails of the first century C.E. Blackfriars vessel have likewise been morphologically analyzed. Two types of nails were distinguished in the construction of the vessel. However, these nails are also drastically different from those of the Kızılburun nails both in size and form.[145] Therefore, comparisons were made with nails having more similar attributes. Using the aforementioned categories, dimensions and characteristics of the fasteners, comparisons with existing typologies of iron nails from Roman cites at Inchtuthil

[144] Foerster-Laures 1990, 175-9; van Duivenvoorde 2011, personal communication.
[145] There are several key differences. The Blackfriars nails have a unique head shape, described by Marsden as a hollow cone, flattened on top; they were round in section, except for the last few centimeters; they were made of iron and they are generally much larger in scale (Marsden 1967, 16, plate 4).

and the Brading Villa, both in England, were attempted and appear both successful and relevant.

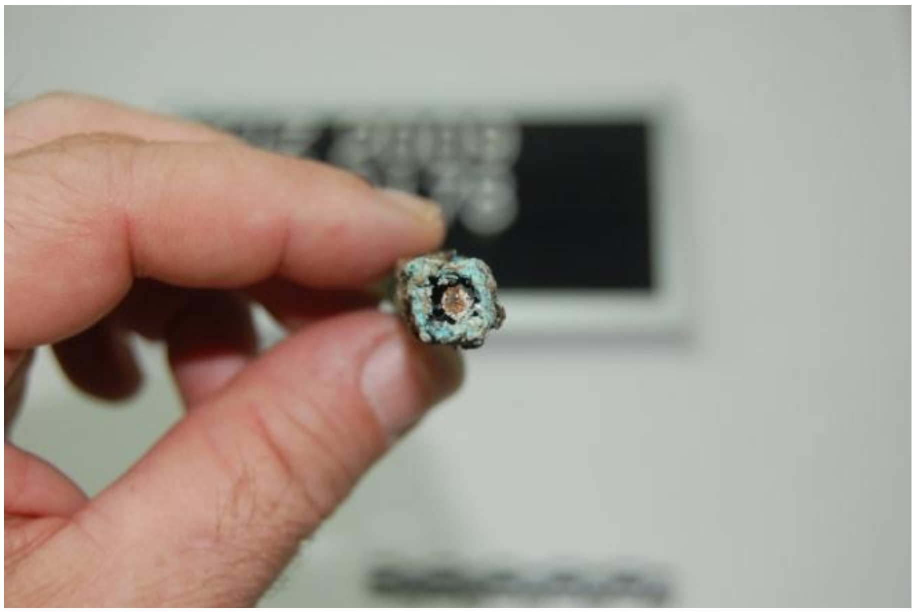


Figure 4.6. Square nail section- Photograph by the author

Six classifications were employed at Inchtuthil in Perthshire, where a first century C.E. horde of approximately 900,000 iron nails was found buried and in a good state of preservation.[146] Angus et al. determined that although the nails from Inchtuthil fell into distinct classifications, there was great variation within the categories, particularly in fastener length.[147] Shank width, however, was remarkably consistent and fit with the model proposed

[146] Angus et al. 1962. Nails were buried to prevent them from falling into the hands of enemy Scots tribes, as the Scots valued iron more than gold or silver for the production of weapons. This report also concisely explains the forging process for iron nails that would also have been used for copper and copper-alloy nails. The researchers felt confident that the six categories they defined were the same that would have been delineated by the Roman military quartermaster that ordered the nails.

[147] Although six classifications were designated (Groups A-F), Group A was sub-divided into A i and A ii. However, when described, these classifications were reduced to Group A, Groups B-E, and Group F.

in my description of dimensions above.[148] Two of the nail types matched well with types published by Cleere for nails from the third century C.E.[149] villa at Brading.[150] Brading type I corresponds to Group A of the Inchtuthil typology, while Brading Type III (a-e) matches with Groups B-E from Inchtuthil. All of these nails share a square-sectioned shank, a flat head, a limited range of shank widths, and varying overall lengths.

Both the Brading and Inchtuthil typologies define large nails by their pyramidal-shaped heads and square shanks of maximum widths ranging between 0.95 and 1.75 cm. Lengths vary significantly from 15.2 to 37.1 cm. In both cases, the authors believed that they had been used for fastening heavy timbers. Based on head shape and shank widths, the few definable large fasteners from the Kızılburun assemblage fit within this type.

Large fasteners

Foerster notes that until his reporting of the cylindrical nails from the Kyrenia shipwreck, "All metal nails of ancient times, whether they be of copper, bronze, or iron, have a square section and tapered form."[151] Tapering round nails were reported from Inchtuthil (Group F) and were shown to have been produced by rounding the edges of a square-sectioned shank.[152] This is supported by Marsden[153] showing that the iron nails of the Blackfriars vessel were of round cross-section until the final one or two inches of the distal end. Foerster was apparently unaware of the finds from the Blackfriars vessel or from Inchtutil.

---

[148] Shank width was found to be remarkably consistent (all were exactly 1/8") in the small nails from the Inchtuthil collection (Angus et al. 1962, 957).
[149] Based on dating by ceramic typology, the villa was occupied from the second century through the end of the fifth century, but the author is less than firm in the abandonment date.
[150] Cleere 1958, 56.
[151] Foerster-Laures 1990, 175. Cylindrical fasteners have also been reported from a Hellenistic assemblage from Ashkelon, Israel (Galili et al. 2010, 130-31). Additionally, Fitzgerald (1995, 159, table 5) reports cylindrical nails of iron from the Jeaune-Garde B shipwreck in France, and of bronze from the Athlit Ram recovered off the Israeli coast, from the remains of the shipwreck at Antikythera, Greece, as well as from his own research at Caeserea, Israel.
[152] Angus et al. 1962, 958.
[153] Marsden 1967, 16.

As observed in the assemblage of nails from Kızılburun, some nail shanks degraded from copper to copper sulfides and began to erode away. Edge definition is often lost and the shape of the shank becomes more rounded until eventually it looks as though it was a nail with a circular section. Further, during the reduction process, the wood of a treenail may adhere to the nail and absorb corrosion products of the degrading metal, giving the shank of the nail an apparent cylindrical shape. However, this is not the case. All fasteners with a discernible shape in this category have a square cross section.

Nail head shape is not easily defined in the Large Fastener category, as nearly every nail head that survives is covered by concretion or has degraded to the point that the head shape is no longer discernible. The few nail heads that survive without concretion have a flattened pyramidal shape (Figures 4.7a and 4.8a). The flattening of the head is most likely the result of the force exerted on the nail to drive it into the timber as demonstrated in tests conducted by Angus and his colleagues.[154]

In examples of large nails that are only minimally degraded or obscured by concretion, maximum shank widths range between 1.0 and 1.8 cm. For comparison, shank widths from Group A of the Inchtuthil fasteners range between 0.95 and 1.75 cm,[155] while those of Type I of the Brading assemblage range between 0.95 and 1.3 cm.[156]

[154] An unused 25.4 cm nail with a pyramidal head (Group A nail) was driven into a 10 cm timber to see if the force of driving the nail into a timber was sufficient to flatten its head. The authors demonstrated that the force exerted on the nail by hammering was sufficient to flatten its head (Angus et al., 1962, 957). Further tests on the materials and methods of nail production from the Inchtuthil assemblage were carried out and published by Boniardi et al. (1992).

[155] Angus et al. 1962, 957-8.

[156] Cleere et al. 1958, 56.

Figure 4.7. Photographs of large cupreous nails from the Kızılburun shipwreck; a. Lot 920 b. Lot 177.03 c. Lot 1329. Photographs by the author.

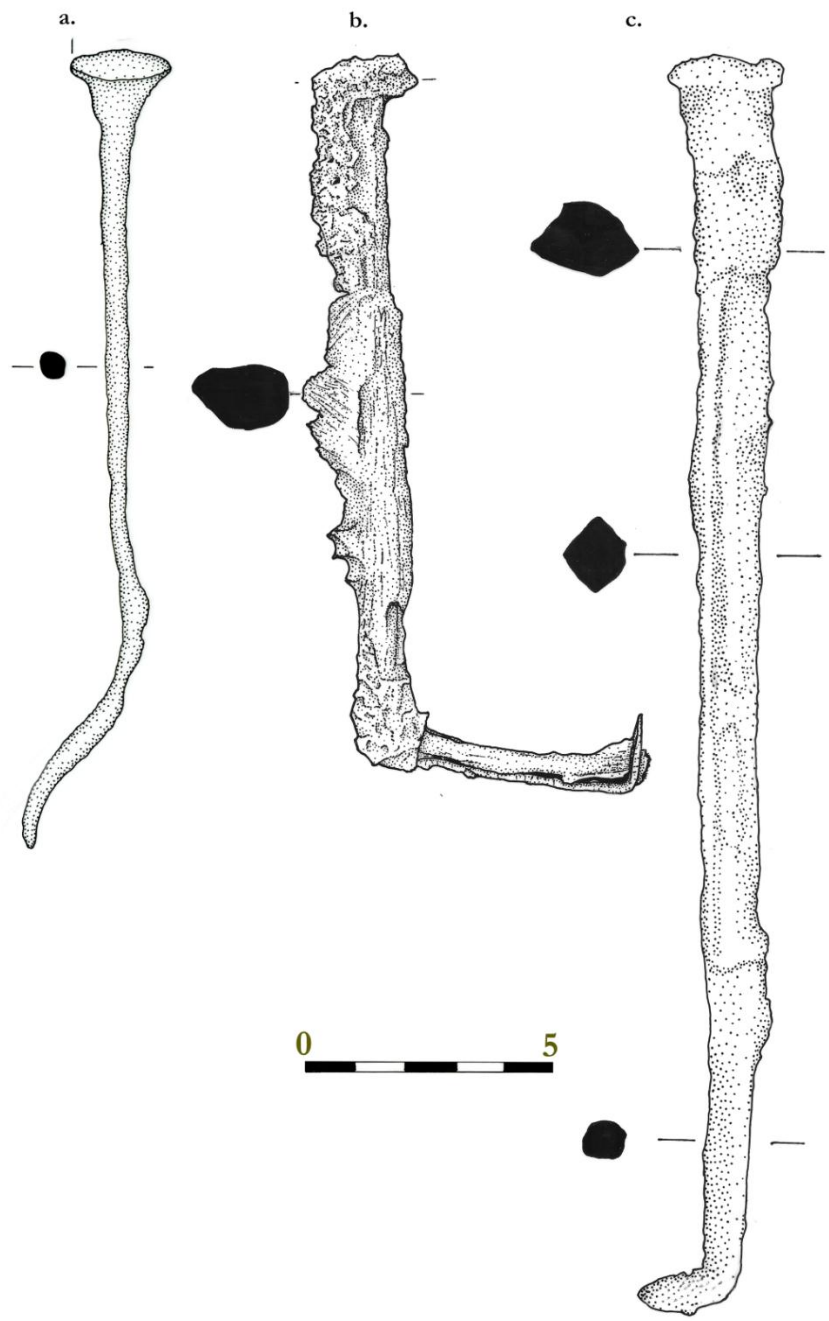


Figure 4.8. Drawings of large cupreous nails from the Kızılburun shipwreck; a. Lot 920 b. Lot 177.03 c. Lot 1329. Drawings by Mustafa Korkmaz (a and c) and Seçil Kayacık (b).

Only six large nails from Kızılburun survive sufficiently for direct measurement of length. Lengths range from 21.3 (Lot 177.03) to 25.4 cm (Lot 1329). Since most of the clenched portion of fastener Lot 1329 is missing, the actual unclenched length would be approximately 7 cm longer,[157] making the total length approximately 32 cm before it was clenched. Although the Kızılburun nail lengths are limited to only a few examples, the dimensions fit within the length ranges provided by both the typology of the Inchtuthil group A nails (22 - 37 cm) and that of the Brading Type I nails (19 – 31 cm).

Small fasteners

As with the large fasteners, the small nails have a square cross section and taper towards the distal end. This group consists of 12 nails having a shank width ranging between 0.6 and 1.0 cm; nine of which (75%) fall between 0.6 and 0.7 cm. Lengths range between 5.2 and 9.8 cm. Head diameters range from 1.5 to 1.9 cm, with one outlier at 2.5 cm (Lot 1657). However, small fasteners have two distinct nail head shapes; a pyramidal shape that is often flattened in the center, presumably from the force of driving the nail into a timber (Figure 4.9a,b), and a flat shape (Figure 4.9c,d). The distinct shapes of the nail heads suggest the nails served different purposes, although those specific purposes are not known. It is reasonable to presume that one of the two types was used to secure the ceiling planking to frames, as a square nail hole of small dimensions (0.55 x 0.64 cm) was located in a section of ceiling planking (6023) (Figure 4.10). The nail hole dimensions are consistent with shank widths in the small nail category.

[157] Steffy (1994, 47-8, fig. 3-28) notes that at least 7 cm were left for clenching of framing nails. This figure holds true for clenches that survive in the Kızılburun assemblage as well.

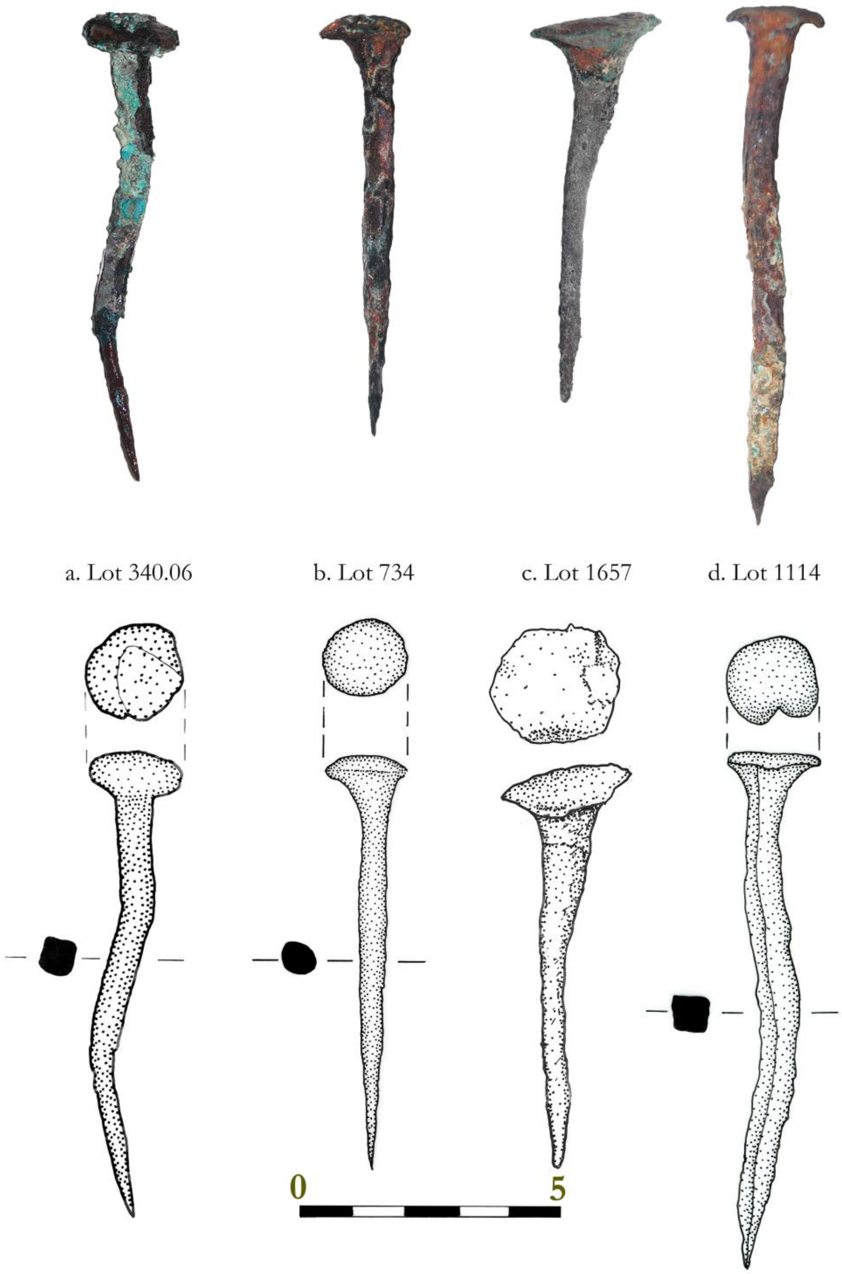


Figure 4.9. Small cupreous nails from the Kızılburun shipwreck.. Photographs by the author. Drawings by Mustafa Korkmaz (a and b) and Seçil Kayacik (c and d).

Figure 4.10. Ceiling planking fragment (6023) with small nail hole and nail head impression. Photograph by the author.

The Brading type III fasteners are reported to be the most common Roman nails. They have a flat head, lengths between 5.1 and 15.2 cm, and a square sectioned shank. Small nails in Groups B-E of the Inchtuthil typology correspond to type III of the Brading assemblage. The small nails with flat heads from the Kızılburun group fit well into these groups, however, neither group is reported as having small nails with pyramidal heads comparable to those from Kızılburun. Lot 1657 is potentially anomalous in that its shank tapers sharply from its large head (2.5 cm), and has a larger shank width (1.0 cm), making it slightly more robust than the other 11 in this category.

Other fasteners

Forty eight fasteners have been assigned to this category of which 46 have an overall diamond or conical shape with no distinct shank and are generally of very small size, with lengths ranging from 0.7 - 3.7 cm and head diameters ranging from 0.4 - 1.7 cm (Figure 4.11- Other Fasteners).

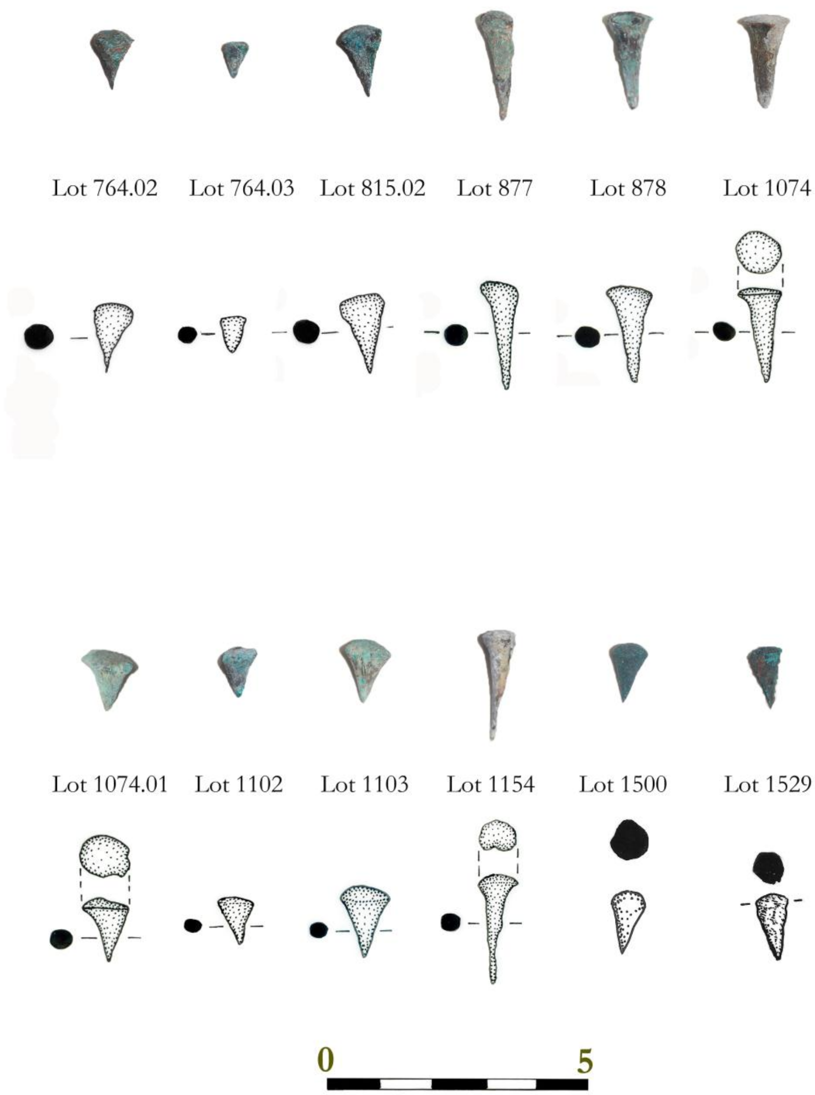


Figure 4.11. Other cupreous fasteners from the Kızılburun shipwreck.. Photographs by the author. Drawings by Mustafa Korkmaz.

These were measured for length and maximum diameter, which is always at the top of the nail unless it exhibited a diamond-shaped profile (e.g. Lot 1103). As demonstrated in the analysis of the copper nails from the fifth-century B.C.E. shipwreck at Tektaş Burnu, these fasteners consist primarily of deteriorated nail heads, the original dimensions of which cannot be determined with any certainty.[158]

One fastener, clearly of a different type than the rest (Lot 1219) (Figure 4.12), has a maximum length of 2.4 cm, a maximum shank width of 0.5 cm along clearly defined edges, and head diameter of 1.5 cm. As with many of the nails in the Small Fastener category, the head of this tack has a flattened, pyramidal shape. It is possible that many of the degraded, indefinable nails originally had this form and similar dimensions. Similar objects have been described as tacks used for securing lead sheathing to hulls, albeit there is no evidence of lead sheathing from the Kızılburun site.[159]

One final nail type (Lot 365) has a large shank with a very flat, poorly defined head, if it can be considered a head (Figure 4.13). The fastener is incomplete, so it is not possible to comment on its overall length, but given the shank width (1.1 cm), it was likely a rather long nail. Its head is vaguely defined, being only slightly wider than the shank. It is possible that this is a broken nail that had been reused in another capacity, although this remains speculative.

[158] Personal communication with Wendy van Duivenvoorde (2011). Upon cutting these remnants longitudinally, the grain of the copper clearly matched that of nail heads shaped by hammering.
[159] Kahanov (1999, 220, 224) reports from analysis of lead-sheathed ancient ships that tack length ranged from 1.0-5.5 cm with an average of 1.96 cm, and head diameters ranged from 1.05-4.5 cm with an average of 1.79 cm. For more on the use of lead sheathing on ancient vessels see Hocker 1995.

Figure 4.12. Fastener Lot 1219. Photograph by the author.

Figure 4.13. Fastener Lot 365. Photograph by the author.

Iron fasteners

Three iron nails and one possible bolt were recovered from the wreck site in the form of calcareous concretions. Very little iron survived within the concretions, thus facilitating epoxy casting techniques to recover a facsimile of the original artifact.[160] None of the casts has revealed a complete fastener. All are missing their heads. However, it is possible to comment on the shapes and sizes of the fasteners. All three nails show a distinct square shank. Two of the three nails are remarkably similar in size; Lot 144 has a shank width of 0.65 cm and is 8.8 cm in length, while Lot 950 has a shank width of 0.64 cm and also is 8.8 cm in length. Lot 144 was found with a group of broken cupreous nails approximately 5 m upslope of the northernmost drums (drums 1 and 2). Lot 950 was found approximately 3 m upslope of Lot 144. Both nails were in a rough line with the keel and therefore centrally located along the longitudinal axis of the hull. Neither nail is clenched and therefore unlikely to have been framing nails. Based on similarity of their sizes, they were likely utilized for the same, albeit unknown, purpose.

The third nail (Lot 655.04) was also found in the upslope area, but on the starboard side of the keel and not associated with either of the other two iron nails. It is slightly larger than the other two iron nails, both in surviving length (at least 12.1 cm) and width (0.9 cm). It has a bend of approximately 45°, but this may simply be a result of the wrecking event, or intended to serve some unclear purpose.

What is possibly an iron bolt was discovered in two sections of concretion that joined together (Lots 396 and 497). These were cast with epoxy resin as a single mold to produce a replica of the artifact. Although the cast is of good quality, it is not possible to discern the head from the distal end as the shank is cylindrically shaped; nor is it possible to distinguish any features due to excessive corrosion and/or deterioration of the bolt prior to the formation of the concretion mold around the bolt. No timber has been located with a hole

[160] Epoxy casts were made of the artifacts by fellow Nautical Archaeology Program student, and INA-BRC interim head conservator, Kimberly Rash as part of her M.A. thesis (*Reconstructing an Assemblage of Iron Artifacts from a First-Century B.C.E. Shipwreck at Kizilburun, Turkey*, forthcoming- supra n. 83) on the iron artifacts of the Kızılburun shipwreck.

of similar diameter. One potential function is as a wale-to-frame fastener, a common feature in vessels from the second century B.C.E. through the second century C.E.,[161] but little evidence exists to support this idea as the actual function of this fastener. Whatever purpose this bolt had on the ship, no evidence survives to reflect its function.

The sparseness of iron fasteners on the Kızılburun site may be due to any number of reasons, including; 1. minimal use of iron fasteners by the shipwright(s), 2. the highly corrosive nature of iron artifacts in seawater, especially those that are as diminutive in size as nails, 3. small scale repairs to the hull, or 4. they may not be directly associated with the hull itself, but instead were part of items carried on the ship, as no evidence of iron fasteners was found in the examination of the ship's timbers, which is an admittedly modest corpus.

FERRO-MAGNETISM AND ELEMENTAL COMPOSITION

All fasteners and fastener fragments were tested using a small, simple rare-earth magnet in order to discern possible ferro-magnetism in the seemingly cupreous nails (Figure 4.14).[162] Six specimens (Table 4.1), of the 1062 inventoried items in the assemblage were found to be ferro-magnetic. Through close examination and removal of all corrosion products and concretion deposits, where such existed, these fasteners were determined to have been made of cupreous materials.

[161] Parker 1992a, 27. Parker's suggested dates may be extended to the seventh-century as the shipwreck excavated at Yassı ada, Turkey also exhibited this feature (van Doorninck, 1982, 51).
[162] Ferro-magnetic materials have characteristics of materials such as iron, nickel and cobalt will react mechanically when a magnetic field is introduced, such as that created by a rare earth magnet.

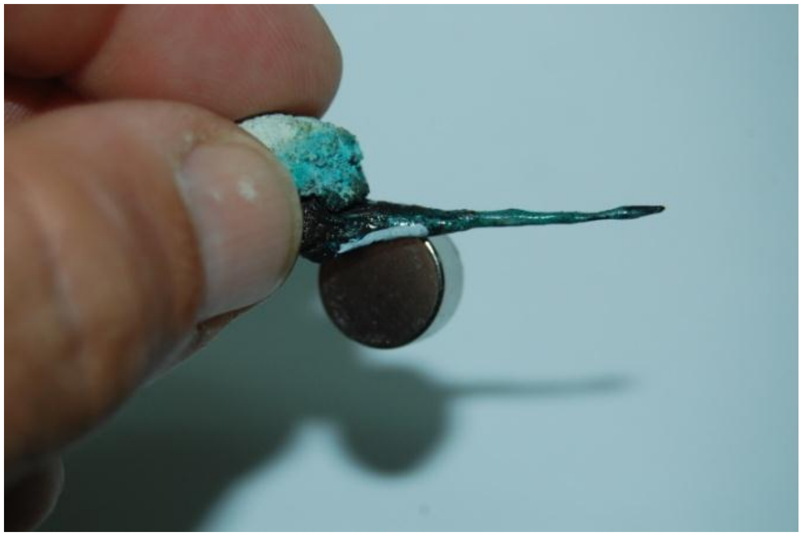


Figure 4.14. Ferro-magnetic cupreous nail (Lot 181.04). Photograph by the author.

Lot #	Locus	Function
37.02	17	small nail
177.03	20	framing nail
181.04	3	unknown
308.01	19	small nail
620.01	18	unknown
1219	U1	tack

Table 4.1. Cupreous nails that exhibit ferro-magnetic properties.

All six ferro-magnetic cupreous nails were excavated from different areas of the wreck site, albeit all in its upslope portion, suggesting that they were not collectively used for a specific purpose in a specific location (i.e., not all on the same side of the keel) or for a specific repair. Furthermore, no single function could be assigned to these nails as one (Lot 177.03) is a double-clenched framing nail, two (Lots 37.02 and 308.01) are small nails, one is a tack (Lot 1219), and two are of indeterminate form and size (Lots 181.04 and 620.01).

Elemental analysis of some of the fasteners, including two nails from the ferro-magnetic group (Lot 308.01 and Lot 1219), was performed by the author using a Bruker Tracer III-V portable XRF (pXRF) (Figure 4.15) in order to determine the primary and secondary metals of manufacture, as well as to determine the source of the ferro-magnetic characteristics of the six nails listed above.[163] Once the pXRF is set up the analysis is very simple. The apparatus is designed to be a point-and-shoot analyzer, but may also be utilized on a tabletop stand for best results. Two key aspects for obtaining proper analysis results are exposing a clear and clean surface for the examination, and isolating that surface from the surrounding surfaces. Isolation of the surface is best accomplished by setting the apparatus on a tabletop stand and placing the artifact to be analyzed directly in front of the laser, under a small metal cover.[164]

In total, 16 nails were tested and compositional data were collected from eight. The other eight nails could not be analyzed for various reasons, including a lack of flat surfaces (important for getting usable data), and nails that were too large to be isolated under the cover of the pXRF. Two samples were cleaned of all concretion and corrosion layers and, mechanically polished, while the rest were analyzed with their existing patinas and corrosion layers left in place.

[163] Portable XRF units have limited capabilities and accuracies, yet are ideal for non-destructive determination of base metal composition, as well as qualifying inclusive metals. Caution should be used when attempting to accurately quantify trace metals and data obtained from a pXRF should be supported with instrumental analysis not subject to the same limitations.
[164] In 2011 visiting scholar/petrographer Yuval Goren (Tel Aviv University) was kind enough to train Deborah Carlson, Ryan Lee, and myself in the use of the pXRF.

Figure 4.15. The author analyzing nails using the Bruker pXRF. Photograph by Ryan C. Lee.

Of the eight fasteners from which data were retrieved (Table 4.2), all showed a percentage of copper (Cu) ranging from 87.60 to 95.55%. Seven nails had Cu percentages ranging from 93.6 to 95.55%. The 87.60% value came from one of the ferro-magnetic nails (Lot 1219), which contained 3.53 to 4.80% iron (Fe), nickel (Ni), and zinc (Zn). The iron and nickel inclusions are the source of ferro-magnetism and all are natural by-products of the smelting of chalcopyrite ore, from which copper is obtained.[165] The second ferro-magnetic sample showed similar results, but in smaller percentages. Since a pXRF samples a localized portion of the nail, different values could be obtained by analyzing different spots on the nail. Although more formal compositional analysis is pending, it has been demonstrated that these six fasteners are ferro-magnetic due to inclusion of iron and nickel, even though the fasteners of this ship were manufactured from a very high-percentage copper (base metal). Once formal analyses are undertaken, which may include analysis by Inductively Coupled

[165] Tylecote 1962, 7, 22, 55.

Plasma Mass Spectrometry (ICP-MS), the results may show that the copper percentage is actually higher, possibly even approaching nearly pure copper.

Lot #	Exposure Time	Cu %	Fe %	Ni %	Zn %
233	31 sec	95.55	2.04	1.12	1.63
655.03	50 sec	93.73	1.22	1.08	0.89
308.01	41 sec	94.53	2.62	0.93	1.42
1488	60 sec	96.12	0.40	2.33	3.69
1219	30 sec	87.60	3.52	4.08	4.80
1194	30 sec	93.60	2.10	0.58	0.43
881	30 sec	94.20	2.45	1.07	1.98
872	30 sec	93.84	0.93	3.30	4.03

Table 4.2. pXRF elemental analysis results of eight copper nails from the Kızılburun assemblage.

PLUG TREENAILS

There are several methods for securing frames to planking in ancient ships; lacing, treenails, and nails with or without plug-treenails (a wooden treenail used with a nail). Fitzgerald states that, "In Greek and Roman Mediterranean ships, the most common method of securing frames to hull planking was by means of treenails." [166] He adds that nails unassisted by treenails are extremely rare in documented wrecks of the Graeco-Roman period.[167] The fifth-century B.C.E. shipwreck at Tektaş Burnu has the earliest known use of plug-treenails.[168] Thus, plug-treenails appear to be a common feature of Graeco-Roman ships, particularly those of at least 20 m length[169] and were utilized in the construction of

[166] Fitzgerald 1995, 155.
[167] Fitzgerald 1995, 163.
[168] van Duivenvoorde (in press).
[169] Fitzgerald 1995, 162.

ships from at least the fifth century B.C.E. until at least the end of the first century C.E.[170]

Plug-treenails prevent splitting of the timbers through which nails are driven.[171] This is accomplished by pre-drilling holes from the interior of the vessel, through the frames and through the hull planking. A cylindrical wooden dowel or treenail is then driven through the hole and cut flush with each surface. Next a nail with a maximum width close to that of the diameter of the treenail is driven from the exterior, through the wooden treenail and double clenched to the inner face of the framing element (Figure 4.16).[172]

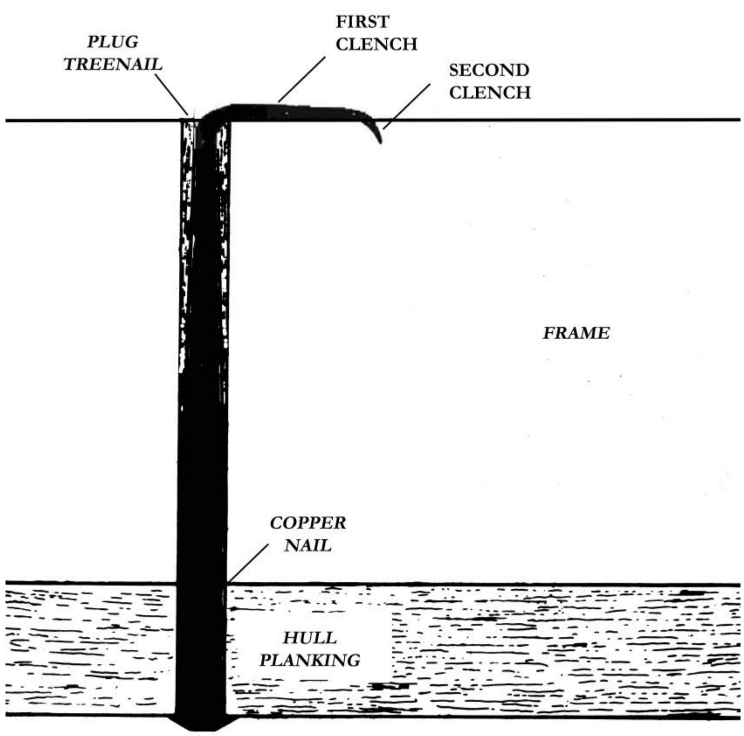


Figure 4.16. Nail double clenched to inner face of a frame (profile view). Drawing by the author.

[170] Fitzgerald (1995, 157-62) cites at least 13 shipwrecks constructed with plug-treenails in this period, although plug-treenail use is not confined to this period.
[171] Steffy 1985b, 91.
[172] See Steffy 1985b, 91, as well as Fitzgerald 1995, 157-8, for a more thorough explanation of the development, use, and purpose of plug-treenails. Also see Marsden (1967, 29).

During initial examination of the ship's timbers, no treenails were observed. In degraded wood, plug-treenails can be especially difficult to see with the naked eye,[173] particularly on the outer face of a frame, as the treenail and the nail are of such similar sizes. However, during analysis of the copper nails, it was noted that many retained fragments of wood along their shanks, which suggested the use of plug-treenails. Closer examination of the wood fragments confirmed their use in the vessel (Figure 4.17**)**. Treenails that survive (16 clear examples) are cylindrical in shape and have diameters ranging between 1.1 and 1.7 cm, with an average of 1.3 cm and a mode of 1.2 cm occurring five times. One would presume the treenails to be of the same or approximately the same diameter if a single auger was used to drill the holes into which these treenails were driven, but there is some variation in their diameters. This variation may be due to preservation processes, to augers of different diameters used in drilling the holes, or the roughly shaped treenails were of slightly different sizes, which, when driven into the uniformly drills holes, fit snugly into some and more tightly in others, expanding the diameter of the hole.

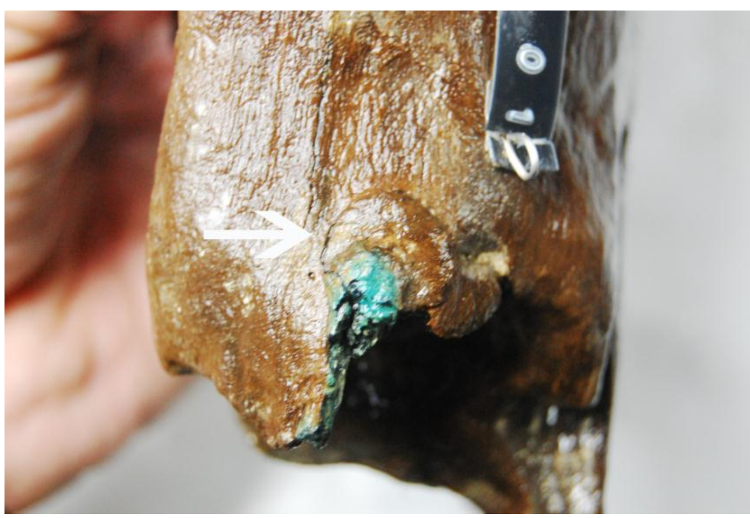


Figure 4.17. Plug-treenail. Photograph by the author

[173] van Duivenvoorde (forthcoming).

Wood samples were taken from six plug-treenails in four separate frames (5000 [2], 5002 [2], 6004, 6008) for species identification. Four of the six sampled treenails are of *Pinus brutia*, while the two samples from frame 5002 are of *Pinus nigra*.[174] Softwoods, such as pine, are common materials for treenails, as they offer some resistance to the nail, but not so much to make it difficult to drive them through the treenail. [175]

CLENCHING

The practice of clenching nails over the inner faces of frames to secure planking to the frames to the planking was a common practice in Mediterranean shipbuilding from the sixth century B.C.E.[176] through the end of first century B.C.E.,[177] regardless of the metal used for the fasteners.[178] In the construction of the Kızılburun ship, double clenched copper nails were used to fasten the frames to the planking.

Many framing fragments retain the clenched tip section of the nail. Steffy notes that nail clenches often constitute at least 7 cm of the nail's total length.[179] This has proven to be the case in those nails retained in the frame pieces, although a true average of the clench length is not possible to quantify as the first clench, or hook, is generally embedded in the timber, making measuring difficult without specialized equipment. Nail example L177.03 is an intact, loose framing nail from which first and second clench dimensions can be taken. The first clench is 1.6 cm in length, while the second clench is 5.8 cm for a total of 7.4 cm.

---

174 Sincere gratitude is offered to Nili Liphschitz of the Institute of Archaeology – The Botanical Laboratories at Tel Aviv University for all wood identifications.
175 Fitzgerald 1995, 157-63. Fitzgerald suggests that a softwood treenail would be more forgiving to the nail than a hardwood one, although he notes that several ships are reported to have had plug-treenails made of hardwoods. Marsden (1967, 16) notes the use of oak for plug-treenails in the Blackfriars vessel.
176 The earliest examples are from Jules Verne 7 (Pomey 2001, 428-9) and the Gela wreck (Freschi 1991, 206-7), both of the late sixth century B.C.E.**;** examples from the fifth-century B.C.E. include; Tektaş Burnu (Jurgens *et al*. 2003, 400; van Duivenvoorde (in press), Ma'agan Mikhael (Yovel 2004, 83-104), and Porticello shipwrecks (Eiseman and Ridgway 1987, 11-6), although the Porticello wreck may actually date to the fourth-century B.C.E. (Lawall 1998).
177 Fitzgerald 1995, 167, 171. The Nemi barges from the first century C.E. are notable exceptions.
178 Fitzgerald 1995, 167-71, Table 6.
179 Steffy 1995, 48.

Other nail clench measurements can be obtained from 22 nails in frame fragments that retain their clenches. Of these, the exposed portion, or the second hook, ranges from 4.7 to 9.0 cm and averages 6.2 cm in length. At least 1 cm would be needed to form the first clench (or hook), and to this figure should be added the average length of the second clench to estimate the total clench length, which averages 7.2 cm, thus supporting Steffy's conclusion.

Frame nail pattern

Nails were staggered across the central axis of the inner face (width) of frames with an alternating pattern; one nail being closer to the foreword edge and the next closer to the aft edge of the frame (Figure 4.18). As with the staggering of the tenon pegs in the keel, the purpose of staggering framing nails is presumably to reduce the effects of possible perforation along the length of the frame and to prevent splitting of the timber. This staggered nail pattern can also be seen in planking section 3007 where two nails exist within a frame impression left on the interior surface of the planking.

Nail clenches were oriented either roughly parallel to one another and the edge of the frame, or with both the upper and lower clenches parallel and slightly angled in the same direction. In both variations the clenches pointed toward the keel along the length of inner face of each frame (Figures 4.18 and 4.19b). This is a different pattern than is seen in the frames of the Kyrenia ship,[180] the Blackfriars ship,[181] or the New Guy's House boat,[182] each of which also had staggered framing nails, yet each fastener's clench was oriented towards the center of the frame in a herringbone pattern (Figure 4.19a).[183] Whether there is a functional difference between the nailing pattern seen in the Kızılburun frames and the herringbone pattern has not been determined. However, the herringbone pattern may offer a slight increase in torsional pulling resistance, but this remains to be tested.

[180] Steffy 1985b, 84, 93; 1994, 54.
[181] Marsden 1967, 12 plate 2, 14 plate 3, 17, 18 plate 5, 21 plate 6.
[182] Marsden 1967, 32 fig. 14.
[183] Steffy (1985b, 54) notes the downward herringbone pattern as a common attribute of Mediterranean shipbuilding for several centuries.

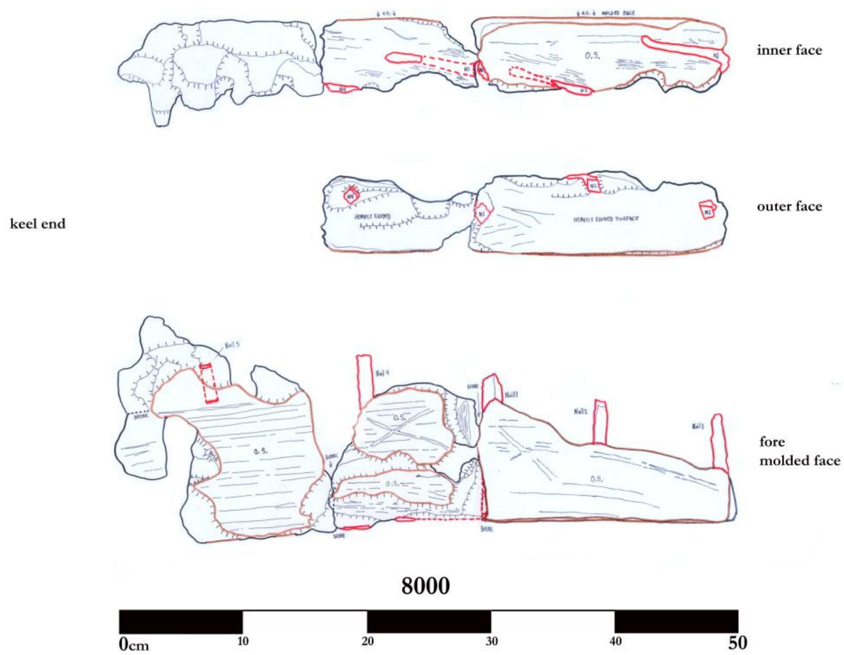


Figure 4.18. Frame 8000 showing nail staggering. Drawing by the author.

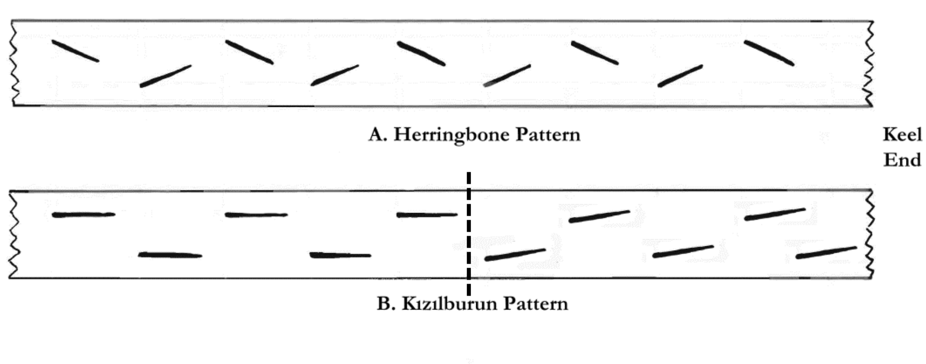


Figure 4.19. Frame nail patterns. Image by the author.

OTHER INFORMATION GLEANED FROM FASTENERS

In addition to metal choice and fastener dimensions, the examination of the fasteners coupled with direct observation of the wood brought to light and/or confirmed certain aspects of the ship's construction. Specifically, study of the fasteners corroborated details and observations regarding the dimensions and spacing of frames and planking thickness.

Frame dimensions

Based on a small sample of complete and reconstructed nails, it was possible to obtain molded (thickness) dimensions of several frames. This was accomplished by subtracting the planking thickness of 4.0 to 5.0 cm from the length just beneath the nail head to the top of the clench bend of complete nails, resulting in frame thicknesses between 8.7 and 20.1 cm. Verification of these dimensions is supported by examination of nine framing timbers (3001, 5000, 5001/5002, 5014, 5020, 6004, 6005, 6008, 8000). Due to the degraded state of the original edges of the frames, however, it is uncertain if these timbers are representative of full molded dimensions. The lengths of the clenched nails also suggest that the molded dimension of frames varied. Evidence from two frames shows that molded dimensions increase towards the keel [e.g.: 3001 (12.3 – 19.4 cm) and 5000 (13.6 – 21.4)] indicating the use of sculpted floors.

This is further supported by several extant framing nails. Nail L177.03 is a complete framing nail with shank length from the bottom of the nail head to the first clench of 12.7 cm corresponding to the combined dimension for both planking thickness and the molded dimension of the frame it once secured. By comparison, L1329, also a framing nail, has a shank length from the bottom of the nail head to the first clench of 21.4 cm, corresponding not only to a greater combined planking/frame timber thickness, but also indicating that these dimensions varied. Presuming a relatively standard planking thickness, the inferred data show that floors were certainly sculpted to different molded dimensions over the keel. As previously noted in Chapter III, sculpted floors are a common feature of Graeco-Roman shipbuilding.

Frame spacing

Rows of nails were discovered in situ stretching across the east-west axis of the site in several areas. In areas 19/20 there were 55 nails (46 with heads) in nine rows found with their heads down (Figures 4.20 and 4.21). Area U7 had 14 nails forming two parallel rows. Areas U1 and U8 had patterns of similarly aligned nails. With the confirmation of the keel running in a north-south direction and the absence of other wood remains or artifacts beneath these nails, they are almost certainly planking-to-frame nails. Thus, from the patterns of these nails, an average frame spacing of 25 cm was determined. This figure was observed early in the excavation, although it was unclear if the frame pieces from which the measurement was derived had been displaced from their original positions in the hull. This spacing figure is further supported by examination in the laboratory of planking fragments from area U1 that retain impressions of frames.

Planking –to-framing nail breakage pattern

While cataloging nails from the wreck, a pattern of breakage was noted on nail fragments that retained their heads, suggesting a common weak point. Of the 1062 non-ferrous nail fragments, 396 retained heads. Of these 396, 178 (approximately 45%) were broken between 3.9 and 5.1 cm length along the length of the preserved nail shank (Figure 4.22). An additional 31 fragments (totaling 53%) with heads were broken between 3.7 and 5.3 cm. These figures might have been higher if the heavily degraded nail fragments could have been conclusively identified as either small nails or large frame nails. However, even without the ability to eliminate the non-descript nails, there still appears to be a clear correlation between this nail breakage pattern and planking thickness. This deduction is supported by post-excavation examination of the planking fragments (discussed in Chapter III). In the laboratory, the original planking thickness was determined by the discovery of a fully preserved knot in a planking fragment as well as by a nail fragment (Lot 1145.03) embedded in a planking section, which was broken at 3.9 cm below the nail head. To further support this idea, the rows of plank-to-frame nails found in Areas 19 and 20 were examined with the result that of 46 distinct framing nails, 21 were broken between 3.9 and 5.1 cm (46%), and another 25 were broken between 3.7 and 5.3 cm (54%). These figures

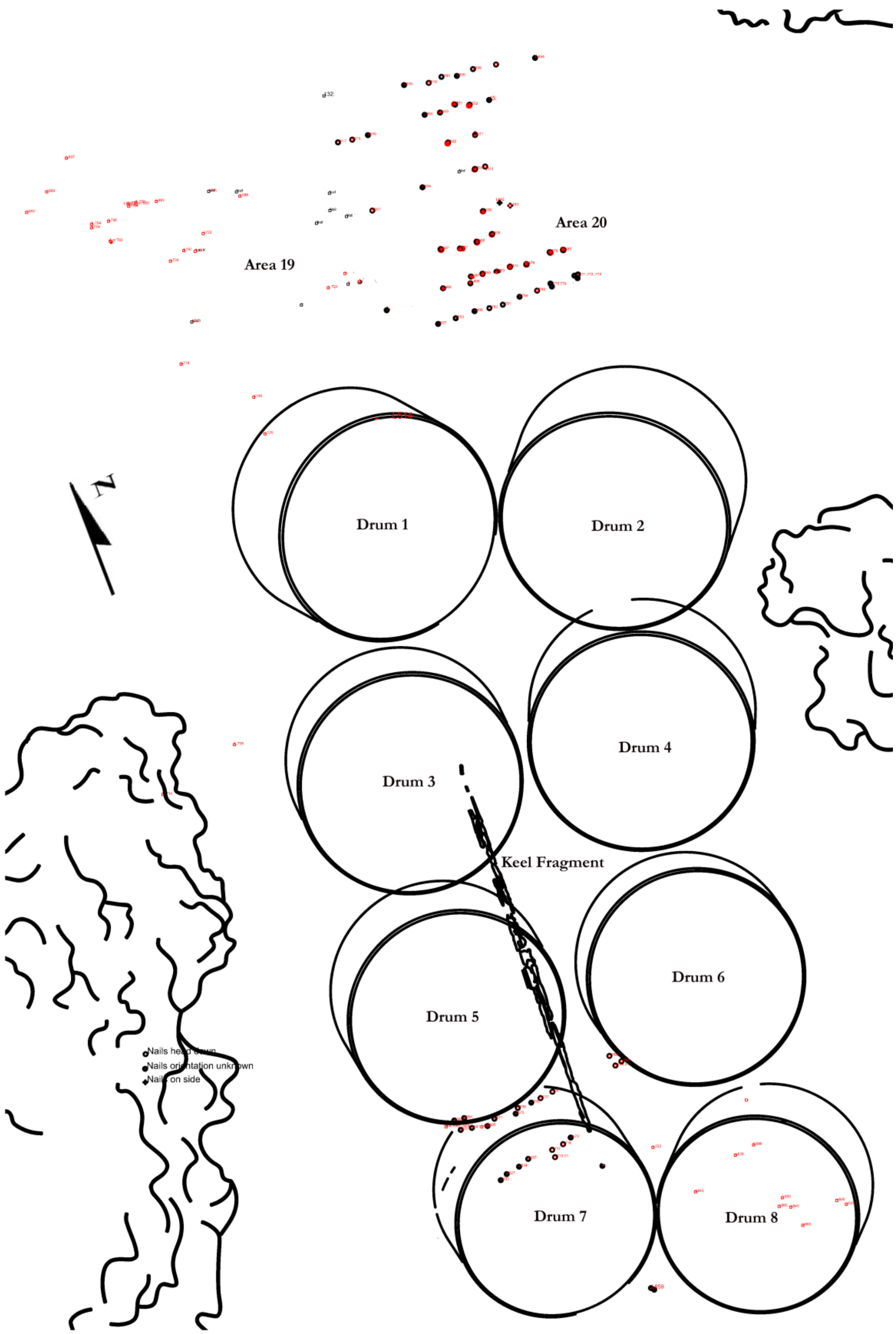


Figure 4.20. Site plan with nails found heads down. Image by Sheila Matthews and the author.

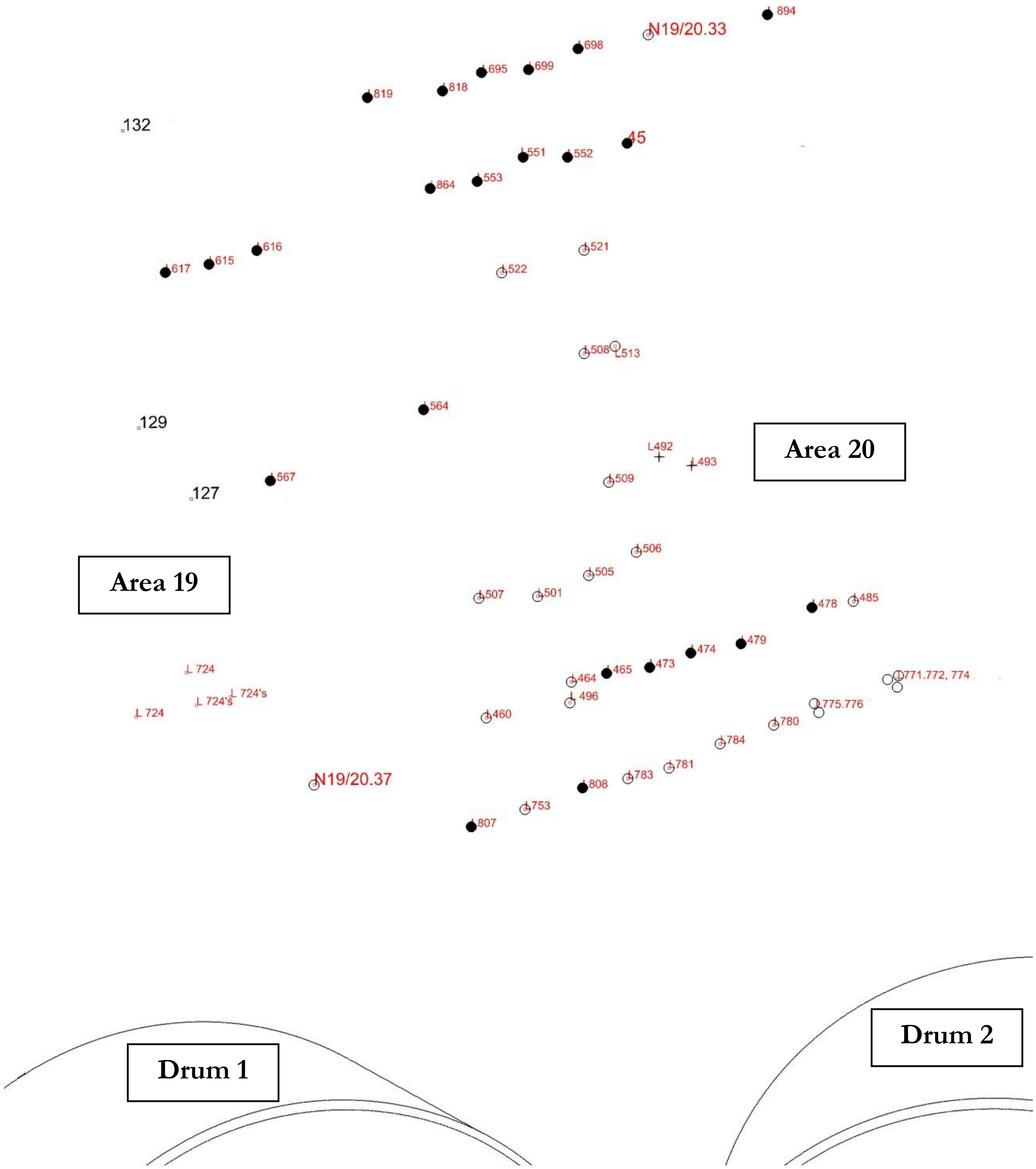


Figure 4.21. Detail of Figure 4.20 showing rows of nail on the seafloor in areas 19 and 20. Image by Sheila Matthews and the author.

correlate well with the overall nail breakage pattern figures and are likely higher had some fasteners not been eroded beyond recognition and thought to be tacks. A further verification of the original plank thickness became apparent later when documenting and modeling the keel, which had a rabbet width is 4.0- 4-5 cm.

Figure 4.22. Nail Lot 888.01 with head. Photograph by the author.

False keel

Also notable were three nails (Lots 1724, 1741, 1742) found beneath the keel at the time of its raising. These nails were clearly still attached to the bottom of the keel, but were freed and fell in place on the seafloor when the timber was lifted.[184] All three fasteners were positioned with their heads down. This suggests the use of a false keel that was attached to the bottom of the keel to protect its outer surface. However, no other evidence for such a timber survives; there are no wooden fragments of a false keel, and the outer face of the

[184] Personal communication with Sheila Matthews, who was the primary excavator of the keel section in 2009. She felt strongly that the nails were not simply displaced nails adhering to the bottom of the keel, but were indeed driven into the timber.

keel is in such poor condition that the three nails could not be positively matched to their corresponding holes in the keel. However, Lot 1724 was remarkably close in size to a nail hole observed from the top (inner face) of keel fragment 5011.25. If this nail and nail hole on the keel fragment are associated, then the nail must have penetrated the entire thickness of the keel, which seems unlikely given the size of the nail hole (1.5 cm width). There is no evidence of a nail clench on the inner face of the keel or other timbers that may have been attached to the inner surface of the keel. Moveover, if this nail had indeed originated from this hole, no additional nail remnants are preserved in the keel section. A small section of the nail shank disintegrated upon lifting, making the nail's original shank length and shank width indeterminate.

Material loss

Steffy estimates over 3000 fasteners were used in the construction of the 14.5 meter-long Kyrenia ship's hull.[185] The Kızılburun ship was certainly larger, by approximately 25%, yet only 396 distinct nails survived (442 if the 46 remnants mentioned as "Other" fasteners are considered). Given that the width of the planks making up the scarfed plank section of 3007 are approximately 24 cm and that framing nails were regularly spaced at an average of 9.3 cm, one may assume that as with the Kyrenia ship, there were at least two nails attaching each plank to individual frames. Since an average frame spacing of 25 cm was also shared by both vessels, it is likely that the Kızılburun ship had at least approximately 25% more than nails than the Kyrenia ship, or an estimated 3750 fasteners. If this estimate is accurate, then only about 13 to 15% of the ship's original fasteners are accounted for. For comparison, I would estimate the extant wooden remains of the vessel to be less than 5%. This in turn attests to the large amount of material lost from the hull of the vessel.

[185] Steffy 1994, 49.

CHAPTER V
TIMBER RECONSTRUCTIONS, HULL DIMENSIONS, AND CONCLUSIONS

TIMBER RECONSTRUCTIONS

J. Richard Steffy suggested that "the quality and quantity of information to be gleaned from ancient fragmentary hull remains are usually limited only by the ingenuity of the observer."[186] To that end I have tried to utilize every available source of data including the modeling of several incomplete timbers in order to gain a better understanding of the material and to see if a closer approximation of the original dimensions and shapes can be attained. Both drawings and three-dimensional (3-D) modeling were employed for key members of the vessel; namely the keel, garboard and a reconstructed floor from approximately midships. Certain inferences had to be drawn, but every attempt has been made to remain true to the evidence at hand and keep conjecture to a minimum. Computer modeling was done using Rhinoceros 4.0 and Adobe Photoshop CS4 software.

Modeling the keel in 3-D

The maximum *surviving* dimensions of the keel (8.3 cm wide on the inner face, 11.5 cm sided, and 18.3 cm molded) may give the impression of a keel with gracile dimensions. To understand the original dimensions of the keel, these data, coupled with measurements from 21 cross-sections, were used to project the minimum original size of the keel that was at least slightly greater than the surviving dimensions as shown in Figure 5.1. This projected profile was used to create a 3-D model of a section of the Kızılburun ship's keel in Rhinoceros 4.0 software (Figures 5.2 and 5.3).

No rockering of the extant keel is evident. In fact, there is little discernible change in the keel along its surviving length of nearly 3 m, however, the deteriorated nature of the timber may conceal subtle changes that once existed (e.g. rabbet angles, rabbet surface dimensions,

[186] Steffy 1978, 53.

etc.). If the inner face of the keel was truly as flat and unchanging along the extant section as the surviving fragment suggests, then the model should be highly representative of the original keel and may permit general comparison of its cross-section to that of other shipwrecks. The model is also useful in testing projected drawings of other timbers, such as the partial garboard strake and a floor timber from midships, all excavated from approximately the same area beneath Drum 5.

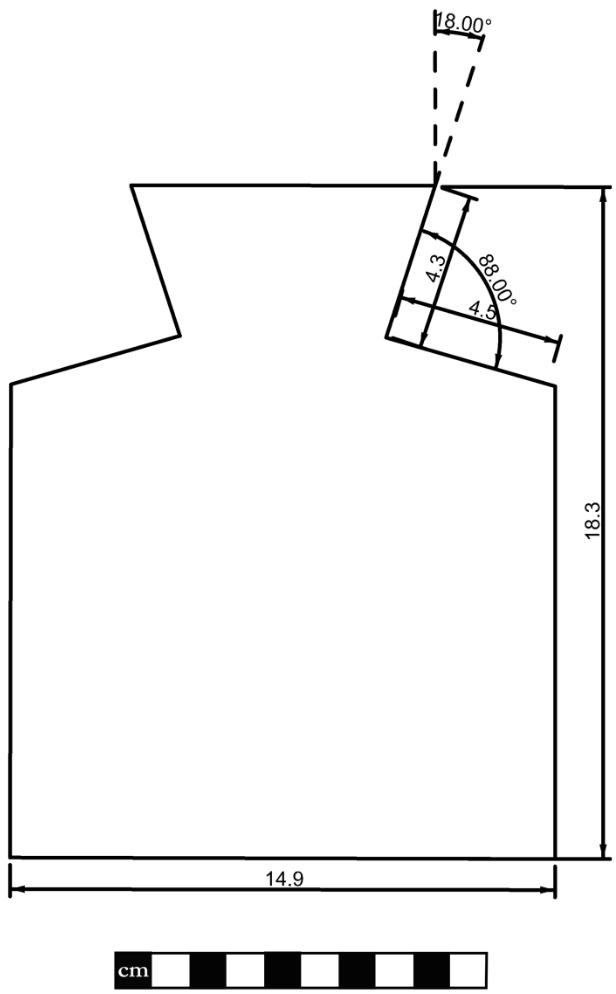


Figure 5.1. Cross-section of the Kızılburun keel. Image by the author.

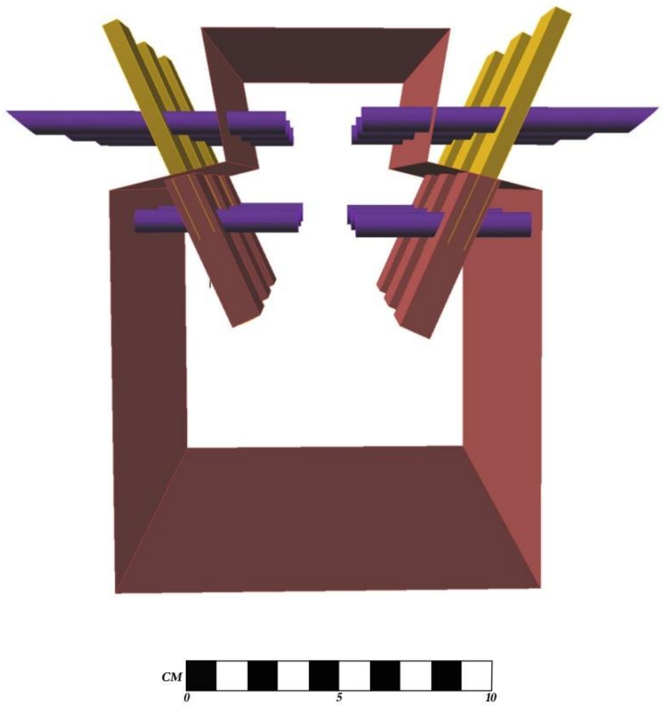


Figure 5.2. 3-D model of the Kızılburun keel cross-section. Image by Sheila Matthews and the author.

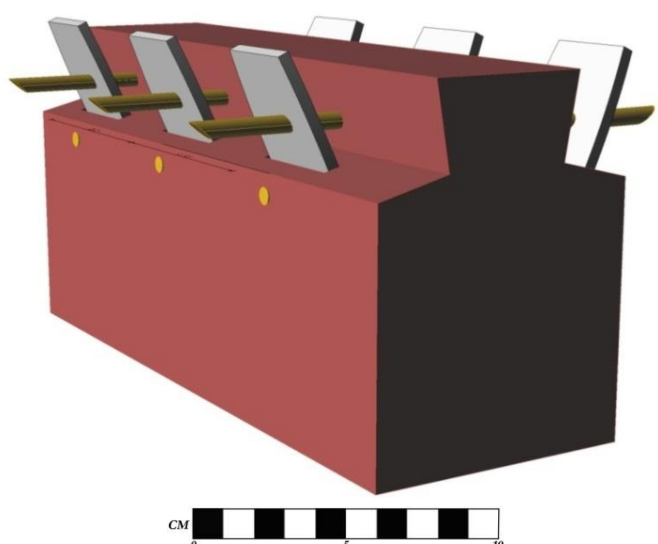


Figure 5.3. 3-D model of the Kızılburun keel. Image by Sheila Matthews and the author.

Projecting the garboard strake

In my examination of the keel, the sharp deadrise (75-80°) of the garboard was clear and this became even more prominent in the model. This initially suggested a wine-glass hull shape, like that of the ship excavated at Kyrenia, Cyprus. Since the garboard had been disarticulated from the keel, it was necessary to fit the two together in order to understand their relationship to each other and gain a better understanding of the shape of the lower portion of the hull. However, due to the highly degraded nature and fragility of both timbers, this was not physically possible. As an alternative, information gleaned from its 3-D keel profile was coupled with information from the garboard fragment in order to make a drawing of the keel and garboard junction (Figure 5.4)

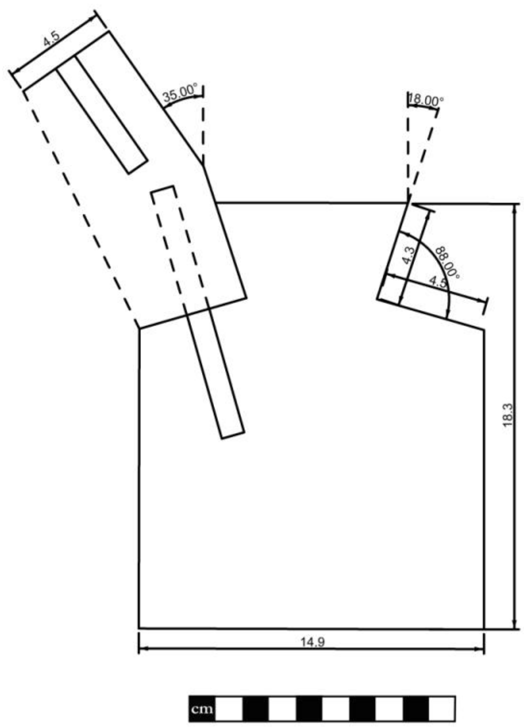


Figure 5.4. Garboard strake and keel in profile. Image by the author.

The upper portion of the port side garboard strake is shaped to form an angle of approximately -35˚ (145˚) from vertical. There is no extant original outer surface; it has been entirely destroyed by biological activity and degradation processes. However, knowing the rabbet width in which the garboard was seated (4.5 cm) and using the planking thickness of 4.5 cm, the outer face could be reconstructed. The hypothesized reconstruction gives the garboard a robust five-faceted section.[187] This is a conjectural shape, as the outer face may have been a sculpted surface like the inner face. However, the five-faceted (pentagonal) shape would have afforded more strength to the garboard and appears to be a common and therefore perfectly feasible shape to consider for modeling purposes. Whichever shape the original garboard employed does not change its function in this discussion.

Projecting a floor from near midships

Although there are breaks between frame fragments 5000, 5005, and 5007, it is clear these fragments belong to the same frame. Reconstruction is possible based on a slab of marble (Lot 1258- block BAP) that sat atop the timber, which left a defined impression that allowed for very close approximation of the fragment's positions on the original frame and its shape. As previously discussed, the shape of frame fragment 5000, when considered with fragments 5005 and 5007, is highly suggestive of a floor timber.

Frame fragment 5017 was recovered in 2006 from under column Drum 5 prior to the lifting of drums 5-8.[188] Floor timber fragments 5000, 5005, and 5007 were also excavated from beneath drum 5 after it was relocated offsite, albeit a year later. The relationship of fragment 5017 to the other floor fragments was determined four years later (2011) through careful

[187] Similar five-faceted garboards can be seen on the inner and outer layers of planking of the Cavalière (Charlin et al. 1978, Fig. 34, 64 Fig. 39, 66 Fig. 42, 67, 69 Fig. 45, 73 Fig. 49) ship, on the inner planking of the Mahdia hull (Höckmann 1994, 61 Fig. 8), the Madrague de Giens ship (Steffy 1994, 63; Tchernia et al. 1978, 77 Fig. 10, 78, 86 Fig. 12), and the Titan ship (Basch 1972, 46 Fig. 31c). Interestingly, all of these vessels were double planked.

[188] First attempts at lifting the heavy column drums met with logistical problems due, in part, to inadequate equipment for the job. This problem necessitated the removal of some substrate from beneath drum 5, unexpectedly exposing timber 5017. The frame fragment was removed in 2006 for fear of further damage in the lifting process and lifting equipment was subsequently upgraded for the 2007 season and the lifting of the remaining column drums.

evaluation of divers notes, interviews with excavation team members, close scrutiny of in situ photographs, and the examination of the timbers themselves.

As noted by McGee, "sweet wooden curves follow mathematical rules and the spline is the analogue for these rules."[189] By using the curvature of the fragments and average nail spacing of 9.3 cm on the outer surface, seen not only fragments of this floor, but among many of the other Kızılburun frame fragments as well, fragment 5017 can be approximately positioned in relation to the other pieces of the floor timber by extending its natural curvature with a spline, thus allowing for a reconstruction of the port side of a floor timber (Figure 5.5). The timber is drawn as found with the molded forward face up (i.e. toppled 90º downslope).

As found, seven of the eight column drums were canted at varying degrees, with all seven top surfaces canted inward toward the keel. This may suggest the drums had a greater diameter than the distance from the keel to the turn of the bilge (termed the bilge), causing the canting. The topography of the site prior to the wrecking event is unknown, so it is unclear if the in situ, canted orientation of the marble drums was partially a product of site formation or if it is purely suggestive of the original lading of the vessel. After the removal of the column drums from the wreck site, a 50-cm probe was used to gauge where the bedrock started and the amount of substrate that lay between the bedrock and the column drums. In most cases there was more than 50 cm of sandy substrate. Therefore, the topography of the bedrock is not a likely cause for the canted position of the drums.

Presuming a fair amount of symmetry, the reconstructed portion of the floor timber can be mirrored across a vertical plane (the keel) to simulate a full or nearly full floor timber as it would have been originally under Drums 5 and 6 (Figure 5.6).[190] Expanding on this idea, the reconstructed floor timber can be superimposed upon the garboard/keel reconstruction

[189] McGee 1977, 210.
[190] Ships such as the one excavated at Kyrenia, Cyprus have been shown to be somewhat asymmetrical on opposite sides of the keel due to the nature of the construction method (Steffy 1985b, 99; 1992, 77). However, any asymmetry from port to starboard sides of the Kızılburun vessel should not alter the reconstruction significantly.

presented earlier. In this manner, one reconstruction is used to support or refute the other and informs the reconstruction's viability (Figure 5.7). The resulting combined reconstruction hints at the bottom shape of the vessel, but this is still less than conclusive. Therefore, one more element may be added to the model to further test its feasibility.

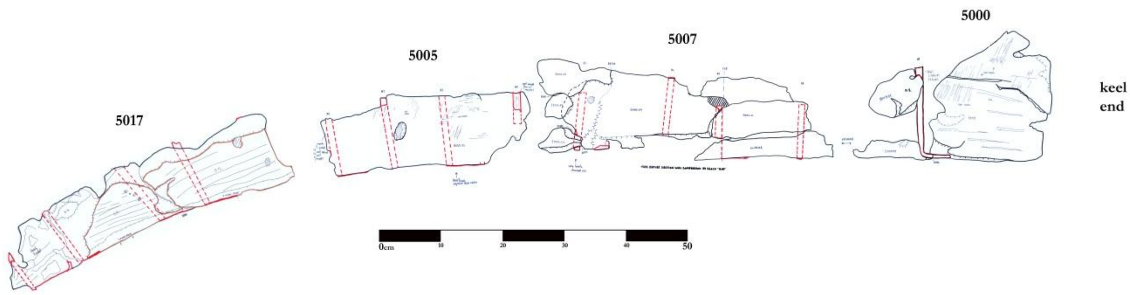


Figure 5.5. Frame fragment 5017 joined with floor fragments 5007/5005/5000 (forward molded face up as found). Image by the author.

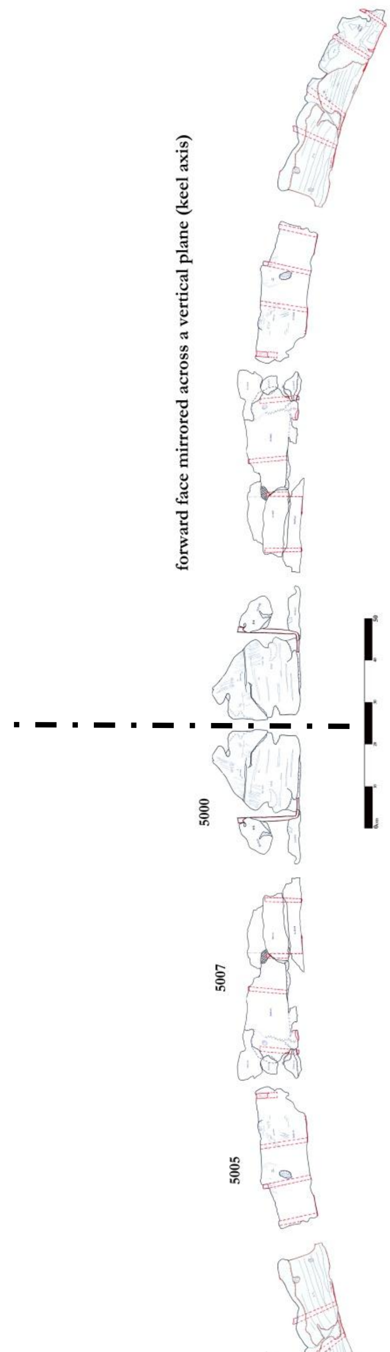


Figure 5.6. Floor fragments 5017/5007/5005/5000 mirrored across a vertical plane. Image by the author.

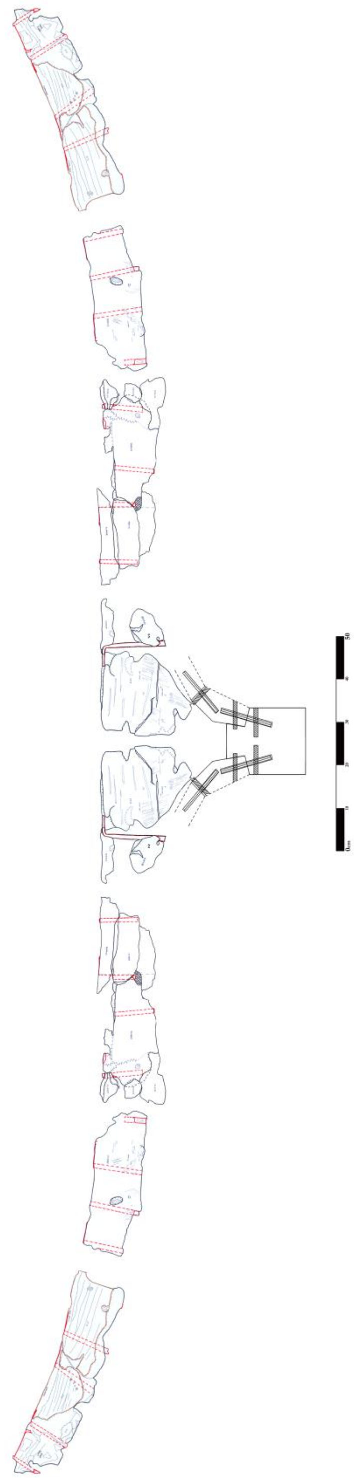


Figure 5.7. Reconstructed floor rotated and superimposed onto the garboard and keel. Image by the author.

The canted, in situ positions of the column drums suggest the drums were of a greater the diameter than the bilge dimension. This hypothesis can be tested by superimposing Drums 5 and 6 (row 3 of the drums) onto the combined reconstruction of the keel, garboard, and floor timber (Figure 5.8), using measurements published in 2010.[191] Additionally, a row of marble blocks was placed under the port side column drums before the drums were loaded onto the vessel. These may have been needed to create slightly more space between the two files of drums in the hold. Another possibility is that Drum 6 rested on the mast step (assuming the use of a mast) and the port side blocks were used to raise Drum 5 to the same level and thus, help balance the load for improved sailing quality.[192] There are two looming problems that stem from this idea. First, there is no evidence of a mast step and second, there seems to have been no room for a mast to have been erected within the presumed central cargo area as there was little room between the column drums, and the capital was placed atop Drums 1, 2, 3, and 4 with two large marble blocks occupying the space atop Drums 3, 4, 5, and 6 (Figure 5.9). Since the heavy cargo could not have moved upslope, against gravity, the only space the mast could have possibly occupied in the central portion of the ship is between Drums 7 and 8, thus placing it aft of midships, making this scenario unlikely.

There are, however, two possible scenarios to accommodate the lack of room for a central mast. First, the mast must have been placed forward of the cargo, either as a foremast rig or an inefficient lone artemon sail. A second scenario was first presented by Long in reference to the Carry-le-Rouet stone carrier; that being the vessel was towed.[193] The concept of a lone foremast (lateen rig) was also suggested in regards to the Kızılburun vessel by Dr. Fred van Doorninck given the obvious lack of space for a central mast. This concept has more recently been revisited by Beltrame and Vittorio in reference to a possible depiction of a *navis lapidaria* in a relief carving at Leptis Magna in modern day Libya.[194]

---

[191] Carlson and Aylward 2010, 150 table 2.
[192] Personal communication with Dr. Cemal Pulak 2012.
[193] Long 1988, 27.
[194] Beltrame and Vittorio (forthcoming) note that this relief is not definitively illustrating a stone cargo. Further, they note the lack of a mast and quarter rudders and suggest it may have been common practice to either tow these vessels or use only an artemon sail, an idea that seems rather problematic due to the poor

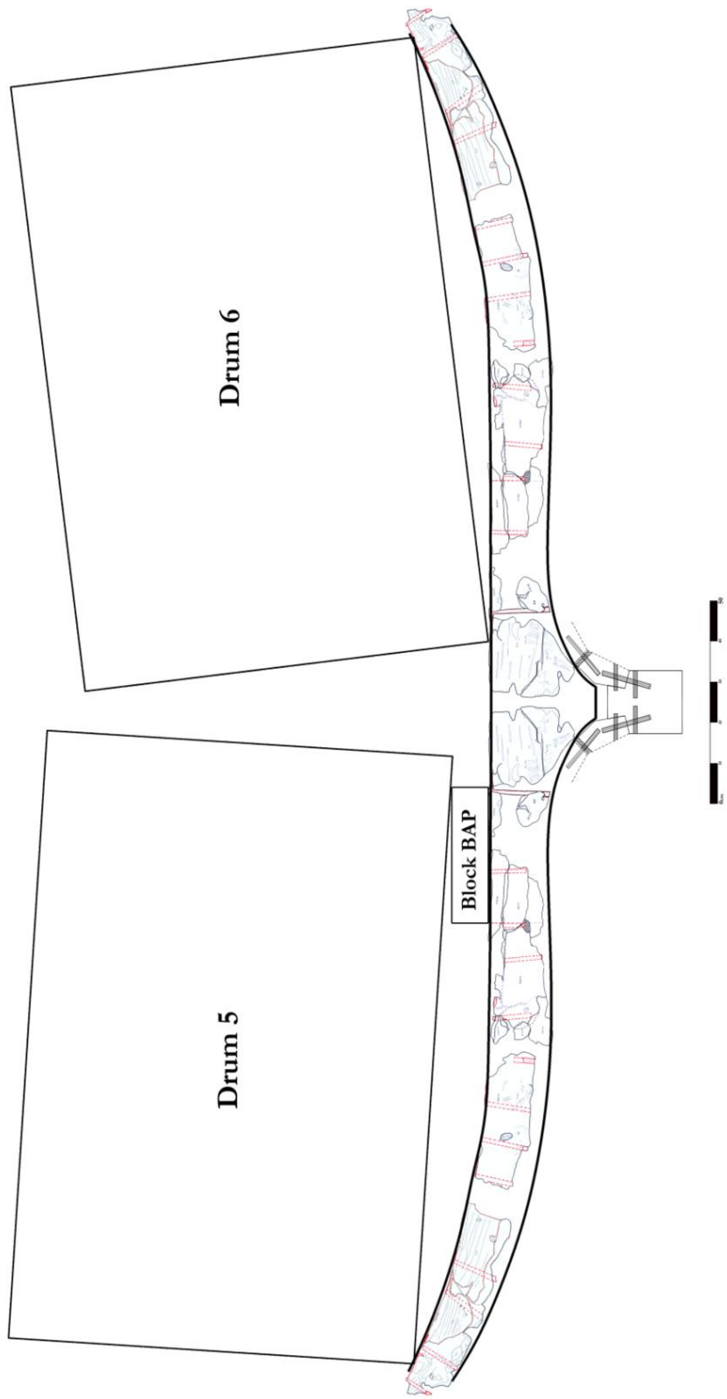


Figure 5.8. Reconstructed floor timber with column drums in place. Image by the author.

sailing qualities offered by such a sparse sail plan. The authors do not cite Long's (1988) report of the Carry-le-Rouet vessel as support for the concept of the stone-carrier being potentially towed.

Figure 5.9. Lading of the Kızılburun cargo. Image by Sheila Matthews.

Returning to the position of the drums in the Kızılburun vessel, if the third row (Drums 5 and 6) of column drums is superimposed on the reconstructed floor timber that they covered, it is evident that the drums would have fit into a hull with the suggested bottom shape, that the drums would have canted in a similar manner as found, and that the reconstructed hull-section presents a feasible profile of the vessel. Presuming a centrally positioned cargo and assuming a minimal downslope shift of the cargo (less than 2 m), this location would have approximately corresponded to amidships.

Although this reconstruction works well, it is not without problems. One primary concern with this interpretation is its potential as a midships or near-midships profile. The extant portion of the modeled floor was excavated from the central area of the column drum cargo, yet evidence suggests an indeterminate downslope slippage of the heavy cargo. If the shift of the cargo was slight, as presumed, the reconstruction should be representative of the ship's midship profile and is among the most diagnostic for comparison to other vessels. However, if the shift was two meters or greater, the reconstruction becomes potentially problematic as the ship should have narrowed on either side of midships towards the extremities. However, this profile reconstruction is not totally inconclusive, as the overall beam of the vessel would have been either the same or slightly greater in the case of more downslope movement of the cargo since the movement would be in a direction of beam narrowing.

The rabbets of the keel are the most telling characteristic of a ship's narrowing in lieu of actual hull planking as the rabbet angle will become more vertical as the keel approaches bow and stern. The original length of the vessel can only be estimated by the artifact scatter (approximately 18-20 m discussed below), and no change in the rabbet angle could be determined. However, the lack of a distinguishable change in the keel's rabbets may simply be due to the degraded nature of the keel. Alternatively, the rabbets may truly be of a static shape and representative of the mid-section of a vessel with little narrowing through the central cargo hold. This is somewhat supported by the lack of extant keel rockering, although far from conclusive. It is, therefore, feasible that the shift of the cargo was negligible.

DIMENSIONS OF THE KIZILBURUN VESSEL

Thus far, the presentation of data has served to establish the construction details of the Kızılburun vessel. In order to facilitate comparison to other Graeco-Roman stone carriers and merchantmen ships of the era, a discussion the of of the vessel's overall dimensions is neccessary. The length and beam of the Kızılburun vessel cannot be precisely determined as both extremities of the vessel are missing. In fact, due to the incomplete nature of the hull remains, one can only estimate its overall dimensions. Howver, this discussion is facilitated by the nature of the heavy cargo coupled with an estimate of the ship's beam dimension.

Factors to consider when estimating length and beam of the vessel are: (estimated) weight of the cargo, dimensions of the artifact scatter, slope and topography of the seafloor on which the vessel came to rest, and dimensions of extant hull remains. Given the ability to model some components of the Kızılburun ship, such as the floor timber previously discussed, we can also consider these data. Finally, some attributes such as keel size, planking thickness, mortise-and-tenon size, mortise-and-tenon spacing, frame dimensions, and frame spacing are likley shared with contemporaneous vessels of similar size and should be considered as well.

Tonnage

Overall vessel size can be best understood given three dimensions; length, beam, and displacement (total tonnage).[195] Parker categorizes vessels based on tonnage,[196] yet many

---

[195] Displacement as defined by Steffy (1994, 251) is the weight of the vessel and its entire burden and shouldn't be confused with tonnage (weight of cargo) or cargo capacity.

[196] As defined by Parker (1992a, 26; 1992b, 89), the smallest category is a vessel of less than 75 tons cargo and is the most common found in all periods from the fifth century B.C.E. through the 12th century C.E. The medium category is defined by vessels ranging from 75 to 200 tons, while those exceeding 200 tons are considered large. Most ancient shipwrecks do not have sufficient remains to calculate the vessel's displacement. Therefore, most excavation reports rarely include this figure, opting instead for estimated

ancient shipwrecks lack sufficient data to determine, or even estimate, their tonnage. The use of tonnage figures can be very misleading and should not be confused with either estimated cargo weight or cargo capacity,[197] both of which are often published in excavation reports.[198] Tonnage is based on the displacement of a vessel. Cargo capacity is often used synonymously with tonnage, but as Throckmorton notes, rarely would a captain be foolish enough to load a ship with more than two-thirds (66.6%) of its full capacity.[199] This concept is supported in Steffy's reconstruction of the Kyrenia vessel that was carrying a weight equal to 64.7% (22 tons) of its 34 ton total displacement).

While extant cargo weight is an important piece of data, it should not be confused with cargo capacity, as many factors can contribute to the loss of cargo (i.e. looting of material, decomposition of organic material, etc.).[200] However, in certain cases where cargo loss appears to be minimal, as is the case with the Kızılburun shipwreck, one may be justified in using extant cargo weight to calculate tonnage (displacement). Defining the parameters of this justification is difficult and should be approached on a case-by-case basis. In the example of the Kızılburun vessel, the cargo is estimated to weigh at least 52 tons.[201] Allowing for the weight of the hull, provisions and crew, an overall minimum estimate of at least 60-65 tons is feasible. Presuming that Throckmorton's statement is correct, that the ship was loaded to a maximum of 2/3 it's full displacement,[202] and that there was minimal organic cargo loss, the tonnage or displacment of the vessel can thus be estimated at a minimum of 90 tons, placing it on the low end of the medium-sized vessels by Parker's standards. Parker does not assign length and beam dimensions to his categories, but perusal of the literature generally suggests small vessels to be of less than 20 m, medium or

---

cargo tonnage or estimated length. For this discussion, I make comparisons to vessels of less than 25 m estimated length.

[197] Steffy 1994, 144.

[198] For example, two distinct publications on the Tre Senghe shipwreck list the tonnage as 45 tons (Volpe 1998, 557) and 100 tons (Freschi 1982, 97). This is likely a case of Volpe reporting the estimated cargo weight, while Freschi offers an estimated tonnage or displacement.

[199] Throckmorton 1972, 76.

[200] Steffy 1994, 251.

[201] Carlson and Aylward 2010, 156. Royal (2008, 63 Table 3) prematurely reported the cargo as 75 tons.

[202] Parker (1992a, 28; 1992b, 95) suggests most ships would have been loaded to capacity. Likewise sailing quality tests performed by Marean (1987, 101) suggests ancient ships needed to be loaded close to capacity for proper performance.

moderate vessels to be of lengths between 20 and 30 m, and large vessels to be of greater than 30 m length.[203]

Length and beam

The Kızılburun vessel came to rest on a moderate slope dropping just over 3 m in elevation over a length of approximately 25 m, with the ship roughly aligned with the slope. Since a heavy lead anchor stock and other artifacts were located on the upslope portion of the wreck, it is unlikely they moved up the slope due to the effects of gravity.[204] It is safe to presume that these artifacts represent one extremity of the ship. Although artifacts from the shipwreck were scattered approximately 25 meters down the slope from the upper limit, most were concentrated in an area 20 m in length. As previously discussed, there appears to have been movement of the cargo and artifacts in a downslope direction, although the amount of movement cannot be determined with certainty. Therefore, based on artifact scatter alone, it is safe to make a conservative estimate of the vessel's length being between 15 and 25 m, suggesting again that it was a small-to-medium sized ship. However, this figure may be further refined.

Although there were no definable extant hull remains from above the bilge (e.g. the sides of the ship, decking, etc.), the distance between the port and starboard bilges must have at least equaled the diameter of two column drums plus a space between them, roughly 3.25 m as shown in the floor reconstruction (Figure 5.8). The sides of the vessel clearly flared out from the turn-of-the-bilge and had to be of a height greater than that of the column drums (approximately 1 meter) plus an appropriate amount of freeboard (likely at least an additional meter at midships). Gassend et al. support this idea in their examination of the Laurons 2 vessel, stating that the depth of hold below the main beam was 1/3 of the breadth of the vessel.[205] Parker adds, "…this convention for the hull-form of a sailing vessel

---

[203] Fitzgerald (1995, 117-28) employs a similar categorization: large vessels are greater than 30 m in length, moderate vessels are between 20 and 25 m, and others are smaller vessels.
[204] Although it is possible that some artifacts were displaced by fishing nets.
[205] Gassend et al. 1984, 101.

holds good for Roman ship, too."[206] Therefore, the breadth of the vessel was likely at least 4.5 to 5 m with a depth of hold below the main beam of at least 1.7 m to accommodate the height of the drums in the hold. When these figures are applied to length-to-beam ratios of ancient merchantmen (3:1 or 4:1),[207] the length of the Kızılburun ship can be alternatively estimated at 15 to 20 m, again supporting the previous estimates. If the depth-of-hold and length-to-beam formulas hold true, then we must conclude the ship was at least 4.5-5 m in breadth and 13.5-20 in length. For comparison, the Tre Senghe vessel is estimated to have had a beam of 5 m, a length of 20 to 24 m, and a tonnage of 100 tons, suggesting that the Kızılburun ship was most likely closer to 20 m in length.[208] Other small-to-medium sized vessels are also listed in Table 5.1 for comparison.

With regard to the reconstructed timbers and dimensions of the vessel, I must reiterate the words of Meiggs, "When the evidence is so fragmentary, there is a serious danger of making too much of too little and imposing a tidy pattern on developments for our own satisfaction.[209] Of course, every attempt has been made to avoid making too much of too little in utilizing the preserved data in reconstructing key elements of the vessel. These models and reconstructions must be recognized as such; based in evidence, but with elements of inference and occasional conjecture.

COMPARANDA

In Chapter III I drew comparisons between some of the less commonly discussed attributes of Graeco-Roman vessels,[210] while in the current section, the focus is on

---

[206] Parker 1992a, 237.
[207] These ratios are attested by several wrecks listed in Table 5.1 and are stated as common for Graeco-Roman merchantmen vessels by Fitzgerald (1995, 124). Fitzgerald (1995, 128) further states that shipwrights, "would have employed general rules of thumb to govern, if only roughly, the relationship between the length (and therefore breadth and depth) of a ship and the thickness of its planking."
[208] Freschi 1982, 97. However, Fitzgerald (1995, 124) suggests the dimensions are based on the artifact scatter and the greater length dimension is exaggerated as it falls outside the common known ratios.
[209] Meiggs 1972, 257.
[210] Fitzgerald (1995, 116) places the outer limit of Graeco-Roman ships in the third century C.E. citing a shift from shell-first to more frame-based techniques around this time. Steffy (1994, 78) similarly restricts Graeco-Roman shipbuilding to the third century C.E. Parker (1992a; 1992b) does not use the term Graeco-Roman, but instead refers to any vessel dated between 150 B.C.E. and 400 C.E as Roman, thus extending the limit through the fourth century C.E. as I have done. My rationale for the extended limit is based on the

comparing typical construction features of the Kızılburun vessel with those of vessels from the Late Hellenistic and Early Roman Imperial periods. It should be noted however, as Gibbins explains, that "…these wrecks vary hugely in their state of preservation, in the extent of investigation, and in the quality of available information."[211] While comparison of many attributes of a particular vessel may be possible, others may not be. Major attributes available for comaparison are summarized in Table 5.1.

Keel size

Four shipwrecks (Chrétienne C, Cavalière, Fiumicino I, and Laurons 2) have a keel with similar or proportionately similar dimensions to those of the Kızılburun vessel's keel (15.5 x 18.3 cm), presuming an 18 to 20 m length for the vessel. These are rectangular in section with a molded dimension greater than the sided dimension. Of interest here is the fact that similar dimensions are shared with vessels carrying amphorae and therefore not particularly concentrated point loads where extra support or more robust construction has been suggested for the latter by previous researchers.

Planking thickness

The Kızılburun vessel had a single layer of planking 4 to 4.5 cm thick. At least eleven wrecks share a similar planking configuration (Congue de Salins, Ashkelon Roman, Carry-le-Rouet, Miladou, Grand Ribaud D, Tre Senghe, la Giraglia, Ladispoli A, St. Gervais 3, Grado, and Laurons 2). Interstingly, three of these wrecks (Grand Ribaud D, la Giraglia, and Ladispoli A) were dolia carriers.[212] Dolia represent smaller, but similar point loads to the column drums of the Kızılburun ship, while Carry-le-Rouet was also a stone carrier with at least a 30 ton cargo.

---

unclear departure from common features of shell-based construction still seen in vessels of the fourth century. The ambiguity of details during this transition is discussed by Pomey 2004, 31-2.

[211] Gibbins 2001, 274.

[212] A dolium is a very large earthenware container, often as much as 190 cm tall, with a wide mouth and no handles. At least ten shipwrecks dating from the first century B.C.E. to the third century C.E. apparently carried as many as 14 dolia as a primary cargo. For a thorough discussion of the description and use of dolia see Brenni 1985. Also see Marlier and Sibella 2002 and Gianfrotta 1990.

	Shipwreck (country)	date	length (m)	beam (m)	tonnage	keel (cm)	frame s x m (cm)	frame sp. (cm)
1	Chrétienne C (FR)	2nd c. BCE	15-16	5.5-6	15	12 x 18	8 x n/a	38
2	Conque de Salins (FR)	2nd c. BCE	15	>2.2		19 x 9	12-14 x n/a	80-96
3	Apollonia 1 (LY)	2nd-1st c. BCE	15					
4	Ashkelon Roman (IL)	2nd-1st c. BCE	15-25					
5	Carry-le-Rouet (FR)	2nd-1st c. BCE			>30		12 x 10	
6	Cavalière (FR)	2nd-1st c. BCE	13	4.6	27	11 x 16	10 x 20	30
7	Grand Congloué B (FR)	2nd-1st c. BCE	23					
8	Miladou (FR)	2nd-1st c. BCE	15			9 x 11	7.4 x 12	23-27.5
9	Dramont A (FR)	1st c. BCE	25	7				27
10	Grand Ribaud D (FR)	1st c. BCE	18		>52		8-10 x 10-12	
11	Tre Senghe (IT)	1st c. BCE	20-24	5	45-100*			
13	Diano Marina (IT)	1st c. CE	22-25			13 x 17		
14	Fiumicino I (IT)	1st c. CE	19				6-10 x 6-12	
15	la Giraglia (FR)	1st c. CE	20			7.2 x 6	8-11 x 10-15.5	21-33
16	Herculaneum (IT)	1st c. CE	8.6	2.2		9.5 x 11.5	5 x 5	24
17	Kinneret (IL)	1st c. CE	9	2.5		14.5 x 12	6 x 7	25
18	Ladispoli A (IT)	1st c. CE	18-20	>3.3			10 x 20	25
19	St. Gervais 3 (FR)	1st c. CE	17			11 X n/a		
20	Grado (IT)	2nd c. CE	16.5	6.1	>25	12 x 20	9-10 x 14-17	
21	Laurons 2 (FR)	2nd c. CE	15	5			20-22	
22	Torre Sgarrata (IT)	2nd c. CE	30		>160, 250			
					> estimated cargo weight			

Table 5.1. Small to medium shipwrecks from the second century B.C.E. through the second century C.E. with published dimensions of relevant hull features, as available.

	plank th. (cm)	mortises (cm)	mortise sp. (cm)	ceil. th. (cm)	primary reference
1	2.9-3.6	3-5.5 x 8-16 x 0.7	12		Joncheray 1975, 41-77.
2	3.4-4.6	5.5-10 x 10-18 x 0.7-1.5	14-20		Roquette et al. 2004, 35-8.
3	3	6 x 16 x 1			Laronde 1987, 322-30.
4	4-5				Galili et al. 2010, 125-45.
5					Long 1986, 22-7.
6	3	6 x 12 x 0.6	11	3	Charlin 1978, 9-94.
7	4.5 & 2.2 †	5-7 x 6-8 x 0.6	16-18		Benoit 1961.
8	2.4-4.3	6.5 x 14 x 0.6	8.8-13		Dumontier and Joncheray 1991, 109-74; Long and Ximenes 1988, 159-83.
9	2.5-3 & 3-4 †	6 x 13 x .75 outer 8 x 16 x 1.4 inner	15 outer 16 inner		Santamaria 1973, 133-6.
10	4	6 x 8 x 1	16	4.4	Hesnard et al. 1988, 1-180.
11	4				Fitzgerald 1995, 176; Parker 1992, 435.[1]
13	6	8 x n/a x n/a	12		Pallarès 1995, 127-39.
14	3.5-4.5	4.7 x 8-9 x 0.6	16.2-74		Boetto 2008, 29-62.
15	2.9-4	4.8 x 10.7 x0.9	12.8-15.8	4-6	Sciallano and Marlier 2004, 70-2; 2008, 113-52.
16	2.5	5.2 x 5.1 x0.5	13		Steffy 1985, 519-21; 1994, 67-71.
17	3.1	5-6 x 5-7 x 0.5	12		Steffy 1990, 29-47; 1994, 65-7.
18	4-4.5	5.5 x 15 x 1.5	15		Carre 1993, 9-30.
19	3.5-4.5	7 x13 x0.7	13.2		Fitzgerald 1995, 174, 177, 179, 233, 250; Liou and Gassend 1991, 157-264.
20	2.5-4.5				Beltrame and Gaddi 2005, 79; 2007, 138-47.
21	2.5-4.5	6 x 13 x 0.4	12	3	Gassend et al. 1984, 75-105.
22	7.2	12 x 16.7 x 1.1	15-20		Steffy unpublished.

Table 5.1. Continued.

A ship constructed by means of a shell-based philosophy relies heavily on the planking for strength, while frames offer secondary strengthening. As Steffy notes, "It appears that shipwrights in the first century B.C.[E.] still considered the planking shell a primary source of hull strength…"[213] With this in mind, one might expect the planking of a shell-based ship carrying a stone cargo to be rather thick and robust. What has been found in the study of this vessel is somewhat surprising in that the planking is not remarkably thick; but, instead, of common thicknesses used among contemporary shipwrecks.

Mortise-and-tenon size

When considering mortise-and-tenon joints in terms of the strength they offer a hull, size is important, but the spacing of these joints is equally important as demonstrated in experimental tests conducted by Pulak.[214] However, with the addition of frames, stringers, and ceiling planking over time, the size of tenons was reduced from those of Bronze Age vessels.

Several researchers have attempted to make correlations between ship construction features such as nail size, mortise-and-tenon dimensions, mortise-and-tenon spacing and vessel size.[215] While this may be valid, no definitive formula has been developed thus far. What is clear is that vessels of similar length often have mortise-and-tenon joints of similar size and spacing.

For the sake of comparison, I use the average tenon dimensions from the Kızılburun planking (6.5 x 13.6 x 1.0 cm)[216] and note that these were tightly fitted in their mortises.[217] Seven vessels listed in Table 5.1 share similar mortise-and-tenon sizes: Congue de Salins, Apollonia 1, Cavalière, Grand Congloué, Miladou, Grand Ribaud D, and St. Gervais 3.

[213] Steffy 1994, 65.
[214] Pulak 2002, 627. Pulak tested a model of a Bronze Age vessel that had no evidence of frames and considerably larger mortise-and-tenon joinery.
[215] Kahanov 1999; Fitzgerald (1995, 132-3, 140 note 7) relates planking thickness to mortise-and-tenon size.
[216] No complete tenons have survived; therefore their lengths must be doubled in order to approximate the original full length.
[217] Fitzgerald (1995, 132) suggests this is common practice for Graeco-Roman ships.

Mortise-and-tenon spacing

Mortise-and-tenon joints decrease in size, yet increase in frequency during the Graeco-Roman era.[218] Pulak suggests that tenon spacing was regular in the strake in Graeco-Roman ships.[219] These two ideas are supported by data from the Kızılburun vessel as spacing of tenons in the planking ranged between 11.5 and 13.6 cm with an average of 12.5 cm. The range of tenon spacing in the keel is slightly smaller and ranges between 11.2 and 12.6 cm, with an average of 11.7 cm.

Eight shipwrecks compiled in Table 5.1 have similar tenon spacings ranging between 11 and 13.2 cm; Chrétienne C, Cavalière, Miladou, Diano Marina, Herculaneum, Kinneret, St. Gervais 3, and Laurons 2.

Frame size

Frame size is likely the most difficult to compare as the frame pattern of the Kızılburun ship is not completely understood, therefore making it difficult to distinquish floors from half-frames. However, one detail is clear; by comparison, the frames of the Kızılburun ship are less than robust, and are similar in design and dimensions commonly seen in contemporaneous vessels, often carrying lighter loads.

I have demonstrated that the Kızılburun floors have a sided dimension of 9.2-11 cm and that the molded dimension increases as the floor approaches the keel, from 10 to 21 cm. These dimensions are very similar to those of the Cavlière and Ladispoli vessels (10 x 20 cm), the latter of which was a dolia carrier. Similar dimensions are also seen in the Grand Ribaud D, la Giraglia, and Grado vessels, two of which were also dolia carriers.

[218] Pulak 2000, 34; Steffy 1994, 77-8.
[219] Pulak 2002, 627.

Frame spacing

The relationship between frame size and frame spacing is analogous to that of mortise size and mortise spacing in Graeco-Roman vessels. Adding frames to a shell-based hull and topping them with ceiling planking helps to distribute the weight of the point-loads. Increasing the frequency of frames helps distribute this weight even more. This concept was familiar to the Graeco-Roman shipwright as six vessels from Table 5.1 (Cavalière, Miladou, Dramont A, la Giraglia, Herculaneum, and Kinneret) share nearly the exact same average frame spacing of 25 cm with the Kızılburun ship.

CONCLUSION

The Kızılburun vessel was most likely 4.5 to 5 m in breadth and 18 to 20 m in length with adisplacement of at least 90 tons. This is based on extant remains and supported by comparison to available evidence from contemporaneous vessels. This information, along with the other numerous details of the vessel's construction, is significant for future comparison with other stone carriers and cargo vessels of similar size; for, as noted by Throckmorton, "None of these [Roman merchant] ships has been reconstructed, even in part, because the amount of material recovered has been small."[220] His statement was true in 1973 and still holds true today for not only Roman merchant vessels, but also for Hellenistic period merchant vessels and certainly for stone carriers of antiquity.

In the initial stages of excavation of the Kızılburun marble carrier, researchers looked for evidence of a presumably robustly constructed vessel. Although the hull remains of the Kızılburun vessel are sparse, detailed examination and analysis demonstrate that the individual features of the ship's construction, as well as the overall dimensions are in concordance with not only contemporaneous small to moderately- sized stone carriers, such as that excavated at Carry-le-Rouet,[221] but also of contemporaneous amphorae and dolia carriers of similar size; in other words, with general merchantman of the era. The size of the Kızılburun ship, particularly the beam dimension, coupled with the fact that the ship was

[220] Throckmorton and Throckmorton 1973, 244.
[221] Long 1988.

barely large enough to accommodate the column drum cargo, suggests that the ship was neither specifically built for stone transport, nor for the last cargo it carried. There are also broad cultural, if not economic, ramifications extending from these data, particularly concerning the early marble trade since the Kızılburun vessel does not appear to have been designed specifically for the transport of stone. When the estimated size and cargo weight from the Carry-le-Rouet vessel are also considered, one may formulate a potentially testable hypothesis that, at least in the Late Hellenistic Period, stone transport appears to have been carried out, at least in part, by common merchant vessels.[222] This is not to suggest that there were no ships built for the sole purpose of transporting architectural stone cargoes or even that there were not purpose-built ships, as dolia carriers appear to have been at very least heavily modified, if not purposely constructed during this time.[223] However, this study does challenge the popular notion that most, if not all, stone transport must have been carried out with heavy, robustly constructed ships and further challenges the notion of a specialized ship type for transporting stone in pre-Imperial Roman times. This presumption of robust construction and even specialized ships may hold true for later stone carriers during the time of massive expansion of the marble trade that began under the reign of the Roman emperor Augustus (31 B.C.E.-14 C.E.), but may not have been a primary concern in selecting ships for stone transport prior to this time.[224]

Furthermore, the study of the Kızılburun hull remains introduces several research questions: if one assumes the existence of the *navis lapidaria* as a specialized ship-type (most likely during the Roman Imperial period if such a ship existed), which party involved in the stone trade (final customer, quarry owner, merchant, or some other party) was responsible for the construction and ownership of such vessels and; was there a standard size and style of construction for such vessels? Were these ships visibly different than standard *naves onerariae?* These questions remain unanswered and will remain unanswered until more

[222] Long 1988.
[223] Fitzgerald 1995, 246; Hesnard et al. 1988; Marlier and Sibella 2002. Some ships had dolia affixed in the cargo hold of ship with frameworks of wood, thus modifying the ship specifically for dolia transport.
[224] Beltrame and Vittorio (forthcoming) suggest that although Roman stone carriers (of which they include the Kızılburun vessel) should have been strongly constructed, they were likely not specially constructed for the purpose of stone transport.

detailed studies with complete excavation of architectural stone carriers are undertaken. This examination of the Kızılburun hull remains is but one example of how much information can be gleaned from even the most sparsely preserved hull remains and should serve as a reminder to future shipwreck researchers that even the most scant hull remains can be of great value in providing precious information and should not be neglected or overlooked.

WORKS CITED

Anderson, R.C. 1925. "Queen Hatshepsut's Great Lighter." *Mariner's Mirror* 11:438-439.

———. 1926. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16 c BC, and More on the Question of Whether it Carried One or Two Obelisks at a Time." *Mariner's Mirror* 12 (4):447-8.

———. 1927. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16 c BC, and the Question of Whether it Carried One or Two Obelisks at a Time - a Concluding Comment." *Mariner's Mirror* 13 (2):182.

———. 1941. "Ancient Egyptian watercraft: Suggested Methods of Towing 'Obelisk Ships'." *Mariner's Mirror* 27 (1):82-3.

Angus, N.S., G.T. Brown, and H.F. Cleere. 1962. "The Iron Nails from the Roman Legionary Fortress at Inchtuthil, Perthshire." *Journal of the Iron and Steel Institute* November:956-68.

Ballard, G.A. 1920a. "Ancient Egyptian watercraft - 'Obelisk Ships', 16 c BC, Pt. I. "The Transporting of the Obelisks at Karnak, Pt. I." *Mariner's Mirror* 6 (3):264-73.

———. 1920b. "The Transporting of the Obelisks at Karnak pt. II." *Mariner's Mirror* 6 (4):307-14.

———. 1926. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16 c BC, and More on the Question of Whether it Carried One or Two Obelisks at a Time- A reply." *Mariner's Mirror* 12 (2):221.

———. 1927. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16 c BC, and More on the Question of Whether it Carried One or Two Obelisks at a Time- A further Explanation." *Mariner's Mirror* 13 (1):89.

———. 1941. "The Great Obelisk Lighter of 1550 B.C." *Mariner's Mirror* 27 (4):290-306.

———. 1947. "The Egyptian Obelisk Lighter." *Mariner's Mirror* 32 (4):158-64.

Basch, L. 1972. "Ancient wrecks and the archaeology of ships." *IJNA* 1:1-58.

Bass, G.F. 1972. *A History of Seafaring*: Thames and Hudson.

Beltrame, C., and D. Gaddi. 2005. "The Rigging and the 'Hydraulic System' of the Roman Wreck at Grado, Gorizia, Italy." *IJNA* 34 (1):79-87.

———. 2007. "Preliminary Analysis of the Hull of the Roman Ship from Grado, Gorizia, Italy." *IJNA* 36 (1):138-47.

Beltrame, C., and V. Vittorio. forthcoming. Roman Ships Carrying Marble: Were These Vessels in Some Way Special. In *Between Continents: Proceedings from the Twelfth Annual International Symposium on Boat and Ship Archaeology, October 12-16, 2009, Istanbul, Turkey*, edited by Nergis Günsenin. Istanbul.

Benoit, F. 1961. Fouilles Sous-Marines: L'epave du Grand Congloue a Marseille. In *Supplement A Gallia XIV*. Paris: Centre National de la Recherche Scientifique.

Blackman, D. J. 1972. "Further early evidence of lead sheathing." *IJNA* 1:117-9.

Blandford, P.W. 1980. *Practical Blacksmithing and Metalworking*. Blue Ridge Summit, PA: Tab Books.

Boetto, G. 2001. "Les Navires de Fiumicino." In *Ostia: port et porte de la Rome antique*, edited by J.-P. Descoeudres, 121-30. Paris: Musèes d'art et d'histoire, Genève.

———. 2008. "Fiumicino 1." *Archaeonautica* 15:29-62.

Boniardi, M., E. Gariboldi, and M. Vedani. 1992. "Metallographic Studies on an Ancient Roman Nail." *Metallurgical Science and Technology* 10 (1):28-38.

Bonino, M. 1989. "Notes on the Architecture of Some Roman ships: Nemi and Fiumicino." In *Tropis I - 1st International Symposium on Ship Construction in Antiquity - Piraeus 1985 Proceedings*, edited by H. Tzalas, 37-53. Athens.

Bound, M. 1991. *The Giglio Wreck: A Wreck of the Archaic Period (c. 600 BC) off the Tuscan Island of Giglio ENALIA Supplement 1*. Athens: Hellenistic Institute of Marine Archaeology.

Bowens, A. 2009. *Underwater Archaeology: The NAS Guide to Principles and Practice*. 2nd. ed. Portsmouth: Blackwell Publishing.

Burford, A.M. 1969. *The Greek Temple Builders at Epidauros; a Social and Economic Study of Building in the Asklepian Sanctuary, During the Fourth and Early Third Centuries B.C.* Toronto: University of Toronto Press.

Carlson, D.N. 2006. "A Monumental Cargo: The Roman Column Wreck at Kızılburun, Turkey." *INA Quarterly* 33 (1):3-10.

———. 2007. "An Uplifting Summer: The 2006 Excavation Season at Kızılburun, Turkey." *INA Quarterly* 34 (1):3-10.

———. 2009. "A Marble Cargo of Monumental Proportions: The Late Hellenistic Shipwreck at Kızılburun, Turkey." In *Archéomatériaux : Marbres et autres roches. Actes de la IVe Conférence internationale de l'Association pour l'étude des marbres et autres roches utilisés dans le passé, ASMOSIA IV, Bordeaux, Talence, 9-13 octobre 1995*, edited by P. Jockey, 475-94. Bordeaux: Presses universitaires de Bordeaux ; Centre de recherche en physique appliquée à l'archéologie.

Carlson, D., and D. Hamilton. 2009. "Kızılburun 2008: Research at the Bodrum Center." *INA Annual 2008*:11-4.

Carlson, D.N., and C.E. Atkins. 2008. "Leaving No Stone Unturned: The 2007 Excavation Season at Kızılburun, Turkey." *INA Annual 2007*:22-8.

Carlson, D.N., and W. Aylward. 2010. "The Kizilburun Shipwreck and the Temple of Apollo at Claros." *AJA* 114 (1):145-59.

Carre, M.-B. 1993. "L'epave a dolia de Ladispoli (Etrurie meridionale). Etude des vestiges de la coque." *Archaeonautica* 11:9-29.

Casson, L. 1969. "Sailing." In *The Muses at Work; Arts, Crafts, and Professions in Ancient Greece and Rome*, edited by Carl Roebuck. Cambridge, Mass.: MIT Press.

———. 1971. *Ships and Seamanship in the Ancient World*. Princeton: Princeton University Press.

Castelletti, L., A. Maspero, S. Motella, and M. Rottoli. 1990. "Analisi silotomiche e tecnica di lavorazione del legno." In *Fortuna maris: la nave romana di Comacchio*, edited by F. Berti, 136-53. Bologna: Nuova Alfa.

Charlin, G., J.-M. Gassend, and R. Lequement. 1978. "L'epave Antique de la Baie de Cavaliere (Le Lavandou, Var)." *Archaeonautica* 2:9-94.

Cleere, H.F. 1958. "Roman Domestic Ironwork, as Illustrated by the Brading, Isle of Wight, Villa." *Bulletin of the London Institute of Archaeology* 1:55-74.

Clowes, G.S.L. 1927. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16 c BC, and its Possible Difficulties of Keeping off the Mud of the River Nile." *Mariner's Mirror* 13 (1):89.

Creasman, P.P. 2010. *Extracting Cultural Information form Ship Timber*. Dissertation, Anthropology, Texas A&M University, College Station.

Crumlin-Pedersen, O. 1977. "Some Principles for the Recording and Presentation of Ancient Boat Structures." In *Sources and Techniques in Boat Archaeology*, edited by Sean McGrail, 163-77. Oxford: BAR.

Davis, P.H. 1965. *Flora of Turkey and the East Aegean Islands*. Volume 1. Edinburgh: Edinburgh University Press.

———. 1978. *Flora of Turkey and the East Aegean Islands*. Volume 6. Edinburgh: Edinburgh University Press.

———. 1982. *Flora of Turkey and the East Aegean Islands*. Volume 7. Edinburgh: Edinburgh University Press.

DeVries, K. 1972. "Greek, Etruscan, and Phoenician Ships and Shipping." In *A History of Seafaring*, edited by G.F. Bass, 37-64. New York: Walker and Company.

Dumas, F. 1972. "Ancient Wrecks." In *Underwater Archaeology, a Nascent Discipline*, 27-34. Paris: UNESCO.

Dumontier, M., and J.P. Joncheray. 1991. "L'epave romaine du Miladou." *Cahiers d'Archeologie Subaquatique* 10:109-74.

Dyer, F.E. 1926. "Queen Hatshepsut's Great Lighter." *Mariner's Mirror* 12 (2):222-3.

———. 1927. "Ancient Egyptian Watercraft: The 'Obelisk Ship' of Karnak, 16c BC, and the Question of Whether it Carried One or Two Obelisks at a Time - a Concluding Comment." *Mariner's Mirror* 13 (2):182.

Edlin, H.L. 1956. *Trees, Woods and Man*. London: Collins.

Eiseman, C.J., and B.S. Ridgway. 1987. *Porticello Shipwreck: A Mediterranean Merchant Vessel of 415-385 B.C.* College Station: Texas A&M University Press.

Fitzgerald, M.A. 1994. "The Ship." In *The Harbours of Caesarea Maritima 2: The finds and the ship*, edited by J.P. Oleson and R.L. Hohlfelder, 163-255. Oxford: BAR.

———. 1995. *Roman Wreck at Caesarea Maritima, Israel: Study of Hull and Equipment*. PhD Dissertation, Anthropology, Texas A & M University, College Station.

Foerster-Laures, F. 1990. "The Cylindrical Nails of the *Kyrenia*: One too early technical spout." In *Tropis II: 2nd International Symposium on Ship Construction in Antiquity, Delphi, 27,28,29 August 1987*, edited by Harry Tzalas, 175-9. Hellenic Institute for the Preservation of Nautical Tradition.

Freschi, A. 1991. "Note techniche sul relitto greco arcaico di Gela " In *Atti IV Rassegna di Archeolgia Subacquea , Giardini Naxos, Ottobre 1989*, 201-10. Messina.

Frey, D., F.D. Hentschel, and D.H. Keith. 1978. "Deepwater Archaeology: The Capistello Wreck Excavation, Lipari, Aelion Islands." *IJNA* 7 (4):279-300.

Frost, H. 1975. "The Ram from Marsala." *IJNA* 4 (2):219-29.

———. 1981. The Punic Ship: Final Excavation Report. In *Lilybaeum*. Rome: Accademia Nazionale dei Lincei. Notizie Degli Scavi di Antichita. .

Galili, E., V. Sussman, G. Stiebel, and B. Rosen. 2010. "A Hellenistic/Roman Shipwreck off Ashkelon, Israel." *IJNA* 38 (1):125-45.

Gassend, J.-M. 1978. "Vestiges d'une epave antique dans le port de Pommègues (Marseille)." *Archaeonautica* 2:101-7.

Gassend, J.-M., and J.-P. Cuomo. 1982. *La navire antique du Lacydon*. Marseille: Musee d'Histoire de Marseille.

Gassend, J.-M., B. Liou, and S. Ximénés. 1984. "L'epave 2 de l'Anse des Laurons." *Archaeonautica* 4:75-105.

Giachi, G., S. Lazzeri, M. Mariotti Lippi, N. Macchioni, and S. Paci. 2003. "The Wood of "C" and "F" Roman Ships Found in the Ancient Harbour of Pisa (Tuscany, Italy): the Utilisation of Different Timbers and the Probable Geographical Area which Supplied Them." *Journal of Cultural Heritage* 4:269-83.

Gianfrotta, P.A., and P. Pomey. 1980. *Archeologia Subacquea: Storia, technice, scoperte e relitti*. Milan: Arnoldo Mondadori Editore.

Gibbins, D. 2001. *Hellenistic Economies*, edited by Z. Archibald, 273-312. London: Routledge.

Green, J., S. Matthews, and T. Turanli. 2002. "Underwater Archaeological Surveying Using PhotoModeler, VirtualMapper: Different Applications for Different Problems." *IJNA* 31 (2):283-92.

Guibal, F., and P. Pomey. 2003. "Timber Supply and Ancient Naval Architecture." In *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000*, edited by Carlo Beltrame. Oxford: Oxbow

———. 2004. "Dendrochronologie et construction navale antique" *Revue d'archéométrie* 28:35-42.

Haldane, D. 1990. "Anchors of Antiquity." *Biblical Archaeology* 53 (1):19-24.

Hather, J.G. 2000. *The Identification of the Northern European woods: A Guide for Archaeologists and Conservators*. London: Archetype.

Hesnard, A., M. Thinon, M. Blaustein, M. Dumontier, A. Chéné, P. Foliot, and H. Bernard-Maugiron. 1988. *L'épave romaine Grand Ribaud D (Hyères, VAR)*. Paris.

Higgins, C. R. 2007. "Learning How to Map a 70-Ton Ship." *INA Quarterly* 34 (1):11-2.

Hirschfeld, N. 1990. "The Ship of Saint Paul: Historical Background." *The Biblical Archaeologist* 53 (1):25-30.

Hocker, F. 1995. "Lead hull sheathing in antiquity." In *Tropis III - 3rd International Symposium on Ship Construction in Antiquity - Athens 1989 Proceedings*, edited by H. Tzalas, 197-206. Athens.

Höckmann, O. 1994. "Das Schiff." In *Das Wrack: Der Antike Schiffsfund von Mahdia,* edited by G. Hellenkemper Salies. Cologne: Rheinland-Verlag.

Houston, G.W. 1988. "Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports." *AJA* 92 (4):553-64.

Joncheray, J.-P. 1975. "L'Epave <<C>> de la Chrétienne." Paris: *Cahiers d'Archéologie Subaquatique*.

———. 1976. "Mediterranean Hull Types Compared: 1. La Roche Fouras." *IJNA* 5 (2):107-14.

Jurgens, J.A., R.A. Blanchette, and D.N. Carlson. 2003. "Evaluating the Wooden Remnants of the Tektaş Burnu Shipwreck." *Art Biology and Conservation*:391-407.

Kahanov, Y. 1999. "Some aspects of lead sheathing in ancient ship construction." In *Tropis V - 5th International Symposium on Ship Construction in Antiquity - Nauplia 1993 Proceedings*, edited by Harry Tzalas, 219-24. Athens.

———. 2003. "The Hull Remains." In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman, Final Report, Volume 1*, edited by E. Linder and Y. Kahanov, 53-129. Haifa: Israel Exploration Society, University of Haifa.

Kahanov, Y., C. Doherty, and S. Shalev. 1999. "The Metal Nails from the Ma'agan Mikhael Ship." *IJNA* 28 (3):277-88.

Lang, J., S. La Niece, P.T. Craddock., M. Cowell, and W.A. Oddy. 1990. "Examination of Some Objects from Early Wrecks." In *Metals and the Sea: Papers Presented at the March 1990 Conference of the Historical Metallurgy Society held at the National Maritime Museum, Greenwich, London*, edited by J. Lang, 47-8. London: Historical Metallurgy Society.

Laronde, A. 1987. "Recherches sous-marines dans le port d'Appolonia de Cyrénaique." *Bulletin de la Société Nationale des Antiquaries de France 1987*:322-30.

Lawall, M.L. 1998. "Bolsals, Mendean Amphoras, and the Date of the Porticello Shipwreck." *IJNA* 27 (1):16-23.

L'Hour, M., and L. Long. 1986. "L'épave antique de Carry-le-Rouet: un navire lapidaire (fin II^e s. début 1^er s. av. J.-C.)." In *Archéologie sous-marine sur les cotes de France. Vignt ans de recherche*, 55-6. Nantes, France: DRASM.

Linder, E. 1989. "The Ma'agan Mikhael Shipwreck Excavation- first season, 1988." *C.M.S. News* 16:5-7.

Liphschitz, N. 2004. "Dendroarchaeological Investigations." " In *The Ma'agan Mikhael Ship: The Recovery of a 2400-Year-Old Merchantman, Final Report Volume II*, edited by Y. Kahanov, E. Linder and J. Tresman, 156-63. Haifa: Israel Exploration Society, University of Haifa.

———. 2007. *Timber in Ancient Israel : dendroarchaeology and dendrochronology*. Tel Aviv: Emery and Claire Yass Publications in Archaeology, Institute of Archaeology, Tel Aviv University.

Liphschitz, N., and C. Pulak. 2009. "Wood Species Used in Ancient Shipbuilding in Turkey: Evidence from Dendroarchaeological Studies." *Skyllis* 8 (1-2):74-83.

Littlefield, J.D. 2011a. "In Small Things Forgotten: Examining the Kızılburun Column Wreck Fasteners." *INA Quarterly* 38 (1/2):14-5.

———. 2011b. "Sometimes Standard Recording Methods are not so Standard: Recording the Kızılburun Column Wreck's Hull Remains." *CMAC News and Reports* 3 (1):21-3.

———. 2012. "Kızılburun Column Wreck Preliminary Hull Analysis: Maximum Results from Minimum Remains." In *Between Continents: Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009*, edited by Nergis Günsenin, 37-42. Istanbul: Ege Yayınları.

Long, L. 1988. "The Ancient Wreck of Carry-le-Rouet: Evidence of Sea Transport of Stone in the 2nd or 1st Century B.C." In *Archaeology in Solution: Proceedings of the 17th Conference on Underwater Archaeology, January 8-12, 1986, Sacramento, California*, edited by J.W. Foster and S.O. Smith, 22-7. Salinas, CA: Coyote Press.

Long, L., S. Marlier, and M. Rival. 2005. "L'épave *Saintes Maries* 24 (Drassm 04/99)." *Bilan scientifique 2003*.

Long, L., and S. Ximénés. 1988. "Miladou." *Cahiers d'archaeologie subaquatique* 7:159-83.

Lucas, A., and J. R. Harris. 1962. *Ancient Egyptian Materials and Industries*. London: E. Arnold.

MacLeod, I.D. 1985. "The Effects of Concretion on the Corrosion of Non ferrous Metals." *Corrosion Australasia* 10 (4):10-3.

———. 1994. Ancient & historic metals : conservation and scientific research : proceedings of a symposium organized by the J. Paul Getty Museum and the Getty Conservation Institute, November 1991, 1994, at Marina del Rey, CA.

Marean, P. 1987. "Ship Stability, Ancient and Modern." In *The Sea Remembers: Shipwrecks and Archaeology*, edited by P. Throckmorton, 101. London: Mitchel Beazley Publications.

Marlier, S., and P. Sibella. 2002. "La Giraglia, a *dolia* wreck of the 1st century BC from Corsica, France: study of its hull remains." *IJNA* 31 (2):161-71.

Marsden, P.R.V. 1967. *A Ship of the Roman Period, from Blackfriars, in the City of London*. London: Guildhall Museum.

McCarthy, M. 2005. *Ships' Fastenings From Sewn Boat to Steamship*, *Ed Rachal Foundation Nautical Archaeology Series*. College Station: Texas A&M University Press.

McGee, J.E.G. 1977. "Hypothetical Reconstructions in Boat Archaeology." In *Sources and Techniques in Boat Archaeology: Papers Based on Those Presented to a Symposium at Greenwich in September 1976, Together with Edited Discussion*, edited by Seán F. McGrail, 205-14. Oxford: British Archaeological Reports.

Meiggs, R. 1972. *The Athenian Empire*. Oxford: Clarendon Press.

———. 1982. *Trees and Timber in the Ancient Mediterranean World*. Oxford: Clarendon Press.

Mercer, H.C. 1960. *Ancient Carpenter's Tools*. 3rd ed. Pennsylvania: Bucks County Historic Society.

Muckelroy, K. 1998a. "Introducing Maritime Archaeology." In *Maritime Archaeology: A Reader of Substantive and Theoretical Contributions*, edited by L.E. Babits and H van Tilburg, 23-37. New York: Plenum.

———. 1998b. "The Archaeology of Shipwrecks." In *Maritime Archaeology: A Reader of Substantive and Theoretical Contributions*, edited by L.E. Babits and H. van Tilburg, 267-90. New York: Plenum.

Müller, J. 2010. "Holzarten im historischen Schiffbau und ihre Gefährdung durch Terediniden (Tree species used in historical shipbuilding and their risk of being attacked by Teredinidae)." *Skyllis* 10 (1):104-11.

Muller, S.D. 2004. "Palynological Study of Antique Shipwrecks from the Western Mediterranean Sea, France." *Journal of Archaeological Science* 31 (3):343-9.

North, N.A., and I.A. MacLeod. 1987. "Corrosion of Metals." In *Conservation of Marine Archaeological Objects*, edited by Colin Pearson, 68-98. London: Butterworths.

Oleson, J.P. 2008. *Oxford Handbook of Engineering and Technology in the Classical World*. Oxford; New York: Oxford University Press.

Pallarès, F.P. 1996. "Il relitto a dolia del Golfo Dianese: nuovi elementi." *Bullettino di Archeologia Subacquea* 1-2:127-39.

Parker, A.J. 1992a. *Ancient Shipwrecks of the Mediterranean and Roman Provinces*. Volume 580, *BAR International Series 580*. Oxford: B.A.R. (Tempus Repartum).

———. 1992b. "Cargoes, Containers and Stowage: The Ancient Mediterranean." *IJNA* 21 (2):89-100.

Polunin, O., and B. Everard. 1976. *Trees and Bushes of Europe*. London; New York: Oxford University Press.

Polzer, M.E. 2009. *Hull Remains from the Pabuç Burnu Shipwreck and Early Transition in Archaic Greek Shipbuilding*, Anthropology, Texas A&M University, College Station, TX.

Pomey, P. 1995. "Dendrochronologie et dendromorphologie des épaves antiques de Méditerranée." *Bilan scientifique 1994*:35.

———. 1995. "Les epaves Grecques et Romaines de la Place Jules-Verne a Marseille." *Academie es Inscriptions & Belles-lettres. Comptes rendus* (Avril-Juin):459-84.

———. 1998. "Dendrochronologie et dendromorphologie." In *Archeologia Subacquea: Come opera l'archeologo sott'acqua storie dalle acque*, edited by Giuliano Volpe, 425-46. Florence: Edizioni All'insegna del Giglio.

———. 2001. "Les epaves grecques archaiques du VIe siecle av. J.-C. de Marseille: epave Jules-Verne 7 et 9 et Cesar 1." In *Tropis VI - 6th International Symposium on Ship Construction in Antiquity - Lamia 1996 Proceedings*, edited by H. Tzalas, 425-37. Athens.

———. 2004. "Principles and Methods of Construction in Ancient Naval Architecture." In *The Philosophy of Shipbuilding: Conceptual Approaches to the Study of Wooden Ships*, edited by F.M. Hocker and C.A. Ward, 25-36. College Station, TX: Texas A&M University Press.

Pomey, P., L. Long, M. L'Hour, F. Fichez, and H. Bernard. 1988. *Recherches sous-marines*, *Gallia Informations. Prehistoire et Histoire 1987-1988 1*. Paris: CRNS.

Pulak, C. 2000. "Mortise-and-Tenon Joints of Bronze Age Seagoing Ships." In *Boats, Ships and Shipyards: Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, Venice 2000*, edited by Carlo Beltrame, 28-34. Oxford; Oakville, CT: Oxbow ; David Brown Co.

———. 2002. "The Uluburun Hull Remains." In *Tropis VII - 7th International Symposium on Ship Construction in Antiquity - Pylos 1999 Proceedings*, edited by H. Tzalas, 615-36. Athens.

Pulak, C., and E. Rogers. 1994. "The 1993-1994 Turkish Shipwreck Survey." *INA Quarterly* 21 (4):17-21.

Rash, K. 2010. "Casting the Assemblage of Iron Artifacts from Kızılburun." *CMAC News and Reports* 2 (2):31-3.

———. 2012. *Reconstructing an Assemblage of Iron Artifacts from a First-Century B.C.E. Shipwreck at Kizilburun, Turkey*, Anthropology, Texas A&M University, College Station, TX.

Richardson, G. 2007. *An Empire of Stone: Shipwrecks, Sailors, and the Roman Marble Trade*, Department of Archaeology, University of Southampton.

Rival, M. 1991. *La charpenterie navale romaine : materiaux, methodes, moyens*, *Travaux du Centre Camille Jullian, 4*. Paris: Editions du Centre national de la recherche scientifique : Diffusion, Presses du CNRS.

Rougé, J. 1966. *Recherches sur la organisaton du commerce maritime en Méditerranée sous l'empire romain*. Paris: S.E.V.P.E.N.

Rouquette, D., M-P. Jezegou, and S. Wicha. 2004. "Conque de Salins." *Bilan Scientifique du Département des Recherches Archéologiques Subaquatiques et Sous-Marines 1999* 26:35-8.

Royal, J. G. 2008. "Discovery of ancient harbour structures in Calabria, Italy, and implications for the interpretation of nearby sites." *IJNA* 37 (1):49-66.

Russell, B. 2011. "*Lapis transmarinus*: Stone-carrying Ships and the Maritime Distribution of Stone in the Roman Empire." In *Maritime Archaeology and Ancient Trade in the Mediterranean*, edited by D. Robinson and A. Wilson, 139-55. Oxford: Oxford University School of Archaeology.

Santamaria, C. 1973. "Note préliminaire sut le mode de construction de lacoque de l'épave romaine 'Dramont A' (Cap Dramont- comune de Saint Raphael)." *Cahiers d'archaeologie subaquatique* 2:133-6.

———. 1995. "L'epave *Dramont E* A Saint-Raphael." *Archaeonautica* 13:1-193.

Schiffer, M.B. 1987. *Formation Processes of the Archaeological Record.* Albuquerque, NM: University of New Mexico Press.

Sciallano, M., and S. Marlier. 2004. "Épave de la Giraglia." *Bilan scientifique 1999* 26:70-72.

———. 2008. "Épave de la Giraglia." *Archaeonautica* 15:113-52.

Shalev, S., Y. Kahanov, and C. Doherty. 1999. "Nails from a 2,400 Year Old Shipwreck: A Study of Copper in a Marine Archaeological Environment." *Journal of Minerals, Metals, and Materials* 51 (2):14-17.

Sim, D. 1998. *Beyond the Bloom: Bloom Refining and Iron Artifact Production in the Roman World*. Edited by I. Ridge. Oxford: Archaeopress.

Sleeswyk, A.W. 1987. "The Obelsik Lighter of Queen Hatshepsut." In *Tropis II: Second International Symposium on Ship Construction in Antiquity*, edited by H. Tzalas, 305-14. Delphi: Hellenic Institute for the Preservation of Nautical Tradition.

Snodgrass, A.M. 1983. "Heavy Freight in Archaic Greece." In *Trade in the Ancient Economy*, edited by P. Garnsey, K. Hopkins and C. R. Whittaker, 16-26. Berkeley: University of California Press.

Sølver, C. V. 1940. "The Egyptian Obelisk-ships." *Mariner's Mirror* 26 (3):237-56.

———. 1947. "Ancient Egyptian watercraft - 'Obelisk Ships' since 2500 BC. "Egyptian obelisk-ships."." *Mariner's Mirror* 33 (1):39-40.

———. 1948. "Ancient Egyptian Watercraft: More on 'Obelisk Ships'." *Mariner's Mirror* 34 (1):55.

Sottas, J. 1921. "The Ship of St. Paul's Last Voyage." *Mariner's Mirror* 7 (3):258-66.

Steffy, J.R. 1978. "Maximum Results from Minimum Remains." In *Beneath the Waters of Time: The Proceedings of the Ninth Conference on Underwater Archaeology*, edited by J. Barto Arnold, 53-5. Austin: Texas Antiquities Committee.

———. 1985. "The Herculaneum Boat: Preliminary Notes on Hull Details." *AJA* 89 (3):519-21.

———. 1985. "The *Kyrenia* Ship: An Interim Report on its Hull Construction." *AJA* 89:71-101.

———. 1990. "The Boat: A Preliminary Study of its Construction." In *The Excavations of an Ancient Boat in the Sea of Galilee (Lake Kinneret)*, edited by S. Wachsmann, 29-47. Jerusalem: Atiqout: The Israel Antiquities Authourity.

———. 1994. *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station: Texas A & M University Press.

———. 1999. "Seldom Discussed Features of Ancient and Medieval Ship Construction." *Archaeonautica* 14:165-9.

———. 2000. "Influences on Shipbuilding Technology." In *Down the River to the Sea: Eighth International Symposium on Boat and Ship Archaeology, Gdansk 1997*, edited by J. Litwin, 263-7. Gdansk: Polish Maritime Museum.

Strid, A., and K. Tan. 1986. *Mountain Flora of Greece*. Cambridge; New York: Cambridge University Press.

Tchernia, A., P. Pomey, A. Hesnard, M. Couvert, and M.-F. Giacobbi. 1978. "L'epave romaine de la Madrague de Giens (Var.) (Campagnes 1972-1975)." *Gallia* 36 (Supplement).

Throckmorton, P. 1970. *Shipwrecks and Archaeology; The Unharvested Sea*. Boston: Little, Brown.

———. 1972. "Romans on the Sea." In *A History of Seafaring*, edited by G.F. Bass, 65-86. London: Thames and Hudson.

———. 1987. *The Sea Remembers: Shipwrecks and Archaeology*. London: Mitchel Beazley Publications.

Throckmorton, P., and J. Throckmorton. 1973. "The Roman Wreck at Pantano Longarini." *IJNA* 2 (2):243-66.

Traquair, R., and A.J.B. Wace. 1909. "The Base of the Obelisk of Theodosius." *The Journal of Hellenic Studies* 29:60-9.

Turland, N. J., L. Chilton, and J. R. Press. 1993. *Flora of the Cretan area: Annotated Checklist & Atlas*. London: H.M.S.O.

Tylecote, R. F. 1962. *Metallurgy in Archaeology; A Prehistory of Metallurgy in the British Isles*. London: E. Arnold.

———. 1976. *History of Metallurgy*. London: The Metals Society.

———. 1977. "Summary of Results of Experimental Work on Early Copper Smelting." In *Aspects of Early Metallurgy*, edited by W.A. Oddy, 5-12. London: Historical Metallurgy Society and the British Museum Research Laboratory.

———. 1987. *The Early History of Metallurgy in Europe*. London; New York: Longman.

Ucelli, G. 1950. *Le navi di Nemi*. Roma: La Libreria dello Stato.

van Doorninck Jr., F.H. 1976. "A Fourth Century Wreck at Yassi Ada: An Interim Report on the Hull." *IJNA* 5 (2):115-32.

van Doorninck Jr., F.H. 1982. "The Hull Remains." In *Yassi Ada, Volume I*, edited by G.F. Bass and F.H. Van Doorninck Jr., 32-64. College Station: Texas A & M University Press.

Volpe, G. 1998. *Archeologia Subacquea: Come opera l'archeologo sott'acqua storie dalle acque*. Florence: Edizioni All'insegna del Giglio.

Wachsmann, S. 1990. "The Kinneret Boat: The Discovery and Excavation." In *Tropis II - 2nd International Symposium on Ship Construction in Antiquity - Delphi 1987 Proceedings*, edited by Harry Tzalas, 371-384. Athens.

———. 1995. *Sea of Galilee Boat: An Extraordinary 2000 Year Old Discovery*. New York: Plenum Press.

Wheeler, R.E.M. 1954. *Archaeology from the Earth*. St. Paul: Oxford University Press.

White, J., J. White, and S. M. Walters. 2005. *Trees: A Field Guide to the Trees of Britain and Northern Europe*. Oxford: Oxford University Press.

Wicha, S., and M. Girard. 2006. "Archaeobotanical Characterisation of Three Ancient Sewn Mediterranean Shipwrecks." In *Connected by the Sea: Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003*, edited by L.K. Blue, F.M. Hocker and A. Englert, 111-6. Oxford: Oxbow.

Wirsching, A. 2000. "How the Obelisks Reached Rome: Evidence of Roman Double-ships." *IJNA* 29 (2):273-83.

———. 2003. "Supplementary Remarks on the Roman Obelisk-ships." *IJNA* 32 (1):121-3.

Ximénès, S., and M. Moerman. 1991. "Le matérial archéologique de l'épave Laurons II (Martigues-Bouches-du-Rhone)." *Cahiers d'archaeologie subaquatique* 10:209-22.

Yentsch, A., and M.C. Beaudry. 2001. "American Material Culture in Mind, Thought, and Deed." In *Archaeological Theory Today*, edited by I. Hodder, 214-40. Cambridge, UK; Malden, MA: Polity Press ; Blackwell Publishers.

Yovel, I. 2004. "The Typology of the Copper Nails." In *The Ma`agan Mikhael Ship: The Recovery of a 2400 -Year Old Merchantman*, edited by Y. Kahanov, E. Linder and J. Tresman. Jerusalem: Hevrah la-hakirat Erets-Yisrael ve-`atikoteha : Universitat Hefah.

APPENDIX A

KIZILBURUN SHIPWRECK WOOD CATALOG

More than 800 fragments of the wooden hull have been examined for construction details. This appendix is a detailed catalog of the most diagnostic wooden fragments, separated into two major sections: **Reconstructed Timbers** and **Individual Fragments**. Each section is subdivided by function (i.e., keel, frames, hull planking, and ceiling planking). Furthermore, each sub-section is organized by sequential **Wood Numbers** or **Lot Numbers** for those fragments not assigned wood numbers. Every wooden fragment has an assigned **Lot Number**, but not all fragments have a **Wood Number**. As previously mentioned, every artifact, including all wooden fragments, were assigned a Lot Number as a sequential identifier in the field, based on the date it was raised (e.g., L723, L804, etc.). Starting in the third season of excavation (2007) when wooden remains appeared in greater quantities, most wooden fragments were also assigned a four-digit Wood Number that associated the fragment with an area of the site with respect to the column drums that had previously resided above that space, but had been repositioned offsite at that point to allow excavation beneath them (e.g., the area under drum 3 would be assigned wood numbers starting with 3000, 3001, 3002, etc.). Thus, the Wood Number provides a locus for each fragment that received such a number.

Reconstructed timbers include the nearly 3-meter long keel section, 12 frame sections, three hull planking sections, and two ceiling planking sections. I have attempted to include as much pertinent detail as possible, including the number of nails, preserved nail length, nail spacing of both inner and outer faces (where possible), number of mortises, mortise spacing, maximum surviving dimensions (*l.*-length, *w.*-width, *th.*-thickness, *m.*-molded, *s.*-sided) and wood type.[225] All dimensions are given in centimeters.

[225] All wood identification within this thesis was generously performed by Nili Liphschitz of the Institute of Archaeology – The Botanical Laboratories at Tel Aviv University.

Drawings of reconstructed frames are typically oriented with the forward molded face up, as found in situ and looking north toward the bow of the vessel. This may seem an unusual manner in which to draw the frames, but the forward molded face is almost always the best preserved surface and the after molded face is almost always deteriorated so badly that no useful information could be obtained.

I have assigned numbers for cataloging purposes based on the Wood Numbers. If a reconstructed timber is made up of multiple wood numbers, the lowest number was used in the catalog number preceded by **FR** for frame, **HP** for hull planking, or **CP** for ceiling planking (e.g., a frame made up of fragments 5000/5005/5007/5017 has been given the catalog number FR 5000).

Each **Individual Fragment** has the following information listed: Lot Number, Wood Number (where such exists), Function, Wood Type, Dimensions, and a short description of the fragment(s).

RECONSTRUCTED TIMBERS:

KL 5011 Keel *Pinus nigra*

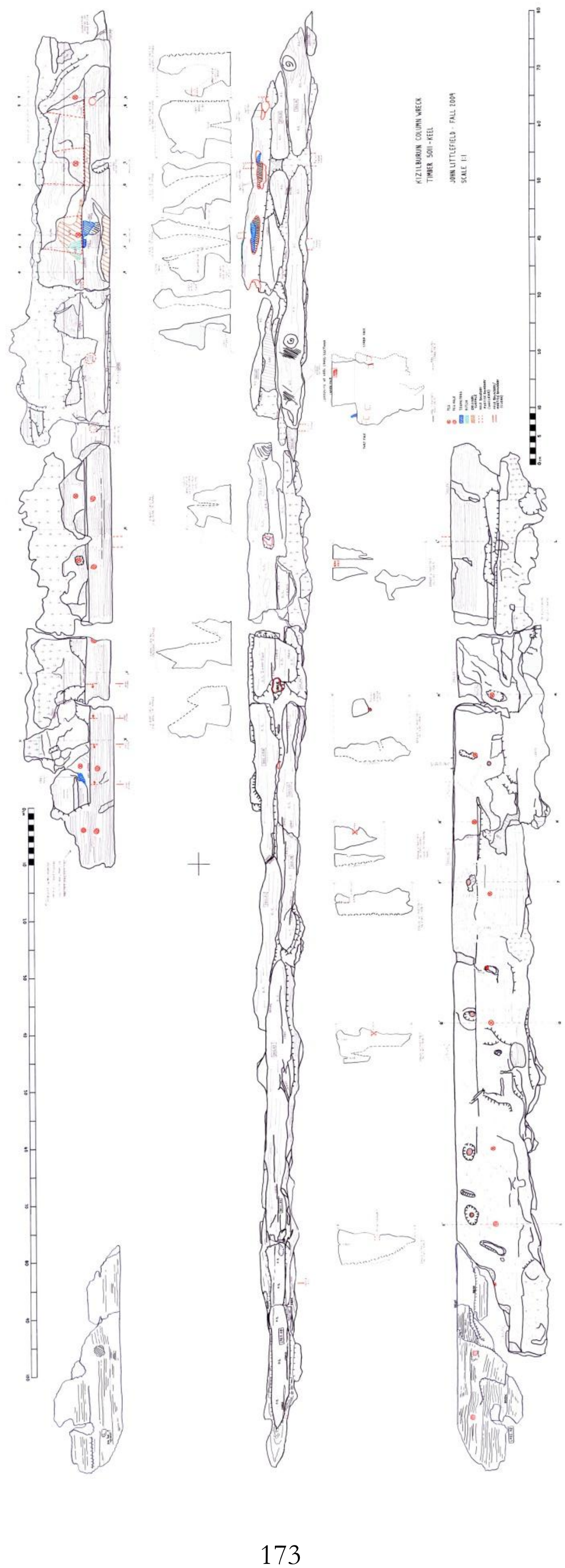
Wood Numbers: 5011.00-5011.30

Lot Numbers: 1728, 1729.03

Fragmentary. Fairly well-preserved inner face. Other surfaces poorly preserved. Tenon pegs staggered along central axis in 27 of 28 tenons peg sets with upper pegs always to the right side of central tenon axis. One tenon has vertical tenon pegs. Back rabbets positioned at approximately 12-15º from vertical. Inner face shows no rockering.

Additional fragment (L259) belongs to this timber, but no longer joins or show clear clues to positioning for reconstruction. It includes one set of tenon pegs spaced at 10.4.

Pres. l. 294; pres. s. 8.3 inner face, 12.1 max; pres. m. 18.3. Nail hole on inner face (5011.07) 1.4 x 1.6. Seven partial mortises with at least one minimally eroded dimension: l. 5.6, avg. of 3 examples ranging from 5.0-6.0; w. 0.6, avg. of 3 examples ranging from 0.6-0.8; depth 5.9, avg. of 4 examples ranging from 5.1-6.2. Mortise spacing (peg center to peg center): 11.7, avg. of 17 examples ranging from 11.1-12.6. Tenons th.: 0.7, avg. of 4 examples ranging from 0.6-0.8. Four partial pegs: diam. 0.9, avg. of four examples ranging from 0.9-1.0. Back rabbet: 4.3, avg. of four examples ranging from 4.2-4.5. Rabbet width: 4.3, avg. of four examples ranging from 4.1-4.5.


KIZILBURUN COLUMN WRECK
TIMBER 5011-KEEL
JOHN LITTLEFIELD · FALL 2009
SCALE 1:1

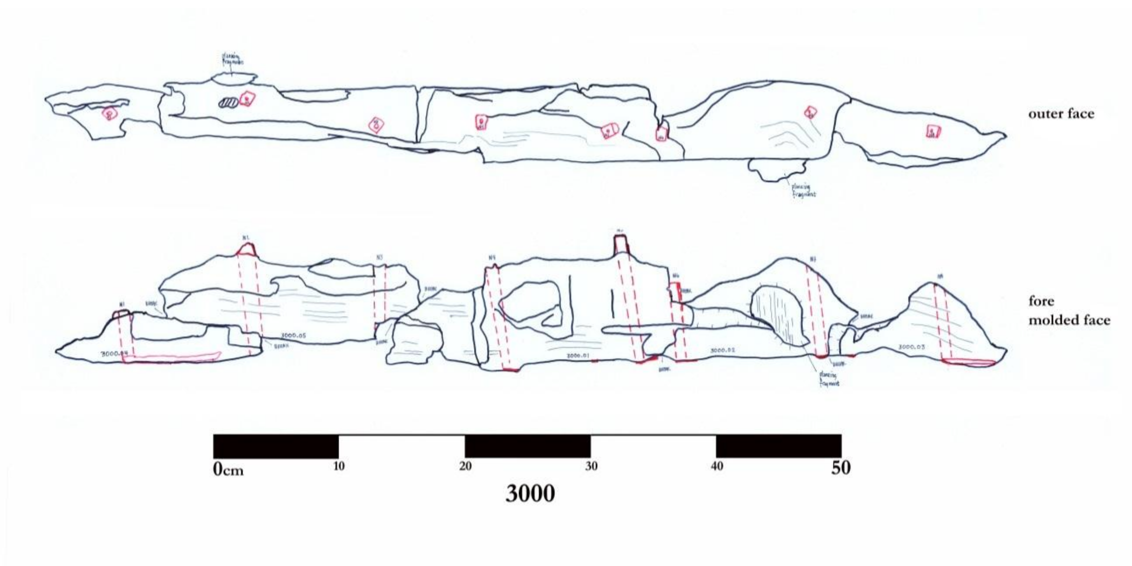
FR 3000 Frame *Fraxinus excelsior*

Wood Numbers: 3000.00-3000.06

Lot Numbers: 1339, 1339.01, 1339.02, 1339.04, 1339.05, 1339.06

Frame heavily worn eaten and deteriorated. Edges appear rounded or beveled. No original after molded surface. Two small patches of pitch on distinct surfaces. Staggered, but regular planking-to-frame nail pattern.

Pres. l. 76.3; s. 6.8; m. 10.5. Eight partial nails: N1 l. 3.85, w. 0.9; N2 l. 7.6, w. 1.05; N3 l. 5.0, w. 1.0; N4 l. 9.7, w. 0.9; N5 l. 10.8, w. 1.0; N6 6.0, w. 1.0; N7 l. 7.2, w. 1.0; N8 l. 6.8, w. 1.1. Nail spacing: N1-N2 inner 10.2, outer 10.6; N2-N3 inner 9.9, outer 10.6; N3-N4 inner 10.2, outer 8.4; N4-N5 inner 10.6, outer 10.2; N5-N6 inner 3.4, outer 4.2; N6-N7 inner 11.0, outer 10.6; N7-N8 inner 9.8, outer 9.8. Three discernible plug-treenails diam.: 1.6, avg. of three examples ranging from 1.4-1.8. Three partial nail clenches: l. 2.2, 3.4, 4.7. One complete nail clench: l. 8.2. Ceiling planking nail (l. 3.5 x w. 0.5) embedded in inner face.



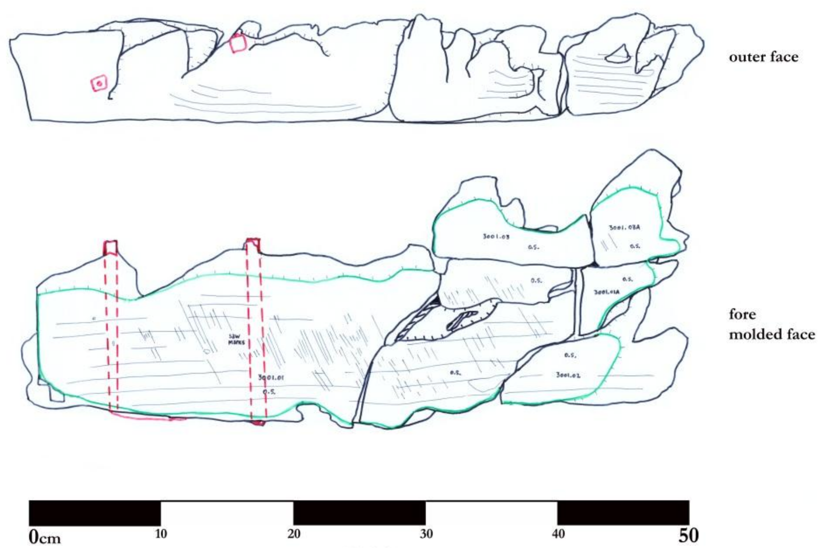
FR 3001 Frame- likely floor *Fraxinus excelsior*

Wood Numbers: 3001.01, 3001.01A, 3001.02, 3001.03, 3001.03A, 3001.04

Lot Numbers: 1411, 1411.01-1411.06

Well preserved forward molded face. No original after molded surface. Saw marks clear and abundant on same surface. Staggered nails in the outer face. Lack of nails in last 30 cm of inboard end. Frame molded dimension increases toward keel.

Pres. l. 50.8; s. 8.1; m. 12.3 outboard, 19.4 inboard. Two nails: N1 l. 13.3 w. 1.1; N2 l. 14.1, w. 1.2. Nail spacing: N1-N2 11.0 inner, 10.4 outer. One nail clench: l. 6.0.



3001

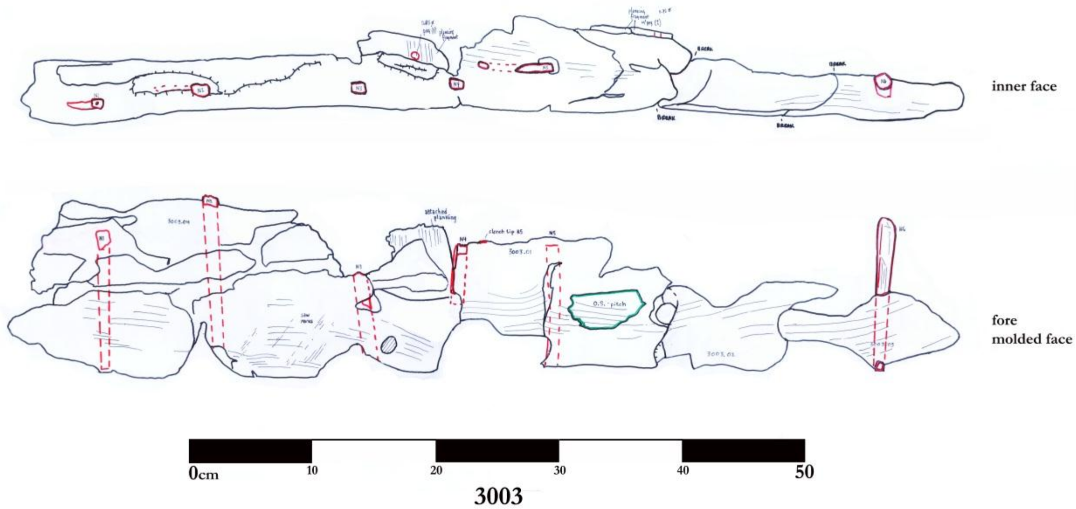
FR 3003 Frame *Fraxinus excelsior*

Wood Numbers: 3003.01, 3003.02, 3003.03, 3003.04

Lot Numbers: 1341, 1341.03, 1341.05, 1341.06, 1341.07

Poorly preserved frame. Saw marks on forward molded surface. This frame was attached to planking section **PL 3007**.

Pres. l. 78.0 cm; s. 6.6; m. 15.9. Six partial nails: N1 l. 11.4, w. 1.2; N2 l. 12.4, w. 1.3, N3 l. 6.7, w. 1.1; N4 l. 4.8, w. 1.1; N5 l. 9.9, w. 1.0; N6 l. 12.4, w. 1.2. Nail spacing: N1-N2 8.5 inner, 8.8 outer; N2-N3 12.1 inner, 11.3 outer; N3-N4 8.1 inner, 9.3 outer; N4-N5 7.4 inner, 7.4 outer; N5-N6 n/a likely missing nail between these two. One plug-treenail: diam. 1.8. Two partial nail clenches: 3.1, 4.7. One complete nail clench: 6.7.



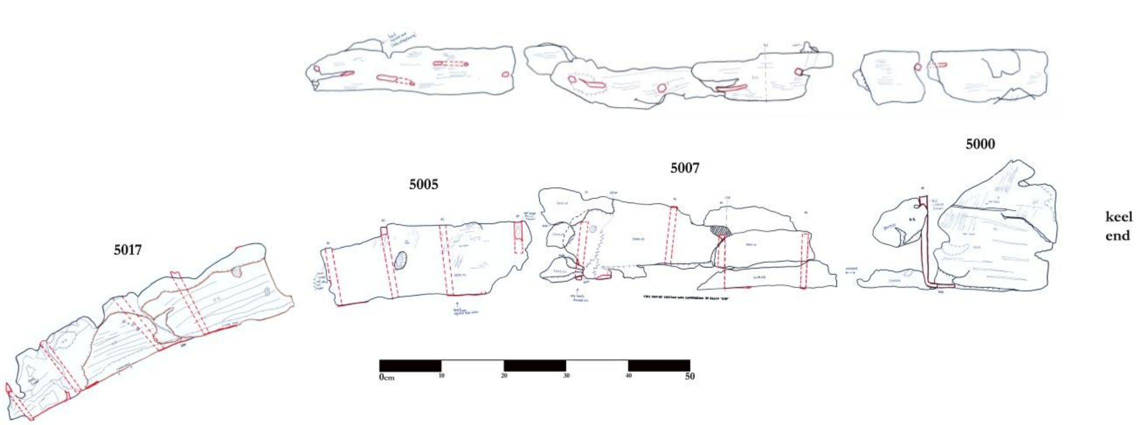
FR 5000 Frame- likely floor *Fraxinus excelsior*

Wood Numbers: 5000.03, 5000.06-5000.11, 5005, 5007, 5007.01, 5007.02, 5017

Lot Numbers: 804, 1205, 1205.02, 1205.05, 1205.06, 1211.00-1211.03, 1258.01-1258.03, 1301

Fragments 5017 and 5000 well preserved. Timber appears to have rounded edges. Nails staggered on inner and outer faces. Saw marks on forward molded face.

Reconstructed l. 161; s. 13.6 outboard, 21.4 inboard; m. 8.6. Sixteen partial nails: N1 l. clench only; N2 clench only; N3 l. broken, w. 1.1; N4 l. 10.0, w. 1.2; N5 l. 11.8, w. 1.4; N6 l. 11.5, w. 1.4; N7 l. 12.6, w. 1.3; N8 l. 9.7, w. 1.2; N9 l. 11.9, w. 1.2; N10 l. 11.5, w. 1.3; N11 l. 5.8, w. 1.2; N12 l. 9.1, w. 1.0; N13 l. 9.6, w. 1.2; N14 l. broken, w. 0.8; N15 l. broken, w. 0.8; N16 l. 13.6, w. 1.1. Nail spacing: N3-N4 9.7 inner, 10.2 outer; N4-N5 13.5 inner, 13.4 outer; N5-N6 7.8 inner, 10.2 outer; N6-N7 10.9 inner, 11.0 outer; N8-N9 9.3 inner, 9.5 outer; N9-N10 8.9 inner, 9.5 outer; N10-N11 11.2 inner, 12.1 outer; N12-N13 14.0 inner, 14.0 outer; N13-N14 9.1 inner, 8.4 outer; N14-N15 13.1 inner, 13.5 outer. Four plug-treenails: 1.2, 1.2, 1.4, 1.5. Nine nail clenches: 7.3, 7.0, 6.3, 6.0, 6.5, 7.8, 6.3, 6.2, 6.1.



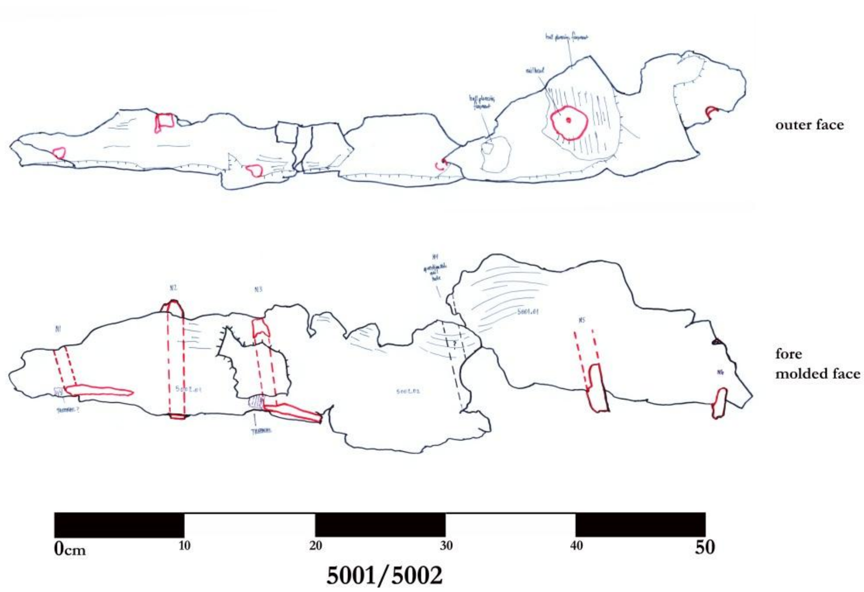
FR 5001 Frame *Fraxinus excelsior*

Wood Numbers: 5001.01, 5002.01-5002.03

Lot Numbers: 1065, 1206, 1207, 1207.01-1207.05

Poorly preserved timber with little preserved original surface. Frame is twisted and heavily worm damaged.

Pres. l. 57.6; s. 9.8; m. 16.1. Six nails: N1 l. 3.7, w. 0.6; N2 l. 9.3, w. 1.4; N3 l. 7.2, w. 0.8; N4 nail hole only; N5 l. 11.5, w. 1.3; N6 l. 6.0, w. 0.8. Nail spacing: N1-N2 8.0 inner, 9.7 outer; N2-N3 7.4 inner, 5.9 outer; N5-N6 9.1 inner, 9.2 outer. Four plug-treenails diam.: 1.3, avg. of four examples ranging from 1.1-1.4. Two partial nail clenches: 4.7, 4.1.



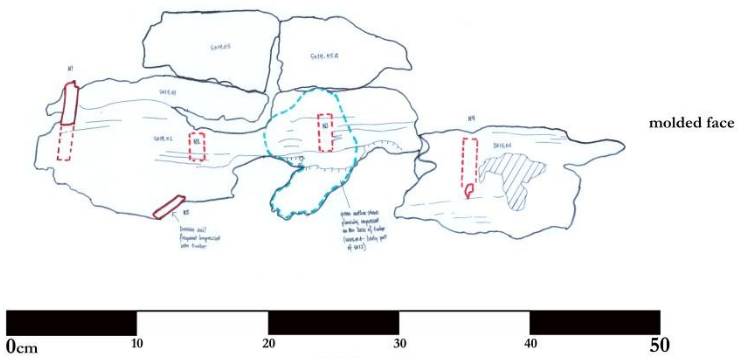
FR 5014 Frame *Fraxinus excelsior*

Wood Numbers: 5014.01-5014.05

Lot Numbers: 1432, 1432.01-1432.04

Poorly preserved frame. Frame 5018 a likely extension of this timber, but could not be placed in relation to FR 5014 with certainty.

Pres. l. 45.3; s. 5.1; m. 20.6. Four nails: N1 l. 6.0, w. 1.0; N2 l. 2.0, w. 0.9; N3 l. 2.7, w. 0.9; N4 l. 4.5, w. 1.0. Nail spacing: (measured centrally due to broken nails) N1-N2 9.5; N2-N3 10.0; N3-N4 11.1. No plug-treenails. No nail clenches.



5014

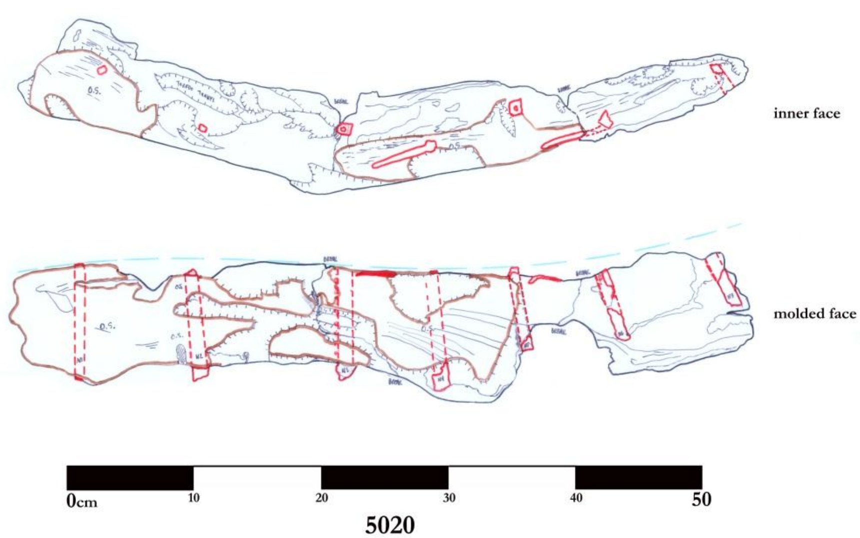
FR 5020 Frame not sampled for wood ID

Wood Numbers: 5020

Lot Numbers: 891, 931, 935

Poorly preserved frame displaying compound curve. Distorted from impact. Staggered nail pattern in inner and outer faces. No pitch retained.

Pres. l. 59.7; s. 7.9; m. 13.9. Seven partial nails: N1 l. 9.0, w. 0.9; N2 l. 8.7, w. 1.3; N3 l. 8.8, w. 1.3; N4 l. 9.4, w. 1.4; N5 l. 6.7, w. 1.0; N6 l. 5.9, w. 1.2; N7 l. 4.8, w. broken. Nail spacing: N1-N2 8.7 inner, 9.5 outer; N2-N3 12.2 inner, 11.5 outer; N3-N4 6.7 inner, 7.5 outer; N4-N5 6.2 inner, 7.4 outer; N5-N6 6.9, 7.5 outer; N6-N7 9.0 inner, 9.3 outer.



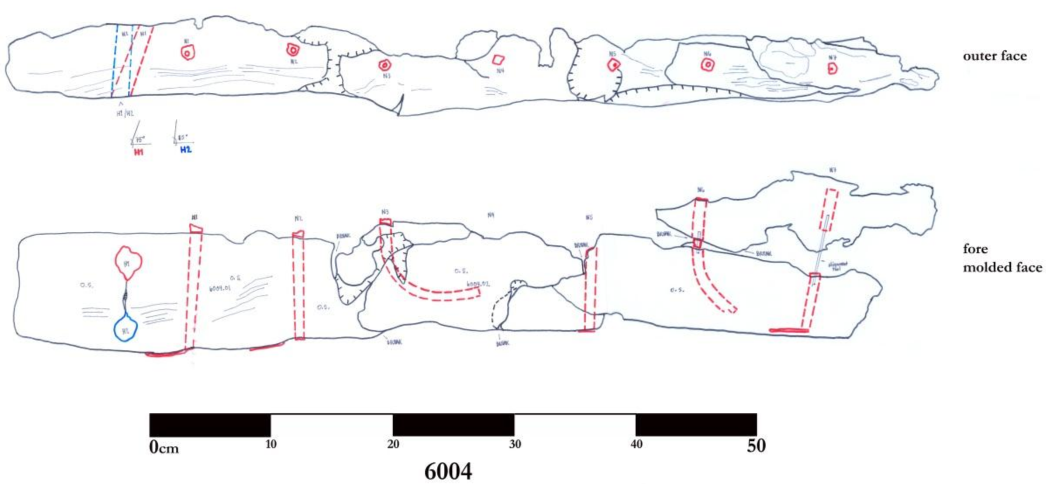
FR6004 Frame *Fraxinus excelsior*

Wood Numbers: 6004.01, 6004.02, 6004.03, 6004.03, 6004.04, 6004.05

Lot Numbers: 1261, 1261.01, 1343, 1343.01, 1343.03-1343.05, 1343.07

Keel end (with two vertical holes) has well preserved forward molded face, inner face, and outer face, otherwise the inner face poorly preserved along remainder of frame. After molded face poorly preserved. Two vertical holes in the keel end: H1, diam. 1.8, drilled at 75º angle with reference to forward molded face. H2, diam. 2.0, drilled at 85º with reference to forward molded face. No pitch retained. No tool marks. Two mis-driven nails embedded in the frame. No plug-treenails observed. Nail staggering slight, if any.

Pres. l. 71.6; s. 6.9; m. 10.5 (broken fragment placed may amend this to 13.0). Six partial nails: N1 l. 11.1, w. 1.1; N2 l. 9.3, w. 0.9; N3 embedded, w. 1.1; N4 l. 7.0, w. 0.8; N5 embedded, w.0.9; N6 l. 5.3, w. 0.8. Nail spacing: N1-N2 9.1 inner, 8.2 outer; N2-N3 7.1 outer; N4-N5 8.2 outer, N5-N6 10.1 outer. One plug-treenail: diam. not discernible. Four partial nail clenches: 3.6, 4.1, 1.0, 3.5.



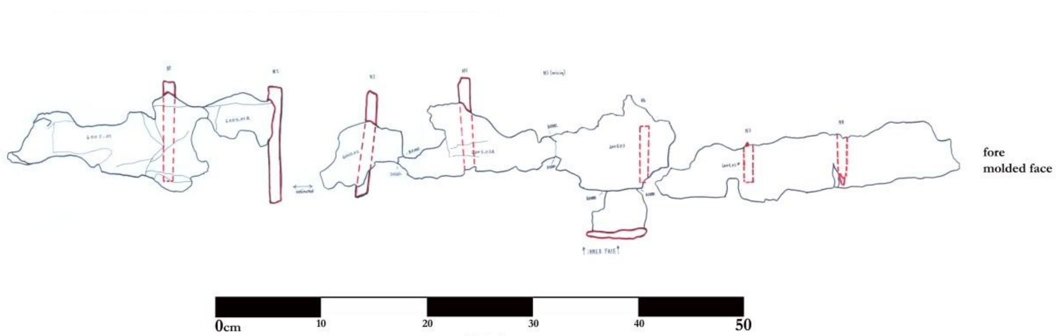
FR 6005 Frame *Fraxinus excelsior*

Wood Numbers: 6005.01, 6005.01A, 6005.02-6005.05

Lot Numbers: 1261.01, 1344, 1344.01-1344.03, 1344.06, 1344.08, 1345

Heavily deteriorated and worn damaged frame. Little original surface of any face.

Pres. l. 90.3; s. 5.9; m. 14.6. Seven nails: N1 l. 9.3, w. 1.2; N2 l. 11.2, w. 1.3; N3 l. 10.3, w. 1.1; N4 l. 8.8, w. 1.2; N5 l. 5.3, w. 1.0; N6 l. 3.9, w. 0.9; N7 l. 4.8, w. 1.0. Nail spacing: N1-N2 9.9 inner, 9,8 outer; N3-N4 10.4 inner, 8.4 outer; N5-N6 9.8 inner, 9.6 outer; N6-N7 8.4 inner, 8.8 outer. No discernible plug-treenails. One partial nail clench: 5.7.



6005

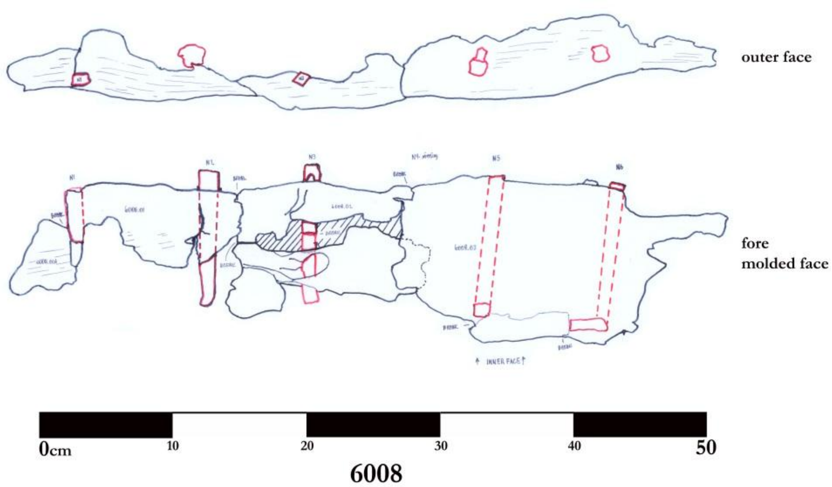
FR 6008 Frame *Fraxinus excelsior*

Wood Numbers: 6008.01-6008.03

Lot Numbers: 1260, 1260.01-1260.02

Poorly preserved frame. Distorted, heavily deteriorated, and worn eaten. Very little original surface. Slight nail staggering.

Pres. l. 54.2; s. 5.5; m. 12.4. Five nails: N1 l. 4.3, w. 1.2; N2 l. 10.4, w. 1.3; N3 l. 7.0 (broken), w. 1.1; N4 l. 11.6, w. 1.2; N5 l. 12.9, w. 1.2. Nail spacing: N1-N2 9.3 inner, 10.3 outer; N2-N3 6.5 inner, 7.6 outer; N4-N5 9.5 inner, 9.0 outer. One plug-treenail: 1.1. One partial nail clench: 4.1.



FR 6009 Frame *Pinus brutia**

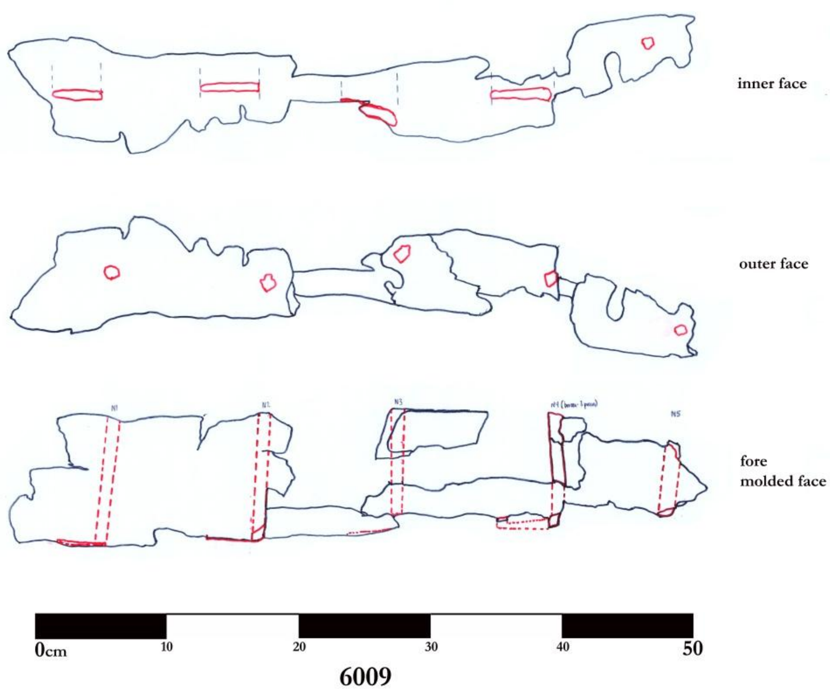
Wood Numbers: 6009.01-6009.03, 6009.05-6009.06

Lot Numbers: 1443.01, 1443.03-1443.06

Poorly preserved frame. Heavily deteriorated and worn damages. Little original surface on any face. Clenches mostly parallel to axis of frame. Slight nail staggering.

Pres. l. 53.1; s. 9.0; m. 10.6. Five nails: N1 l. 10.0, w. 1.0; N2 l. 9.8, w. 0.9; N3 l. broken, w. 1.1; N4 l. 8.7, w. 1.2; N5 l. 5.9, w. 1.0. Nail spacing: N1-N2 12.0 inner, 11.1 outer; N2-N3 11.1 inner, 10.2 outer; N3-N4 12.1 inner, 12.0 outer; N4-N5 8.4 inner, 9,5 outer. No plug-treenails discerned. Two partial nail clenches: 4.3, 4.7.

*(planking fragment 6009.04 attached to the frame)



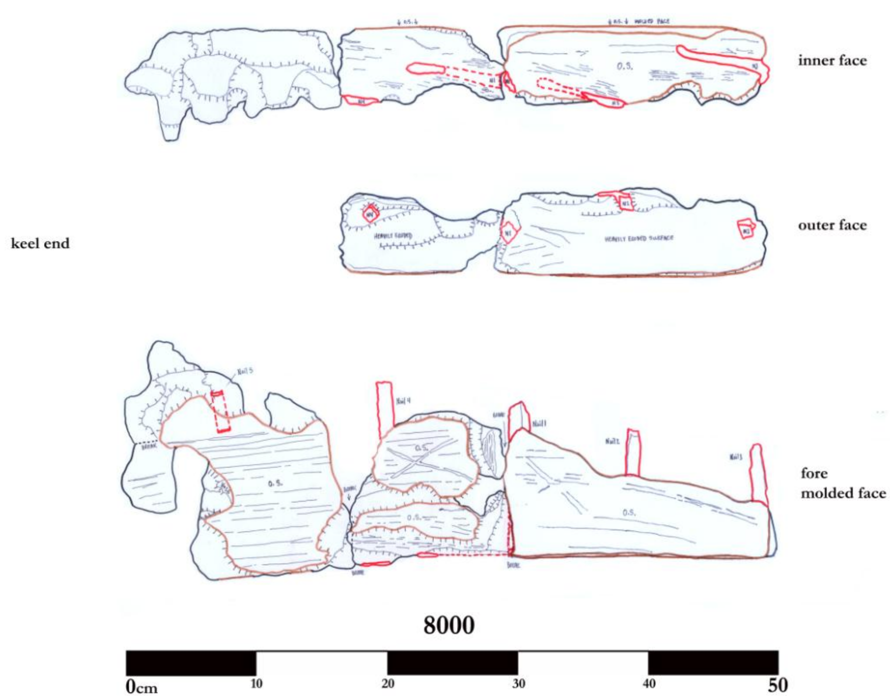
FR 8000 Frame- floor not sampled for wood ID

Wood Numbers: 8000

Lot Numbers: 723

Fairly well preserved forward molded face. Nails staggered across inner and outer faces. All nail clenches parallel to each other but away from central axis of frame. No pitch retained. Edges appear rounded. Molded dimension increases toward the keel.

Pres. l. 50.5; s. 8.6; m. 18.0. Five nails: N1 l. 3.1, w. 1.1; N2 l. 12.34, w. 1.4; N3 l. 10.0, w. 1.2; N4 l. 9.0, w. 1.3; N5 l. 13.8, w. 1.2. Nail spacing: N1-N2 12.6 outer; N2-N3 7.6 inner, 8.7 outer; N3-N4 10.9 inner, 9.5 outer; N4-N5 10.0 inner, 10.2 outer. No plug-treenails discerned. Three nail clenches: 7.8, 6.3, 7.0.



Hull Planking

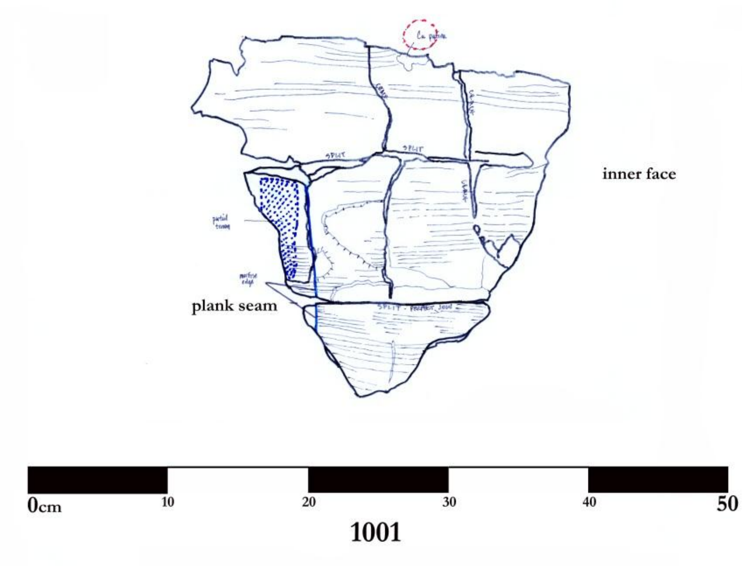
HP 1001 Hull Planking *Pinus brutia*

Wood Numbers: 1001.01, 1001.05, 1001.05A, 1001.05B, 1001.06

Lot Numbers: 1348, 1348.01-1348.09

Two partial strakes with plank seams. Compressed thickness.

Pres. l. 27.2; w. 25.9 (19.1 plank seam to plank seam); th. 2.5. One partial mortise: depth 8.7 (projected to 8.8). One partial tenon: l. 7.2 (projected to 8.7); w. 2.0; th. 0.3. No tenon pegs.



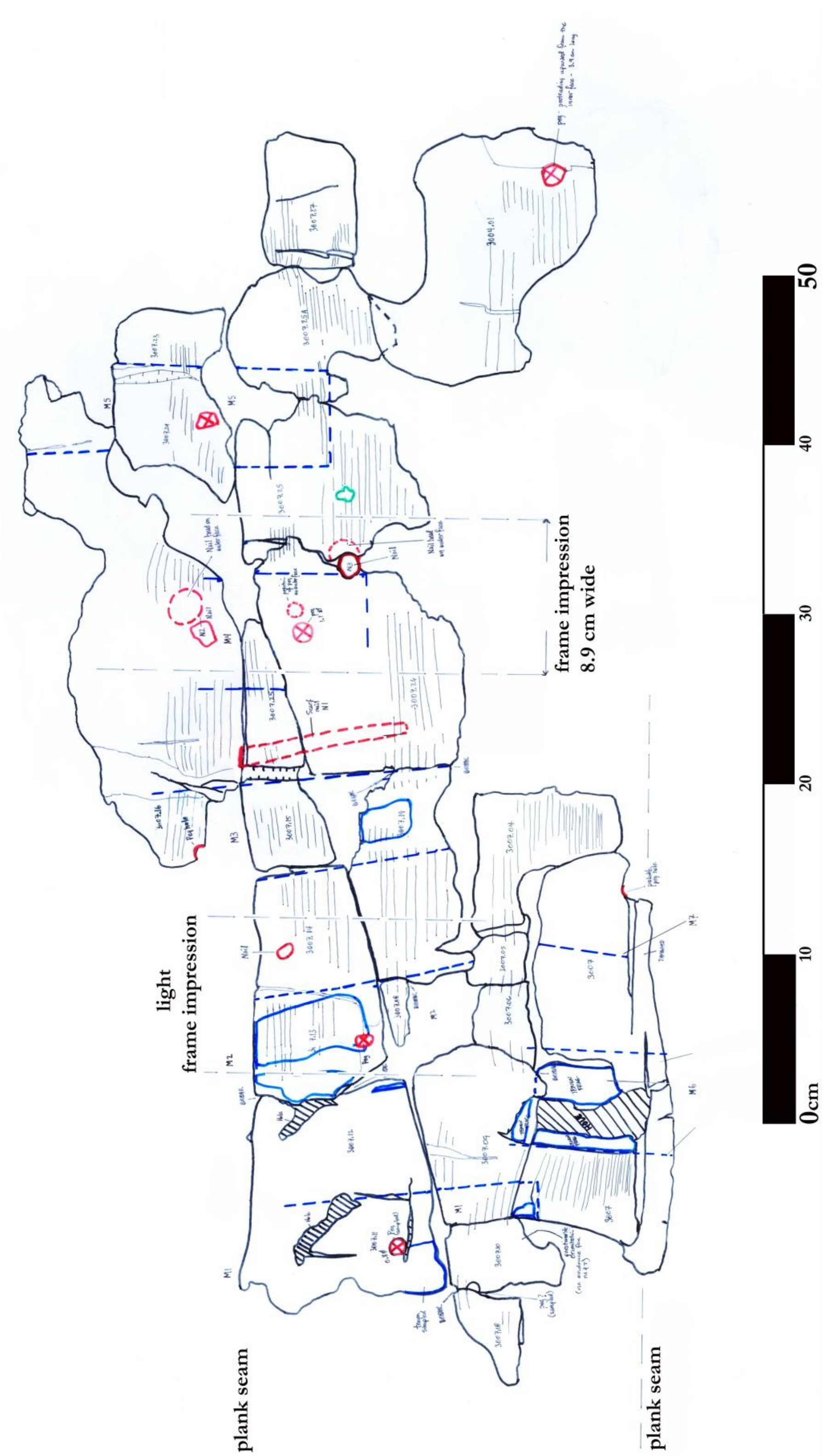
HP 3007 Hull planking *Pinus brutia/Pinus nigra*

Wood Numbers: 3007, 3007.01-3007.29

Lot Numbers: 1268, 1412, 1412.02-1412.05, 1412.07-1412.20, 1442, 1442.02, 1442.03

Two partial strakes with possible small partial third strake fragment. One strake scarfed (pres. l. 52.2- projected l. 80.0). Three mortises in scarf set perpendicular to the scarf seam. Scarf nailed (w. 1.0) from upper plank through lower plank. Mortise 3 (M3) passes from upper strake through scarf tip into lower plank of scarfed strake. Small amount of pitch on inner surface.

Pres. l. 66.3; Overall w. 39.8, strake w. 24.0; th. 3.9. Two partial plank-to-frame nails diam. 1.3, avg. of two examples each 1.3 (inside frame impression) with third partial plank-to-frame nail: diam. 1.1 (inside second frame impression). Eight partial mortises: w. 6.2, avg. of seven examples ranging from 5.7-6.7; depth 7.1, avg. of four examples ranging from 5.5-8.8; th. all compressed. Four partial tenons: all broken in length and width. Five tenon pegs: diam. 1.0, avg. of five examples ranging from 0.8-1.1.


plank seam
light
frame impression
frame impression
8.9 cm wide
plank seam
0cm
10
20
30
40
50

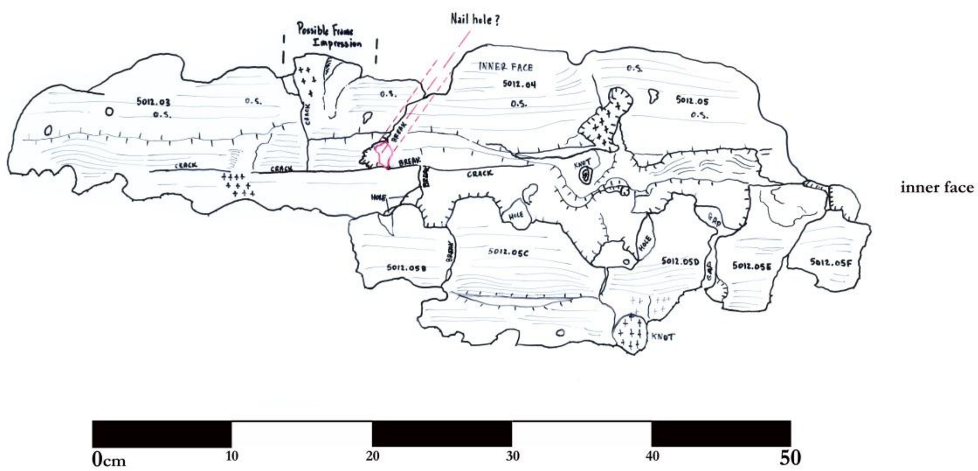
HP 5012 Hull Planking *Pinus nigra*

Wood Numbers: 5012.01-5012.05

Lot Numbers: 1615, 1615.01, 1615.02, 1646, 1670, 1673, 1687, 1687.01-1687.05

Heavily deteriorated garboard strake section. Two partial mortises. Upper section of timber angled at 35º away from vertical. Two knots retain timber thickness. Mortise 1 (M1) is eroded but complete. M2 is incomplete in both width and depth (l.).

Pres. l. 62.3; w. 22.2; th. 4.8. Two partial mortises. M1 l. 5.5; w. 6.2; th. 0.7. M2 l. n/a; w. 5.2; th. n/a. Mortise spacing: M1-M2 (edge to edge) 6.1.



5012- garboard

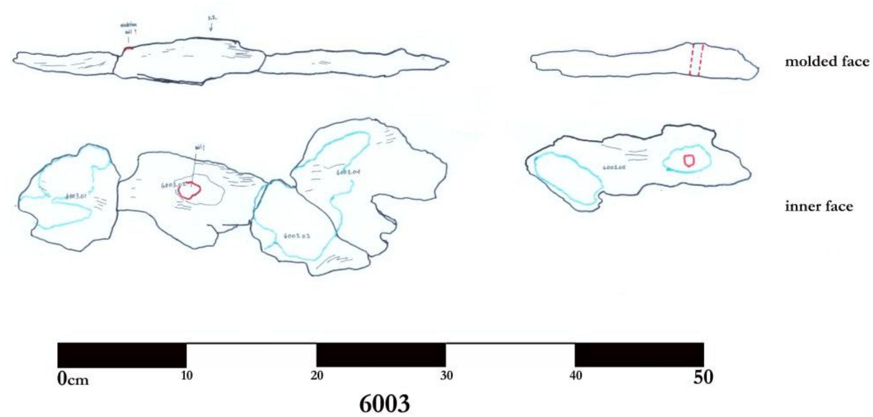
HP 6003 Hull Planking *Pinus nigra*

Wood Numbers: 6003.01-6003.05

Lot Numbers: 1130.01, 1130.02, 1131, 1131.02

Heavily deteriorated planking section. One framing nail hole. Residual iron stain from unknown source.

Recon. l. 46.9; w. 15.8; th. 3.8. Nail hole w. 0.9.



Ceiling Planking

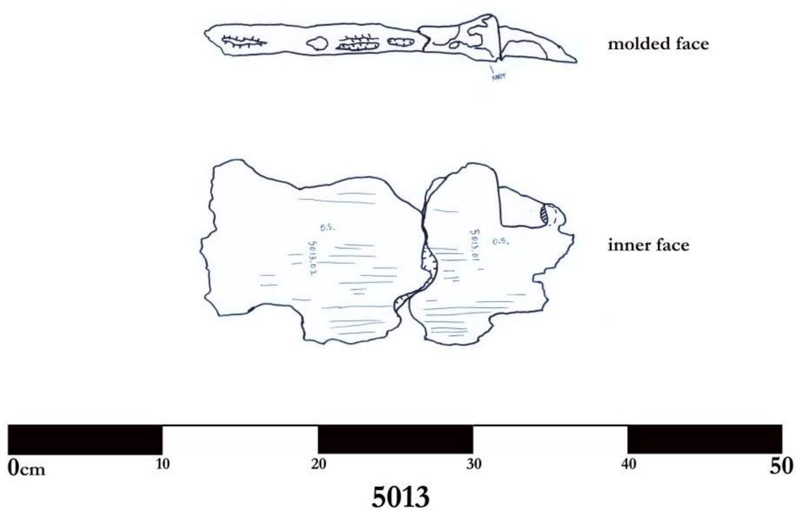
CP 5013 Ceiling planking *Pinus nigra*

Wood Numbers: 5013

Lot Numbers: 1405, 1405.02, 1405.05

Thickness preserved by knot. Otherwise, featureless.

Pres. l. 34.2; w. 12.4; th. 3.1.



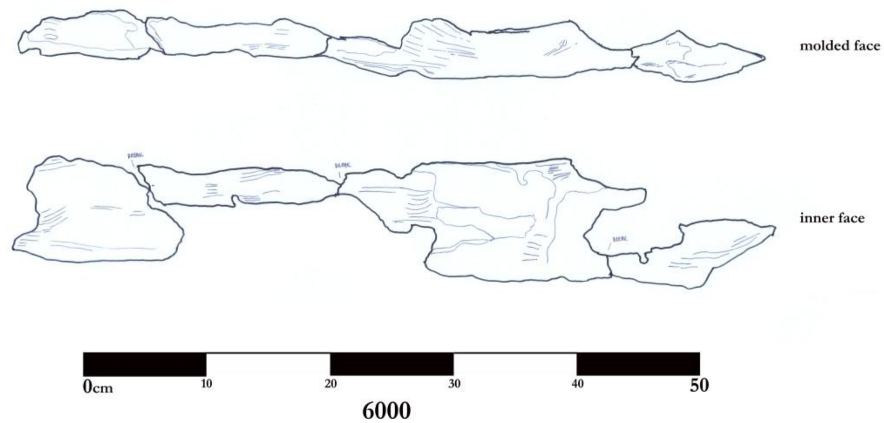
CP 6000 Ceiling planking *Pinus brutia*

Wood Numbers: 6000, 6000.01-6000.06

Lot Numbers: 1129, 1129.01-1129.04, 1184

Featureless.

Pres. l. 61.8; w. 9.8; th. 4.1.



INDIVIDUAL FRAGMENTS

Frames

Lot Number: 594, 680, Wood Numbers: 7001 Frame Not sampled
680.01

Heavily deteriorated frame fragment in three fragments, broken along a treenail. One embedded clenched nail.

Pres. l. 19.8; s. 4.3; m. 5.1. Distinct treenail diam. 1.1. Nail clench l. 4.9.

Lot Numbers 594/680/680.01

Lot Number 680.01

Lot Number: 792 Wood Number: 8001 Frame Not sampled

Mostly deteriorated frame fragment with one partial clenched nail demonstrating minimum molded dimension.

Pres. l. 13.6; s. 3.9; m. 9.7. One partial clenched nail: l. 9.7; diam. 1.2.

Lot Number 792

Lot Number: 903 Wood Number: 5018 Frame *Fraxinus excelsior*

Heavily deteriorated frame fragment. Two partial nails embedded.

Pres. l. 17.7; s. 8.1; m. 10.0. Two partial nails: l. 3.6, 11.0; w. 1.1, 1.3. Nail spacing: N1-N2 10.0. Nail clench: 9.0.

Lot Number 903

Lot Number: 1259 Wood Number: 6002.01 Frame *Fraxinus excelsior*

Heavily deteriorated frame fragment. Two partial nails embedded.

Pres. l. 17.7; s. 6.7; m. 10.2. Two nails: l. 10.6, 9.8; w. 1.0, 1.1. Nail spacing: N1-N2 7.1 inner, 9.6 outer. Nail clench: l. 2.7 (broken).

Lot Number 1259

Lot Number: 1303 Wood Number: 5009.01 Frame *Fraxinus excelsior*

Heavily deteriorated frame fragment with two partial nails. One clear plug-treenail.

Pres. l. 15.5; s. 4.8; m. 8.6. Two partial nails: dist. 10.2 inner. Plug-treenail: diam. 1.6.

Lot Number 1303

Lot Number: 1347 Wood Number: 1000.01 Frame *Fraxinus* sp.
Heavily deteriorated frame fragment with small compressed planking section attached including partial tenon. Two partial nails embedded. Minimum mortise depth taken from partial tenon (5.8). Planking section *Pinus brutia*. Tenon fragment *Quesrcus cerris*.

Pres. l. 19.3; s. 3.8; m. 9.9. Two partial nails: N1 l. 8.0, w. 1.0; N2 l. 3.4, w. 0.8. One attached partial tenon: l. 5.8; w. 3.9; th. 0.3. Nail spacing: N1-N2 6.0 inner, 7.3 outer.

Lot Number 1347

Lot Number 1347

Lot Number: 1444.01 Wood Number: 6010.01 Frame *Fraxinus excelsior*

Heavily deteriorated frame fragment. One nail embedded. Small amount of original forward molded surface and pitch.

Pres. l. 20.9; s. 6.1; m. 11.0. One nail: l. 8.6; w. 1.2.

Lot Number 1444.01

Lot Number: 1455 Wood Number: 3009 Frame *Fraxinus excelsior*

Some original forward molded face surface. Two clenched nails embedded.

Pres. l. 25.8; s. 4.3; m. 8.2. Two nails- spacing: 12.0

Lot Number 1455

Lot Number: 1562 Wood Number: 6018 Frame *Fraxinus excelsior*

Frame fragment with uniform diam. plug-treenail hole.

Pres. l. 8.3; s. 6.6; m. 6.5. Plug-treenail hole: diam. 1.2.

Lot Number 1562

Hull Planking

Lot Number: 1132.03 Wood Number: 6006.04 Hull planking *Pinus nigra*

Part of planking section 6006. To fragmentary to reconstruct. Fragment featureless. Demonstrates planking thickness.

Pres. l. 16.3; w. 11.6; th. 4.1.

Lot Number 1132.03

Lot Number: 1314 Wood Number: 3004.01 Hull planking *Pinus nigra*

Heavily deteriorated hull planking fragment. Partial pegged tenon.

Pres. l. 14.8; w. 14.1; th. 3.8. Partial mortise: w. 3.2 edge to peg center (6.4). Partial tenon: l. 8.2; w. 3.2; th. 0.6. Tenon peg: l. 3.8, diam. 1.1.

Lot Number 1314

Lot Number 1314

Lot Number: 1314 Wood Number: 3004.01B Hull planking *Pinus nigra*
Tiny planking fragment with partial tenon and tenon peg. Compressed in thickness. Tenon of *Quercus cerris*. Tenon peg of *Quercus* sp.

Pres. l. 5.8; w. 7.8; th. 3.0. Partial tenon: l. 6.7; w. 4.8; th. 0.6. Tenon peg: diam. 1.2; min. peg center dist. to seam 1.7.

Lot Number 1314

Lot Number 1314

Lot Number: 1340 Wood Number: 3005.01 Hull planking *Pinus nigra*

Heavily deteriorated planking fragment. Demonstrates both minimum width and thickness of planking.

Pres. l. 16.7; w. 14.9; th. 3.9. One nail: diam. 1.1 driven from outer face.

Lot Number 1340

Lot Number 1350.01 Wood Number: 1003.02 Planking Not sampled

Planking fragment with partial tenon. Demonstrates minimum tenon width. Also demonstrates a thick tenon.

Pres. l.8.8; w. 7.7; th. 3.0. One partial tenon: l. 4.2; w. 6.3; th. 1.1.

Lot Number 1350.01

Lot Number:1445.02 Wood Number: 1004.04 Planking *Pinus nigra*

Tiny planking fragment with partial tenon demonstrating tenon thickness. Planking heavily compressed, tenon less compressed if at all.

Pres. l. 4.0; w. 3.6; th. 1.1. Partial tenon: l. 4.0; w. 3.4; th. 0.9.

Lot Number 1445.02

Lot Number 1445.02

Lot number: 1661 Wood Number: 3011.01 Planking *Pinus nigra*

Planking fragment with attached frame fragment. Mortise shows tapered shape. Partial tenon closely fitted, yet twisted and compressed.

Pres. l. 8.4; w. 11.9; th. 3.8. Half-tenon and mortise. Mortise: l. 7.2; w. 6.4. Tenon: l. 7.2; w. 6.2; th. 0.4 (compressed).

Lot Number 1661

Ceiling Planking

Lot Number: 490 Wood Number: n/a Ceiling Planking not sampled

Featureless.

Pres. l 42.8; w. 14.8; th. 3.0.

Lot Number 490

Lot Number: 886 Wood Number: 5019 Ceiling planking not sampled

Featureless ceiling planking fragment. Demonstrates thickness.

Pres. l. 21.1; w. 7.6; th. 4.2.

no photograph available

Lot Number: 889 Wood Number: n/a Ceiling planking not sampled

Frame fragment and ceiling planking fragment with nail hole. The only frame fragment with definitive ceiling planking attachment.

Pres. l. 15.4; w. 7.0; th. 2.9. One nail hole: w. 0.6.

Lot Number 889

Lot Number 889

Lot Number: 1210.01 Wood Number: 5006.02 Ceiling planking *Pinus nigra*

Featureless ceiling planking fragment demonstrating thickness of timber.

Pres. l. 9.5; w. 3.0; th. 4.1.

Lot Number 1210.01

Lot Number: 1210.02 Wood Number: 5006.03 Ceiling planking *Pinus nigra*

Original inner face surface with saw marks. One nail hole. See Lot Number 1210.01 for thickness.

Pres. l. 13.4; w. 5.6; th. 2.9. Nail hole: diam. 0.4.

Lot Number 1210.02

Lot Number: 1339 Wood Number: 3002.01 Ceiling planking *Pinus brutia*
Heavily deteriorated ceiling planking fragment with one nail hole. Original surface on inner and outer face.

Pres. l. 15.5; w. 7.4; th. 3.5. One nail hole: w. 0.5.

Lot Number 1339

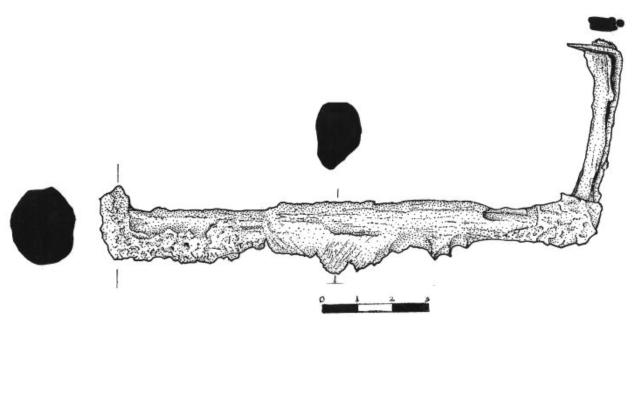
APPENDIX B
FASTENER CATALOG

The assemblage of nails has been separated into four groups; Large Cupreous Fasteners, Small Cupreous Fasteners, Other Fasteners, and Iron Fasteners. For each item its inventory or lot number, area from which it was excavated, excavator's identification, and mapping information (i.e. flag number, tile number, nail number, etc.) is recorded, followed by a brief description of the fastener and an illustration where such exists. Large fasteners are illustrated at a 1:2 scale, while smaller ones are illustrated at a 1:1 scale, unless otherwise noted. All dimensions are in centimeters.

LARGE CUPREOUS FASTENERS (Illustrated at 1:2 scale)

LCF 1. Frame nail Lot 177.03 Area 20

Drawing by Seçil Kayacık.
L. 21.3; max. w. 1.3; diam. head. 2.0; l clench 7.4 cm. Complete in length degraded width. Square section shank. Retains some of the treenail and 3.3 cm of planking wood below the head. Shank length to first clench 12.7 cm preserving the width (molded dimension) of the frame it secured. First clench is formed by an angle of 98º with length 5.8 cm. Second clench 1.6 cm in length.



LCF 2. Frame nail Lot 251 Area 3

No illustration.

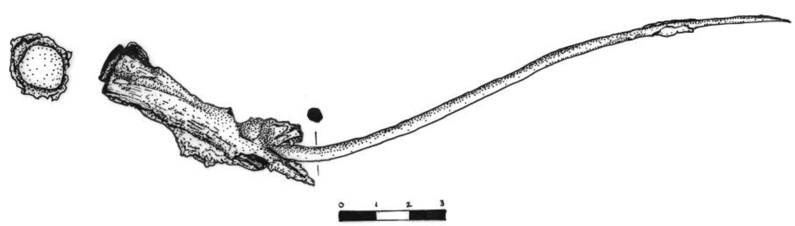
Pres. l. 17.8; max. w. 1.4; diam. head 1.8; clench length n/a. Incomplete and heavily concreted. Head shape is indeterminate. Square section shank. Shank length to first clench 13.7 cm preserving the molded dimension of the frame it secured. The first clench is formed by an angle of 91º, but is incomplete. The second clench is completely missing.

Illustration not available

LCF 3. Nail Lot 298 Area 19

Drawing by Seçil Kayacık.

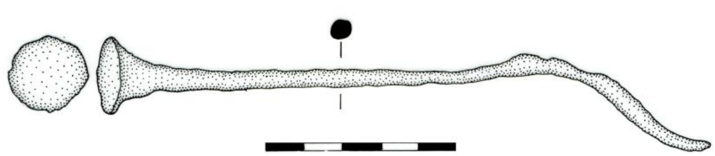
Pres. l 20.2; max w n/a; diam head 1.5; clench length n/a. Flattened pyramidal head. Indeterminate shank shape and width. Remnants of treenail to 5.1 cm below head. Central portion is ferro-magnetic, but not the extremities.



LCF 4. Frame nail Lot 920 East of datum D

Drawing by Mustafa Korkmaz

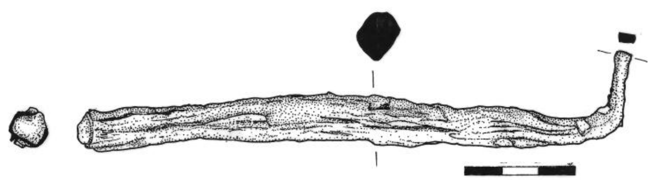
Pres. l. 17.1; max. w. 1.0; diam. head 2.2; clench length n/a. Flattened pyramidal head. Degraded square shank with loss of defined edges. Length to first clench 10.5 cm.



LCF 5. Frame nail Lot 1038 Area U1

Drawing by Seçil Kayacık.

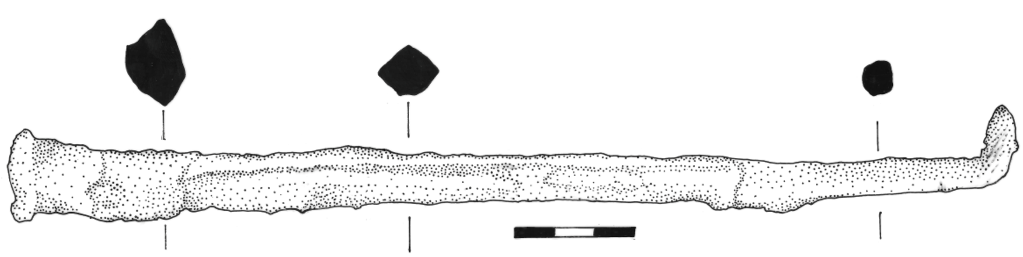
Pres. l. 15.4; max. w. 1.4; diam. head n/a; clench length n/a. Head is heavily eroded and shape is indeterminant. Square shank. Length from head end to top of the clench is 13.9 cm. Shank retains some treenail wood. First clench is formed at an angle of 93º and is mostly missing. Second clench is completely missing.



LCF 6. Frame nail Lot 1329 Area U3

Drawing by Seçil Kayacık.

Pres. l. 26.9 cm; max. w. 1.5; diam. head 2.4; clench length n/a. Restored from four fragments with clearly defined breaks. Indeterminate head shape. Square shank. Shank length to partial first clench 24.1 cm preserving the molded dimension of the floor it secured. First clench is formed by an angle of 104º. Second clench is missing.

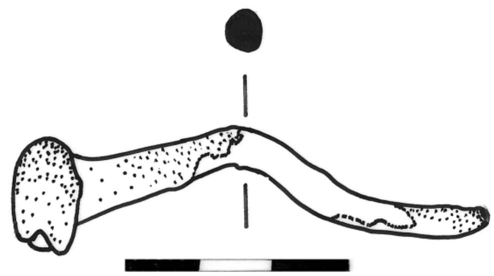


SMALL CUPREOUS FASTENERS (Illustrated at 1:1 scale)

SCF 1. Nail   Lot 233.01   Area U6

Drawing by Mustafa Korkmaz.

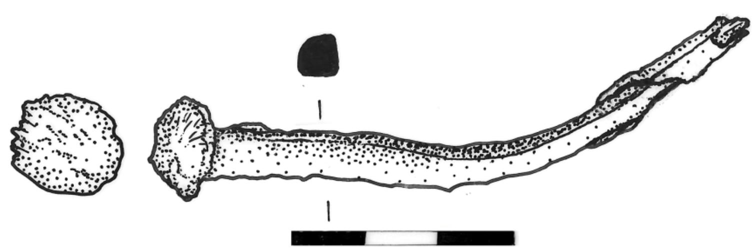
L. 7.0; max. w. 0.7; diam. head 1.6. Flattened pyramidal head. Square shank.. Compound curve starting at 2.8 cm below the bottom of head which is canted 104 degrees to the shank.



SCF 2. Nail   Lot 334.01   Area 19

Drawing by Seçil Kayacık.

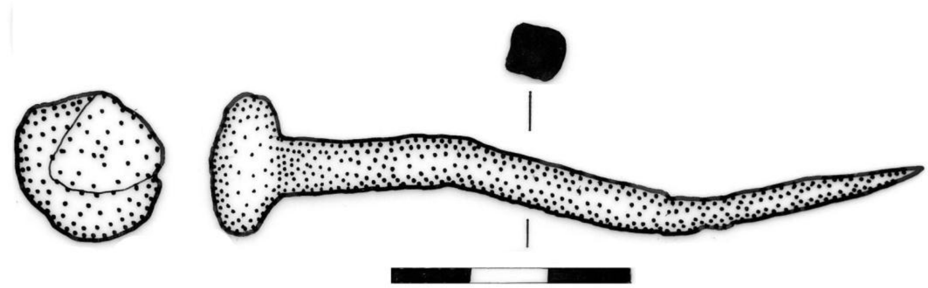
L. 8.4; max. w. 0.7; diam. head 1.5. Flattened pyramidal head. Square shank with a compound curve starting at 4.4 cm.



SCF 3. Nail Lot 340.06 Area 17

Drawing by Mustafa Korkmaz.

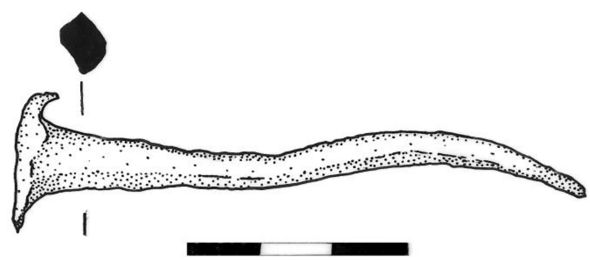
L. 9.2; max. w. 0.7; diam. head 1.9. Flattened pyramidal head. Square shank. with bend starting at 4.5 cm below head.



SCF 4. Nail Lot 655.03 Area 17

Drawing by Seçil Kayacık.

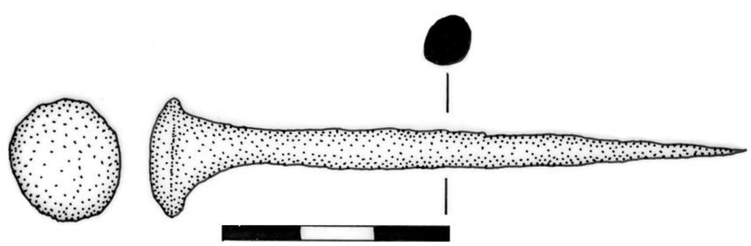
L. 8.0; max. w. 0.6; diam. head 2.0. Flat head. Square shank.



SCF 5. Nail Lot 734 Area 1

Drawing by Mustafa Korkmaz.

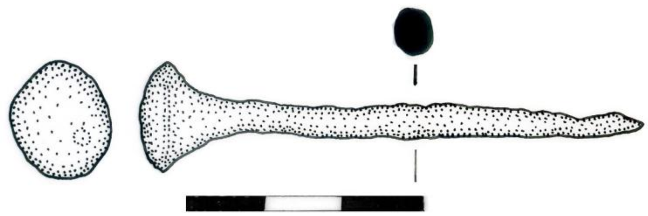
L. 7.6; max. w. 0.7; diam. head 1.7. Flattened pyramidal head. Square shank.



SCF 6. Nail Lot 844 Area 20

Drawing by Mustafa Korkmaz.

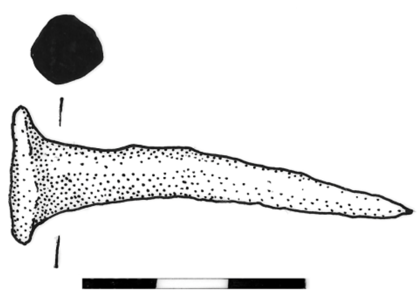
L. 6.5; max. w. 0.6; diam. head 1.5. Flattened pyramidal head. Square shank with degraded edges.



SCF 7. Nail Lot 872 Area 17

Drawing by Seçil Kayacık.

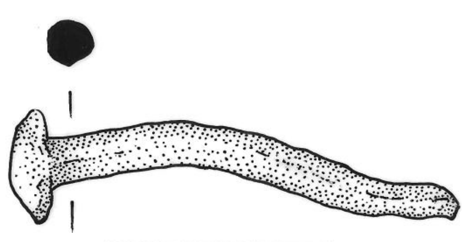
L. 5.4; max. w. 0.9; diam. head 1.9. Flat head. Square shank rapidly tapers toward distal end with slight curvature.



SCF 8. Nail Lot 881 Area 20

Drawing by Seçil Kayacık.

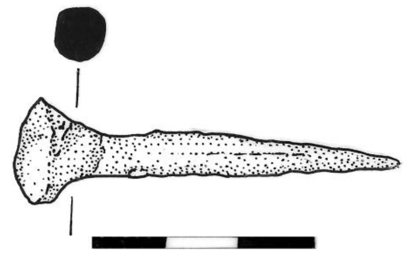
Pres. l. 6.0; max. w. 0.6; diam. head 1.5. Flattened pyramidal head. Square shank., with compound curved shape. Distal end is broken.



SCF 9.Nail Lot 1048 Area U3

Drawing by Seçil Kayacık.

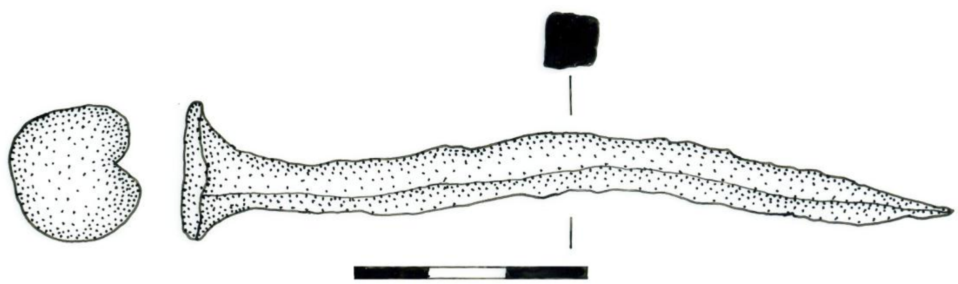
L. 5.2; max. w. 0.6; diam. head 1.5. Flattened pyramidal head. Square shank.



SCF 10. Nail Lot 1114 Area 17

Drawing by Mustafa Korkmaz.

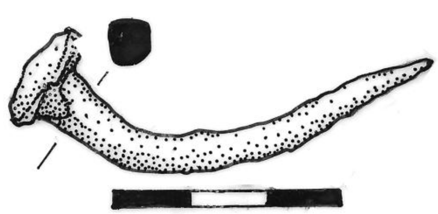
L. 9.8; max. w. 0.6; diam. head 1.7. Flat head split on one side, likely due to impact of heavy hammering. Square shank with broken distal end.



SCF 11. Nail Lot 1482 Area U1

Drawing by Seçil Kayacık.

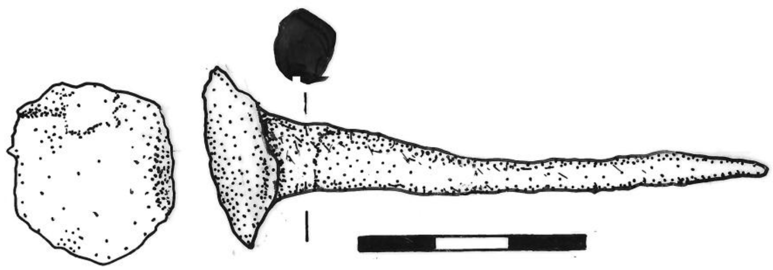
L. 5.6; max. w. 0.7; diam. head 0.9. Flat head. Square shank with eroded edges and a bend starting 1.5 cm below head.



SCF 12. Nail Lot 1657 Area U2

Drawing by Seçil Kayacık.

L. 7.4; max. w. 1.0; diam. head 2.5. Flat head canted at an angle of 104 degrees to the shank. Square shank tapers rapidly toward distal point.

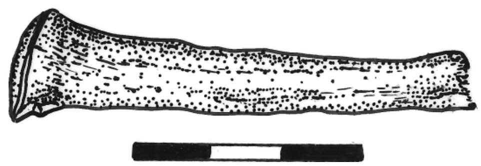


OTHER CUPREOUS FASTENERS (Illustrated at 1:1 scale)

OCF 1. Nail Lot 365 Area 20

Drawing by Seçil Kayacık.

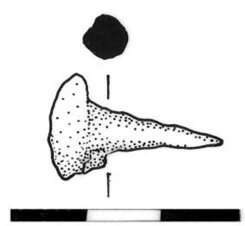
Pres. .l 6.3; max. w. 1.1; diam. head 1.6. Almost indeterminate flat head canted at 10º. Shank broken at 6.3 cm.



OCF 2. Tack Lot 1219 Area U1

Drawing by Seçil Kayacık.

L. 2.4; max. w. 0.5; diam. head 1.5. Flattened pyramidal head. Square shank with crisp edges.

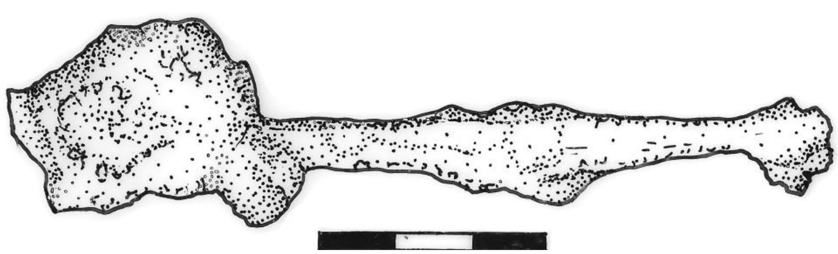


IRON FASTENERS (Illustrated at 1:1 scale)

IF1. Nail Lot 144 Area 18

Drawing by Seçil Kayacık.

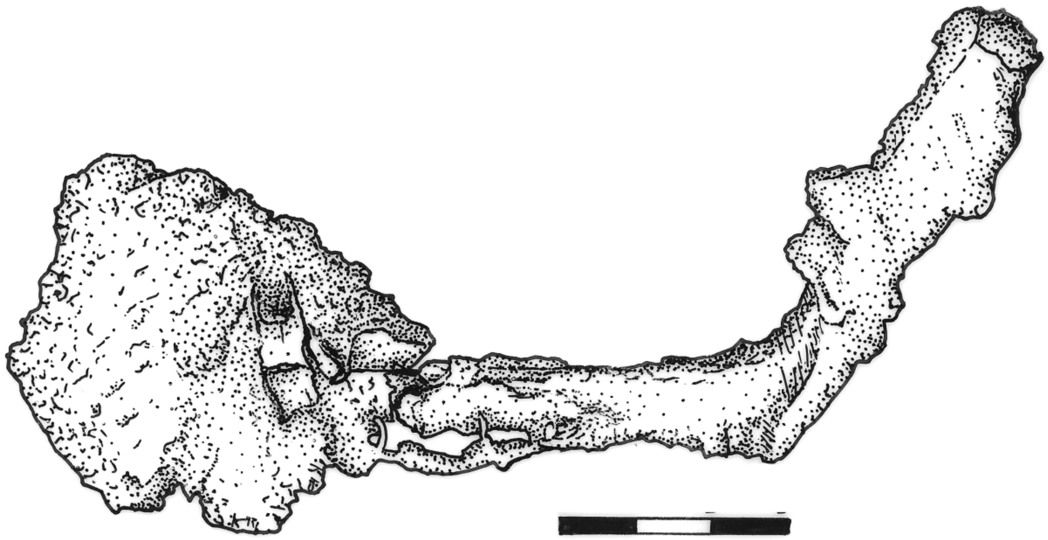
Pres. l. 8.8; max. w. 0.65; diam. head n/a. Incomplete. No head. Square-sectioned shank tapering to 0.45 cm at distal end.



IF2. Nail Lot 655.04 Area 17

Drawing by Seçil Kayacık..

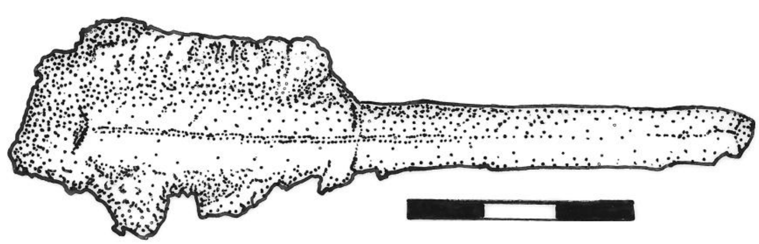
Pres. l. 12.1; max. w. 0.91; diam. head n/a. Incomplete. Head survives under iron bleed but is indeterminate. Iron impregnated wood encases approximately 6.5 cm of the shank. Square-sectioned shank tapers toward missing distal tip (0.91 cm to 0.76 cm).



IF3. Nail Lot 950 Area 17

Drawing by Mustafa Korkmaz.

L. 8.4; max. w. 0.64; diam. head n/a. Incomplete. No head, may be broken off. Square shank tapering toward broken distal tip (0.64 cm tapering to 0.44 cm).



IF4. Possible bolt Lot 396/Lot 497 Area U1

No illustration available.

Pres. l. 32.5; max. w. 2.1; diam. head n/a. Round section. Head and distal end not discernible due to irremovable concretion and epoxy impregnated wood material.

Table B.1. Raw fastener data

Sequential listing of nail Lot Numbers.
* nud- no usable dimensions
† other- conical remnants of deteriorated nail head
high-lighted entries used for cataloging or analysis

Locus	Lot no.	nail no.	mapping No.	head	nud*	other †	l.	max. w.	diam. head	comments
19	19		48				9.9	0.7	0.9	probable complete nail, eroded
20	25.02		53				1.8	0.5		2 fragments
17	37.02		51				6.0	0.5	1.0	probable complete nail, eroded
17	37.02		51				3.3	0.7	1.0	non-distinct head, eroded, ferro-magnetic
3	39.01		57				4.7	1.2	2.5	heavily concreted
3	39.02		57				10.5	1.2		shaft section only
13	46.01		35	√			4.2	1.4	1.7	
5	60.02		7				7.2			heavily concreted.
5	60.02		7		√					fragmentary shaft remnant
5	61		65		√					heavily deteriorated
5	64		62				8.4	1.5	2.7	3 fragments
4	65		61				11.0	1.1		2 fragments, clench bend, joining
3	74		31	√			11.5	1.3	2.1	2 fragments w/ head join
3	74		31				9.2	1.3		shaft fragment
20	77		78						2.2	4 fragments, heavily concreted.
20	86.02		76				7.3			heavily concreted. shaft fragment
20	87.01		43	√			4.4	1.3	2.7	concretion
20	88		BAK			√	1.9	0.7		
20	88.01		AAM				1.5	1.1	1.7	tack?
3	91		50				5.8	0.6	1.3	complete, square section, pyramidal head
3	92		52	√			4.0	1.3	3.7	concretion
3	93		63		√					
13	102.02		10			√			1.0	
8	103		34	√			5.3	1.6	2.7	
20	108.01		ABM	√			4.5	1.6		head nud
3	110		55	√			4.2	1.2		head nud

3	111		29				4.1	1.7		shaft fragment
20	113		near ABP				4.7	0.5	0.9	tack?
3	118		71	√			4.2	1.7	2.8	
20	119		ABR	√			4.9	1.2	2.1	
20	119		ABR	√			3.8			partial head
5	123.03		75				10.7			clench bend at 8.2 cm
6	124		60		√					splintered fragments
20	127		ABP	√			1.7	1.8	3.0	
3	129		72				4.1	0.6	1.5	square section, probable complete nail- eroded
3	129		72				3.6			heavily deteriorated-
3	129		72				2.3	0.7	1.4	eroded version of 1219?
3	129		72		√					heavily deteriorated-
5	130		63				5.0	0.7	1.4	probably complete, heavily eroded
5	130		63		√					
6	131		64	√			3.7	1.4	2.6	
5	132		74				13.6	1.5		multiple frgaments of nails and tacks
5	132		74				8.5			
5	132		74	√			4.5	1.3	2.5	
5	132		74	√			3.7	1.1	2.0	
5	132.01		74				10.1			shaft fragment
5	132.01		74	√					2.0	mushroom head not flattened
5	132.02		74	√			7.7	1.6	3.0	
20	135		ABP	√			3.7	1.4	4.0 ?	splintered fragments
6	136		54				6.0			possibly complete, heavily deteriorated-
13	139.01		61	√			4.5	1.7	3.3	
13	139.02		61	√			5.1	1.6	2.4	partial nail head
13	139.03		61				3.0	1.0		shaft fragments
13	139.04		61	√			6.5	1.7	2.5	broken at 5.0 cm
13	139.05		61	√			4.1	1.5	2.6	
13	139.06		61	√			6.8	1.5	2.8	
13	139.07		61		√					
13	139.08		61				4.5			double clench bend, 3.1cm between bends
20	140		ABP		√					possibly complete, heavily deteriorated-
5	142.01		31		√					
5	142.02		31	√			9.9			heavily concreted. head
20	145.02		ABP	√			3.9	1.4	2.1	
13	148		31, 61		√					bag of fragments
3	151		84	√			6.7		2.5	head and splintered fragments

3	151.01		84				10.2	1.5		shaft fragment
3	151.02		84	√	√					splintered fragments and head heavily concreted.
3	151.03		84				8.8			3 shaft fragments
3	151.04		84		√					
3	151.05		84		√					
3	151.06		84	√			5.6	1.1	2.2	
3	151.06		84	√			7.8	1.1	2.5	
18	153		in amphora	√			5.9	1.7	2.4	head and splintered fragments
8	155		52		√					separate wood fragment , fragment mentary shaft remnant
3	156		84				8.7		1.2	103 degree bend at 4.5cm, heavily deteriorated shank, pyramidal head
3	157		84	√			9.2	1.5	2.3	
3	157.01		84		√					
3	157.02		84	√			11.9	1.1	1.9	shaft fragment w/ head square section
3	157.03				√					splintered fragments
3	157.05						8.1	1.3		clench bend ≈ 80 degrees
20	158		ABP-2		√					
5	160.01		84		√					
3	162		64		√					heavily deteriorated
3	163		73		√					square section shank, heavily deteriorated-
20	164		ABP-2				10.9			shaft fragment
20	164.02		ABP-2		√					lg concretion w/ Cu/Cu alloy staining
18	165		88				6.0	0.6	1.1	
18	165		88				11.4			clench bend, heavily concreted
18	165		88				8.4	2.1		heavily concreted., clench
18	165		88				7.2			heavily concreted.
20	166		ABP-3				10.6			w/ clench at 8.5cm ≈ 50 degrees
20	166.01		ABP-3				10.5			
20	166.02		ABP-3				10.8	1.2		shaft fragment
5	168		84	√			3.9	1.8		head nud
13	169		80				3.4	1.5		shaft fragment
13	170		61	√			6.6	1.4	2.7	
13	170.01		61	√			15.4	1.6	2.8	4 fragments
13	170.02		61	√			3.0	1.3	1.9	partial nail head
13	170.03		61	√			10.6	1.4	2.2	
13	170.04		61	√			14.3	1.7	2.7	
13	170.05		F group				9.7			double clench bend, heavily concreted. 7.5cm between clenches

20	171.01						8.5			bad lot no.; heavily concreted, nud
18	172.01		88		√					
18	172.01		88		√					heavily deteriorated
18	172.03		88		√					
20	173.01		ABP-3		√					
20	175.01		ABP-26	√			5.0	1.6	3.0	head and concreted shaft
20	175.02					√	1.1		1.1	
20	176.02		next to drum 2		√					
20	177.03						14.5	HC	HC	12.3cm to 1st clench- 4.2cm to 2nd clench, complete- 21.3cm straight line length; ferro-magnetic
18	180.03		88		√					heavily concreted
3	181.01		63	√					2.3	
3	181.02		63	√			5.1	1.5	2.6	
3	181.03		63	√			5.2	1.6	2.6	head and shaft
3	181.04		63		√					heavily deteriorated; ferro-magnetic
3	181.04		63			√	1.3	0.8		
3	181.04		63			√	1.2	0.6		
19	182		38	√			4.7	1.6	2.7	head and shaft
20	183		56				11.8		1.8	broken framing nail, retains section of treenail and possibly planking (3.0 cm)
6	185		11				8.7	1.5		shaft fragment
20	186.01		ABU				6.3			heavily concreted. shaft fragment
6	187		62		√					shank fragment
g	191.01		tile 9	√			5.2	1.5	2.6	broken at 4.7cm
9	192.02		b/t drums 7&8				4.7	0.7	1.0	complete
9	192.02		b/t drums 7&8				7.5	1.0		square section, shaft
20	193.01		ABX (anchor)			√	1.9	1.0		
	195.01		26		√					
19	197		NW of drum 1				4.2	1.1		shaft fragment
18	201		b/t drums 7&8				4.2	1.1		shaft splintered fragments
19	202		32				7.2			double clench bend, 5.5cm between bends
20	204.03		anchor				3.9	1.5		shaft fragment
4	206				√					
20	209.01		e of iron anchor	√			6.6	1.8	2.9	possible head
8	214		81	√			4.5	1.5	2.1	
19	215		38	√			4.2	1.7	3.0	bend at 3.0cm
19	216		ABS/AAL	√			6.6	1.5	2.8	
5	219		34	√			5.3	1.2	1.9	

5	219.01		34	√			4.0	1.2		tack??
5	219.02		34		√					splintered fragments
5	219.03		34	√			4.5	1.3	2.3	
5	219.04		34	√			4.8	1.4	3.0	
5	219.05		34	√			4.1	1.3		head nud
5	219.06		34	√			8.0	1.6	2.6	square section
5	219.07		34	√			4.2	1.9	2.6	
5	219.08		34		√					
5	219.09		34	√			5.3	1.7	2.9	square section
5	219.1		34	√			4.0			nud heavily concreted.
5	219.11		34		√					
5	219.12		34		√					
20	220.02		anchor /AAL		√					
13	225		35	√			5.1	1.3	2.7	
13	225.02		60	√			4.1	1.7	2.5	
20	227.01		52	√			8.3	1.5	2.4	partial nail head
3	231		54				9.0	1.4		2 shaft fragments
3	232		34	√			4.2	1.5	3.0	
3	232.01		34	√			5.6	1.4	3.0	
3	232.02		34	√			5.8			heavily concreted. head
3	232.03		34		√					small group of nails
6	233		64							complete but heavily deteriorated
6	233.01		64				6.2	0.7	1.6	6.5 cm length measured w/string, complete, square shank
20	235			√			4.0	1.2	2.2	
20	235						10.0			shaft fragment no join with above
20	236		near anchor		√					
20	238.01		ABX		√					
3	239		63				4.2	1.1		shaft fragment
3	240		34				4.2	1.3		shaft fragment
13	241		82		√					
13	241.01		82	√			4.4	1.5	2.5	
13	241.02		82	√			1.7		2.4	
13	241.03		82		√					
13	242		11		√					thin shank section, no way to know if it was broken or complete
13	242.02		11	√			3.8	1.5	2.4	
13	243		70		√					
19	244					√	2.1	0.7		

3	247		85	√			4.0	1.2	2.9	
3	247.01		85				9.3	1.2		2 fragments, clench bend, no join
3	248		33	√			4.2	1.5	1.9	
3	248.01		33		√					
3	248.02		33	√			13.6	1.4	2.5	2 fragments, head, shank broken at 4.2cm
3	248.03		33		√					
3	251		97	√			15.9	1.4	1.8	long nail and splintered fragments
20	253		ABP-2		√					
20	253.01		ABP-2				11.0	1.4		shaft fragment square section
20	253.02		ABP-2				15.1			
20	253.03		ABP-4	√			4.3	1.4	2.6	
20	253.04		ABP-4	√			5.5	1.6	2.9	
20	253.05		ABP-4	√			5.5	1.5	2.3	concretion
20	254.01		26		√					
20	254.02		26		√					
13	255.01			√			5.4	1.7	2.7	
20	258		under anchor				18.2			heavily concreted.
20	260.03		ABX-3		√					
17/19	263.02		102			√	1.3	0.7		
20	264.01		under anchor	√			7.7	1.6		head nud
20	264.02		under anchor				12.1			heavily concreted.
20	266.02		ABX-3				3.5	1.7		shaft fragments
8	270		rt of drum 8	√			4.2	1.7	2.6	
8	270.01		rt of drum 8		√					
8	270.02		rt of drum 8	√			5.0	1.6	2.7	head broken at 4.0cm
20	271		ABX-4				15.7			heavily concreted.
20	273		ABV	√			15.9	1.6	1.9	
20	273.01		ABV		√					heavily deteriorated no definable dimensions, very small
9	275		62		√					
19	279.01				√					
20	280.02		AAK				9.2			heavily concreted. shaft fragment
20	281.01		TOP of drum 2		√					note position
19	282		AAV				14.3	1.3		shaft fragment
20	283.01		under ABX-4				10.2			heavily concreted.
20	285		AAK/ ABZ				5.8			heavily concreted. shaft fragment
20	286		AAK				5.2			heavily concreted. shaft fragment
1	287		91		√					heavily deteriorated no definable dimensions, very small
20	289.02				√					lightly magnetic, partial double clench

20	289.02				√					wire thin deterioration
19	290.01		AAM/ ACB				10.6			clench bend L shape
19	290.02		AAM		√					splinter
18	293		35		√		12.0			square section tapers to wire thin at 3.3 cm
19	296		55		√					
19	297		92/ABV	√			14.1	1.1	1.9	wood attached
19	297		92	√			3.0	1.1		head nud
19	297.01		92				4.6	0.6		shaft fragment w/40˚ bend
19	298		101				20.2		1.5	heavily deteriorated, thin, first bend at 5.7 cm, second bend at 14 cm
2	299						19.7			large nail shank- very thin,
2	299.01		92				5.6	0.9	1.8	heavily concreted.
2	299.02						10.2	2.0		splintered shaft
19	301		92		√					under 297.01
19	302		55				3.0		0.7	tack?
19	302				√					heavily eroded small nail
9	302.02						5.7	1.0		2 shaft fragments, no joins
19	303		AAV	√			5.3	0.7	1.5	complete, staright
19	305		AAP				10.1			shaft fragment
19	306.03		AAV	√			4.6	1.6	1.7	
9	307.04		b/t drums 7 & 9	√			4.7	1.4	2.3	
19	308		55		√					
19	308.01		55				6.2	0.4		shaft in concretion
19	308.01		55				6.1	0.7		complete ? Head undefined; ferro-magnetic
2	309			√			13.0	0.7	1.2	complete, straight, heavily concreted.
19	312		AAV/AAU		√					
19	313		bottom drum2		√		2.7			splinter
19	313				√					splinter
19	316.01		AAM				6.3	0.5		square section, shaft tip
19	317.02		55				7.9			clench bend
19	317.03		55		√					
2	319				√		9.8			shaft, clench bend, heavily concreted.
2	319				√					heavily concreted shank section, no metal left
2	319.01						12.7			heavily concreted. shaft fragment
2	319.02						3.9	1.0		clench bend
2	319.03				√					
20	321		87				14.2	1.2		heavily concreted. 2 fragments join
20	329.03						10.3			heavily concreted

20	329.04				√					
20	329.05						13.2			heavily concreted.
19	334		102				6.4	0.8		nice nail, heavily concreted. head
19	334.01		102				8.0	0.8	1.7	bend
19	334.01		102				8.4	0.7	1.5	complete - possible broken tip, nice
3	336				√					
3	336.01			√			9.7	1.5	2.5	
3	336.02			√			4.8	1.5	2.4	head and splintered fragments
19	338		w of AAV				15.0			
19	338.01		AAU	√			16.2		1.8	
17	339.05						5.6		1.6	shaft, heavily concreted.
17	339.05		anchor collars						1.5	heavily deteriorated, flat head
17	340.05						11.3			heavily concreted.
17	340.06			√			9.0	0.7	1.9	complete
19	344.07				√					splintered fragments
	346		loose				3.5		1.0	tack
	346		loose			√	1.0		0.7	
??	346						3.5	0.6	1.0	eroded, original dimensions?
??	346					√	0.8	0.8		
19	348.05						6.0	1.0		splintered fragments
	350						12.5			curved, wire thickness
20	356.05				√					splintered fragments
19	360		AAR	√			9.1	1.4	2.3	long nail
20	361.04			√			5.1	1.2	2.0	
20	361.04						4.9			clench bend ≈ 75 degrees
19	363			√			9.0		2.0	
19	363.01				√					
20	364			√			11.4	1.3	2.2	
20	364.01				√					
20	365		33	√			6.2	1.0	1.6	square section, tip broken off
17	365		33				6.2	1.1	1.6	flat head, broken large nail, good metal, removed for analysis
20	366			√			4.9			head nud
19	371.04			√			6.2			head nud
1/2	372		AAN/ABT		√					
19	373.01			√			11.3	1.6	1.7	shaft fragment square section
20	373.02			√			9.7		2.2	shaft fragment square section
20	373.03						7.0			shaft fragment
17	376.03		35	√			8.5	1.5	2.5	

17	376.04			√			3.5	1.2	2.0	partial head
17	376.05						4.8		0.9	tack
17	376.05		35				4.8	0.5	0.9	square section, probably complete nail, ferro-magnetic
17	376.06				√					
17	380.07				√					
17	381.04		11				6.7	0.6	0.9	slight bend
17	381.04		11				6.8	0.7	0.9	square section, eroded, probably complete or near so
17	381.05		11			√	1.6		0.8	
17	381.05		11			√	1.7	0.8		
17	381.06		11	√					1.6	
17	381.06		11	√				0.7	1.6	broken head, flattened pyramidal head shape
19	385.04			√			4.0	1.5	2.6	
19/20	388.01		384	√			5.2	2.0	3.2	
19/20	388.02						8.5	0.9		shaft frag
19	399		103	√			4.4	1.4	2.3	
19	400		104		√					
19	401		5				7.0	0.5		heavily deteriorated
19	404		4		√					
19	405		2				7.0	1.3		shaft fragments
20	408		64	√			9.0	1.4	2.2	partial head and shaft
20	408.01		64				8.4	1.6		shaft
19	410		71	√			5.6	1.4	1.9	
19	410.01		71				6.1			shaft, concretion
19	415		71				7.3	0.8		shaft fragment
19	416		123	√			5.1	1.6	3.0	partial head
19	428.01		103	√			7.4		1.8	
19	430		50				4.5	1.4		shaft fragment
19	432		125		√					shaft fragment
20	436		90	√			7.8			head and shaft fragments
20	436.01		90	√			7.8	1.2	2.4	
17	439		tile 17				4.3	0.5		tip
19	443		102		√					
19	444		14		√					
20	446		64			√	2.2		1.7	
20	446.03		64	√			13.1		1.7	
20	446.04		64	√			14.4		0.8	wire thickness, straight
20	446.05		64			√	1.4		1.0	
20	446.06		64		√					

D	447.01		datum D		√					
17	450.01						2.1		0.8	tack?, heavily concreted.
19	451		8				13.4	1.4		shaft fragment
9	454.01		b/t drums 7 & 8				8.5			shaft fragment
20	457		12	√			2.6	0.6	1.2	heavily concreted.
20	460	N20.01	118				7.2			shaft fragment
19	461		135		√					3 fragments, no join
19	462		ABY			√	1.0		0.8	
20	463.02		12		√					concreted splintered fragments
20	464	N19/20.02					4.0	1.0		clench bend ≈ 80 degrees
20	465	N19/20.03		√			5.2	1.5	1.9	
19	468.01		152	√			5.1	1.5	2.4	
19	468.02		152				7.4	1.2		shaft fragment
19	468.03		152		√					shaft fragments
20	473	N19/20.04		√			5.2	1.6	1.8	
20	474	N19/20.05		√			7.2	1.5	2.1	broken at 5.0
19	476.02		152				4.6	2.0		3 shaft fragments heavily concreted.
20	478	N19/20.07		√			6.5	1.6	2.1	
20	478	N19/20.07					4.0			
20	479	N19/20.06		√					3.1	4 fragments, no obvious join
19	481		141	√			8.0			head nud
20	485	N20.08		√			4.1		3.2	probable iron staining on top
20	486.02		29				14.4			shaft fragment
20	492	N19/20.14		√			9.5			heavily concreted. nail w/ head
20	493	N19/20.13					10.4			heavily concreted.
20	496	N19/20.09		√			5.2		1.9	
20	501	N19/20.10		√			10.5	1.4	2.1	head and shaft join
19	502.01		152				7.0	1.4		shaft fragment
20	505	N19/20.11		√			10.7	1.7	2.9	heavily concreted.
20	506	N19/20.12		√			7.2	1.2	2.3	
20	507	N19/20.15		√			4.9	1.5	1.6	square section
20	508	N19/20.17		√			6.0	1.7	3.3	
20	509	N19/20.16		√			3.5			head NUD
19	511.02		7				3.3	0.7	1.1	3 tack fragments 2 join w/ 90 degree bend
20	513	N19/20.18					4.3	1.3		shaft head
19	514		137	√			14.1		1.8	head broken at 4.9
19	514.01		b/t drums 1&2					1.4		shaft fragment
19	515		184	√			3.4	1.4	2.9	

20	521	N19/20.19	163		√					
20	521.01		163		√					
20	522	N19/20.20		√				1.2	1.7	
19	527.01			√			4.6	1.6	2.3	head and shaft fragments
	529		181	√			5.2	0.5	0.9	
19	530		181	√			4.9	0.5	1.0	
19	539		170				4.9	1.4		shaft fragment
19	540		181A		√					
17	543.02		173				3.8	1.5		shaft fragments
18	546.01		179			√	2.0		0.5	
18	546.02		179			√	1.7		0.6	
18	546.03		179			√	0.7		0.4	
20	551	N19/20.22		√			4.5	1.3	2.2	partial head
20	552	N19/20.23		√					2.9	partial head
20	553	N19/20.21		√			4.2	1.5	2.5	partial head
19	560.01		44		√					
19	561		7A	√			4.6	1.5	2.5	partial head
20	564	N19/20.25		√			8.3	1.6		head and shaft square section
20	567	N19/20.24		√			5.2	1.5		head nud
20	567.01		next to 567		√					splintered fragments
18	570.02		195		√					
19	571		159	√			5.5	1.3	2.8	partial head
19	571.01		159	√			5.5		1.7	break at 4.2
19	571.02		159		√					bag of splintered fragments
19	571.03		159		√					
19	576		183	√			5.2	1.2	2.1	
19	576.01		183B	√			3.8	1.5	2.6	partial head
19	584		159	√			4.3	1.1	2.0	partial head
U7	585.01			√			5.1	1.7	2.6	
U8	586.01		204				3.0	1.3		clench bend, heavily concreted
U8	587.02				√					shaft splintered fragments
U8	588.01		192				3.0	1.0		2 shaft fragments, non-joining
U8	589.02		151		√					
U8	590		204				5.7	1.2		shaft fragment
U7	591		207				2.7	0.8		shaft fragment
20	596.01	N19/20.20			√					
U7	597		205				3.0	0.8		shaft fragments and splintered fragments, no join
U7	599.01		205	√			4.3		2.1	

U7	603.01		loose				5.3	1.4		shaft fragment
U7	604.01		205				6.6	1.0		shaft fragments and splintered fragments
9	607				√					
20	610		168		√					concretion mold only
U7	614.01			√			4.1	1.2		head nud; loose
19	615	N19/20.26		√			5.8	1.3	3.2	
19	616	N19/20.27		√			4.8	1.8	2.9	
19	617	N19/20.28		√			4.7			head nud
18	620.01		177		√					ferro-magnetic
U7	623		loose	√			5.3	1.5	2.5	
U8	626	NU8.03					7.2	1.1		shaft fragment
U7	627	NU7.04					9.1	0.9		shaft fragment w/ clench bend
U8	628	NU8.04			√					
U7	631	NU7.01		√			3.3	1.7		
U7	632	NU7.03		√			7.2 OV	1.5	2.6	head and shaft, 2 fragments, no obvious join
U7	634	NU7.05		√			14.6 OV	1.4	2.5	head and shaft
U8	638	NU8.06		√					2.3	partial head
U8	639	NU8.07						1.4	2.5	splintered fragments
U8	640	NU8.02			√					fragments
U7	641	NU7.02					5.7	1.1		shaft fragment
U7	642		207				5.3	1.0		shaft fragment
U8	643	NU8.05					4.3	1.0		shaft fragment
19	644.01		ABY		√					
19	646.01		201				5.0	1.3		shaft fragments w/ partial head, bend at 4.0
19	650.02		210	√			4.1		2.0	
20	653.01		194			√	1.1		0.7	
17	655.03		190	√			10.1	0.8	2.8	complete, nice, flat head
U7	657	NU7.06		√			14.8	1.4	2.4	
U8	659	NU8.01			√					
U8	660	NU8.08			√					bag of fragments
U8	662	NU8.09					5.5	1.2		bag of fragments
U8	665	NU8.10						1.6		bag of fragments
17	670.04		157				6.8			shaft fragment
17	670.05		157			√	3.7		0.8	
17	670.06		157			√	2.1		0.6	
17	670.07		157			√	0.9		0.9	

U7	671	NU7.08		√			4.0	1.2	2.1	head and splintered fragments
U7	672	NU7.07		√			18.5 OV	1.6	3.0	3 fragments, join
U7	673	NU7.09		√			15.3	1.5		2 fragments missing section- break at 4.2
19	676		224	√			7.1	1.6	1.9	head and splintered fragments
19	676.01		224		√					
U7	681		216			√	3.0		0.9	
U7	681.01		216				5.6	1.1		shaft fragment
U7	683.02		216	√			9.1	0.7	1.2	4 fragments, join
U7	684	NU7.12			√					
U7	685	NU7.10		√			4.3	1.4	1.9	shaft fragment w/ partial head
U7	686	NU7.11					5.7			shaft fragment
18	687		tile 30				7.0		3.0	110 degree bend
19	688	N19.14		√			4.9	1.1	1.6	partial head
19	689	N19.11			√					heavily concreted., shaft
19	690	N19.02		√			4.5	1.5	2.1	shaft fragment w/ partial head
19	691	N19.13		√			5.5	1.0	1.7	shaft fragment w/ partial head, wood attached
19	692	N19.12					5.9	0.9		shaft fragment w/ clench bend
20	695	N19/20.30		√			3.8	1.4	2.2	
19	696	N19.02		√			4.1	1.8	2.6	
19	697	N19.15		√			4.1	0.7	1.5	square section
20	698	N19/20.32				√	2.0		0.7	
20	699	N19/20.31		√			4.4	1.4	2.3	
19	700.01		7		√					
19	700.02		7			√	1.3		0.6	
U7	701.01		215		√					
19	703	N19.17					15.5	1.2		spike ?
19	703.01				√					heavily concreted. Cu/Cu alloy stained frag
19	703.02				√					
19	704		225				0.4		1.7	coin-shaped, likely a head onlyt
U7	705.01		215				4.1			tack? Shaft fragment
U7	706	NU7.13			√					
19	707	N19.21		√			4.1	1.5	2.7	
19	708	N19.20					5.5	1.4		shaft fragment
17	711		209				3.9	0.6		
17	711.01		209	√			2.4	0.7	1.4	square section
17	711.02		209		√					heavily concreted. shaft fragment
17	711.03		209				10.4	1.4		shaft fragment

17	711.04		209				11.3	1.2		shaft fragment
17	711.05		209				5.4	1.4		shaft fragment
U7	715		218E		√					
U7	715.01		218E				4.2	0.9		concreted clench bend
U7	716	NU7.17		√			10.4 OV	1.7	2.7	2 fragments head and shaft fragment
U7	717	NU7.16			√					
19	719	N19.22			√					
U7	723		206	√			4.3	1.7	3.2	3 fragments non-joining
U7	723		206	√			4.4	1.4	2.7	
U7	723		206	√			4.7	1.0	1.4	tack w/ partial head
U7	723		206				3.2	1.0		tack shaft? square section
19	724		266		√					
19	724.01		266	√			3.5	1.3	2.1	
19	725	N19.23					4.0	0.9		shaft fragment
U7	726	NU7.14			√					
U7	727	NU7.15		√			4.2	1.6	2.8	
U7	728	NU7.18		√			4.6	1.5	2.3	head and shaft
20	732.01		near N19/20.01		√					
19	733.01		15	√			4.2		2.1	
1	734		57	√			7.6	0.7	1.7	complete
1	735		TOP of drum 1	√			3.8	0.7	1.3	
1	736		25				4.9	1.2		2 fragments
19	736.01				√					concretion basket
U7	737			√			4.2	1.5	2.6	shaft fragment w/ partial head
20	739.01	N19/20.01	circa				4.8	0.9		shaft fragment
3	744		b/t drums 3 &5	√			3.7	1.8	2.7	
3	744.01		b/t drums 3 &5	√			4.0	1.5	2.3	partial head
3	744.02		b/t drums 3 &5		√					
19	745		198			√	3.3		1.2	conical shaft?
19	745.01		198				2.3	0.3		tip ?
19	747	N19.18		√			4.7	1.8	3.2	partial head
19/20	753		253	√			4.0	1.6	3.2	partial head
19	754	N19.05			√					
19	755	N19.01		√			4.5	1.5	2.2	partial head
U7	756.02		197	√			5.7	1.2	2.5	2 fragments, join square section
U7	756.03		197	√			7.1	1.4	2.6	2 fragments join
U7	757.01						6.0	1.1		2 shaft fragments, join

18	758		under anchor stock	√			16.8	1.5	2.6	splintered fragments, heavily concreted.
20	761.01						0.4		1.5	coin-shaped head
17	764		datum J	√			5.9	0.5	0.9	nail or tack?
17	764.01		datum J			√	2.2		1.0	complete
17	764.02		datum J			√	1.2		0.8	complete
17	764.03		datum J			√	0.7		0.5	
17	764.04		datum J		√					
17	764.05		datum J		√					splintered fragments
U7	768		SW edge of drum 6	√			5.2	1.7	2.5	2 fragments join
U7	769		SW edge of drum 6	√			11.4 OV	1.5	3.0	2 fragments no join
U7	770.02		259				2.6	0.8		2 fragments clench bend no join
U7	771		BAL	√			4.2	1.5	2.2	
20	772	N19/20.45 A		√			7.8	1.4	2.3	
20	773	N19/20.45 B		√			4.1	1.4		head nud
20	774	N19/20.45 C		√			4.7	1.4	2.2	
20	775	N19/20.44 A			√					
20	776	N19/20.44 B		√			5.0	1.6	2.0	
20	778		ABW				8.2	1.3		shaft fragment
20	779		ABW				9.8			shaft fragment
20	780	N19/20.43			√					
20	781	N19/20.41		√			4.6	1.5	2.1	
20	783	N19/20.40		√			3.6	1.4	1.9	
20	784	N19/20.42		√			2.2		1.6	partial head
U7	793.01		197				5.1	1.4		3 fragments likely 2 nails
U7	793.01		197				4.0	1.1		
19	796	N19.03					4.4	1.4		shaft fragment
20	797	N19.19		√			6.4	1.7	3.2	partial head
5	800.01			√			4.3	1.2	2.5	partial head 2 fragments no join
3/5	801.01		b/t drums 3&5	√			4.5			head nud
3	801.02		b/t drums 3&5	√			4.2	1.5	2.3	
3	801.03		b/t drums 3&5				2.2	1.6		shaft fragment w/ attached wood
3	802		b/t drums 3&5	√			3.3	1.4	2.1	partial head
3	802.01		b/t drums 3&5	√			4.5	1.6	2.5	partial head

3/5	802.02		b/t drums 3&5		√					
3/5	803						13.0			shaft fragment
U8	806.01		211				2.4	1.5		shaft fragment
20	807	N19/20.46 A		√			4.7	1.5	2.6	partial nail head
20	807.01	N19/20.46 B		√			5.2	1.8	2.5	partial nail head
20	807.02						3.8	1.2		shaft fragment ; assoc. w 807.01
19/20	808	N19/20.39		√			3.9	1.5	1.8	
5/6	809.01		b/t drums 5&6		√					
5	811.01			√			3.4	1.5	2.0	
U7	814		under drum 5	√			4.0	1.7	3.1	
17	815.01		tile 32				5.7	0.5	1.0	
17	815.02		tile 32			√	1.5		0.8	
19/20	818	N19/20.35		√			4.2	1.5	1.9	2 fragments, non-joining
19/20	819	N19/20.36					6.3	1.2		shaft fragment square section
U5/U7	820		loose in U5	√			9.1	1.5	1.8	fragments- break at 4.2cm
U7/U8	835.01		262, 271				6.9	1.5		shaft fragment
U6	837.01		SW edge of drum 6	√			4.6	1.6	2.8	
U6	837.02		SW edge of drum 6	√			4.4	1.7	2.2	
U6	837.03		SW edge of drum 6	√			3.0	1.4	2.0	
U6	837.04		SW edge of drum 6	√			1.4		2.2	partial nail head
U6	837.05		SW edge of drum 6	√			1.3		2.2	partial nail head
U6	837.06		SW edge of drum 6				13.6	1.2		shaft fragment
U6	837.07		SW edge of drum 6		√					4 shaft fragments, likely several nails
20	840.02		250	√			3.7	1.3	3.0	
20	840.03		250	√			4.4	1.7	2.5	partial nail head
20	840.04		250	√			6.0			head nud
20	840.05		250				4.3	1.5		shaft fragment
5/6	842.01		259		√					
U5	843.02		LL	√			4.3	1.6	2.9	partial nail head
U5	843.03		LL	√			4.1	1.6	2.1	partial nail head
20	844		256				6.5	0.6	1.5	small nail, complete
U5	845.03						5.2	1.0		shaft fragments
19	846.01		202		√					splintered fragments
U6	847.01						9.7	1.1		shaft fragment
U6	847.02			√			4.3	1.3	2.1	
U8	848.01				√					splintered fragments

U8	848.05			√			4.2		2.8	wood attached
U8	848.06		part of frame	√			3.1	1.2	1.7	tack?
U8	848.07			√			3.7	1.3	2.2	partial nail head
U8	848.08			√			4.4	1.1	2.4	partial nail head
U8	848.09		part of frame		√					
U8	849.02		part of frame	√			3.8		2.1	
U8	849.03		223		√					
U8	849.04		223				10.5 OV	1.2		fragments join
U8	850.02		262	√			4.7	1.3	1.8	break at 4.2
19	851.03		225		√					
19	851.04		225			√	1.0		0.6	complete
19	851.05		225			√	1.2		0.7	complete
U7	859.02		197	√			4.7	1.6	2.5	
U7	859.03		197	√			3.3	1.8	2.6	
U7	859.04		197				3.7	1.5		bag of fragments
19	860	N19/20.48				√	1.1		0.8	complete
U5	861.01		350, 363	√			4.3	1.4	2.6	
U8	862.03		254	√				1.6	2.5	heavily concreted.
U8	862.04		254		√					
U8	862.05		254	√			1.9	1.2	2.1	
U8	862.06		254		√					
U8	862.07		254		√					
19	864	N19/20.47					3.8	1.3		shaft fragments and splintered fragments
17	872		321				5.5	0.8	1.9	tack?, complete square section
PB	874.01		phone booth				2.3	0.6		shaft splinter
20	877	N20.01	348			√	2.2		0.8	complete
20	878	N20.03	348			√	2.0		1.0	complete
U5/U7	879		b/t frames 5&6				4.9			shaft fragment
20	881		348				5.9	0.6	1.5	complete small nail
20	881.01		348				8.2	1.8		heavily concreted. nail shaft
20	881.01		348				8.3	0.5	0.8	core of above?
20	881.02		348		√					heavily concreted.
20	881.03		348		√					
20	881.04		348		√					concretion and splintered fragments
20	881.05		348		√					
20	881.06		348				2.4		2.1	possible nail head
U5	883		b/t frames 5&6				5.4			splintered fragments

20	884		348		√					concretion and splintered fragments
20	884.01	N20.02	348			√	2.2		0.6	
U7/U8	885		259	√			3.4		1.9	
U7/U8	885.01		w edge of drum 6				7.7	1.4		shaft fragment
U5/U7	888.01		loose	√			4.8	1.7	3.0	partial nail head
U5/U7	888.02		loose	√			4.4	1.7	2.6	partial nail head
U5/U7	888.03		loose				7.2	1.0		shaft splintered fragments
U5	891.01		343	√	√					heavily concreted.
20	893	N19/20.49				√	1.9		0.6	
20	894	N19/20.34		√			4.2	1.3	2.4	partial nail head
U5	895.01		b/t frames 5&6						3.0	heavily concreted.
U5	895.02		b/t frames 5&6	√			4.0	1.4	2.3	
U5	895.03		b/t frames 5&6	√			3.6	1.2	2.1	
U5	895.04		b/t frames 5&6		√					
20	896.02		228				4.2	0.8		shaft fragment
U5	897.01		357		√					splintered fragments
U5	897.02		357	√			12.2	1.4	2.2	3 joining fragments
20	900		348	√			4.7	1.7	2.2	partial nail head
20	900.01		348		√					shaft fragment splinter
F	901.01		84				9.6			shaft fragment - heavily concreted.
U5	908.01		b/t frames 5&6	√			3.9		2.5	partial nail head
E	920		340	√			16.2	1.0	2.2	complete, S shape
U5	924.01		loose in U5		√					splintered fragments
U5	926.01		frame 8	√			4.8	1.1	2.5	
U5	927.01		frame 8	√			5.0	1.5	2.3	
U6	930		351				7.5			4 shaft fragments
18	932		195			√	3.5	0.7	1.1	complete
U5	933.01		under BAL				3.9	0.9		clench tip
U5	936.01		259				8.6	1.5		shaft frag
U5	940.01		under BAL				8.7	1.2		shaft frag
1/2	942.01				√					heavily concreted. partial head
U5	943							1.3		4 shaft fragments non-joining
19	955.01		445	√			7.0	1.5	2.9	head appears to be concave w/ a flat edge along the outside
19	956		439	√			4.4	1.5	3.3	2 fragments broken at head
3	957.02		drum 3	√			5.6	1.6	2.6	
3	957.03						3.8			2 small fragments & concretion
1/3	960.02						6.2	1.8		shaft fragment
	961						11.4	1.4		2 fragments no join shaft fragment; found in concretion

										basket
19	969		416	√			12.2	1.5	3.0	square section
20	970				√					found in concretion basket
19	976		418				3.8	1.5		shaft fragment
19	981						10.4			shaft fragment
U1	985		loose				5.6			heavily concreted
U1	986		436			√	1.7		0.7	complete
U1	998		462				8.7	1.3		shaft fragment
U1	998		462				7.2	1.2		shaft fragment no join w/ above
U3	1000		413				5.2	0.7	1.1	complete tack
U4	1003	NU4.01		√			11.6	1.7	2.4	2 fragments join partial head square section
U1	1005		BAS				7.1	1.2		2 shaft fragments no obvious join
U3	1009		sw corner of BAR				3.2	0.9		shaft fragment
U1	1010		477	√			5.1	0.7	1.8	shaft
19	1011		466	√			4.2	1.9	3.7	
U5	1013		LL2	√			3.8	1.5	2.6	square section
19	1025.01		478				1.1	2.5		ovoid outer shape
U1	1028		476		√					
U1	1029		476		√					splintered fragments
U1	1030		476				6.4	1.2		shaft fragment
U2	1032		450				3.2	1.5		shaft fragment, heavily concreted.
U1	1034		476				13.6	1.3		2 shaft fragments w/ clench bend probable join
U5	1035		422				2.7			splintered fragment
U1	1038		431				16.0	1.4		square section
U1	1039.02		436				2.3	0.4		
U4	1045		472	√			4.1	1.6	2.6	sqaure section
U4	1046	NU4.02		√			5.8	1.7	2.8	head and other fragments, non-joins
U4	1047		486	√			4.4	1.2	2.7	2 fragments join
U3	1048		490				5.2	0.6	1.5	complete tack, well preserved
U3	1048.03		490				3.4			3 splintered shaft fragments
U1	1053		489		√					shaft fragment
U1	1053		489				10.0	1.0		shaft fragment w/ clench bend 90 degree
U1	1054		408				5.2	1.1		shaft fragment
U1	1054.01		408				6.9	1.6		2 shaft fragments, probable join
U1	1055		499				6.7	1.6		shaft fragment square section
U2	1058		458				1.4	2.4		splintered head fragment
U3	1059		ass w/ 3000				3.8	1.5		shaft fragments
U6	1060	NU6.09					4.1	2.0		shaft fragment

U3	1063.01		loose				6.2	0.8		shaft splintered fragments
20	1064.02		424				4.4	1.2		shaft fragment
U5	1065.01		frame 7				8.2	1.1		shaft fragment
U6	1066	NU6.04		√			3.7	1.5	2.9	
U6	1067	NU6.01		√			4.7	1.7	3.2	partial nail head
U1	1074		484			√	2.0		0.9	complete
U1	1074.01		484			√	1.4		1.0	complete
U5	1076		loose near 3003				3.8	1.1		splintered fragments
U1	1077		492				4.9	1.0		shaft fragment
U3	1082		BAR				4.4	0.9		shaft w/ clench bend
U6	1083	NU6.12		√			3.3	1.9	2.2	
U6	1086	NU6.13			√					shaft splintered fragments
U1	1089		473				6.1		0.4	complete?
U1/U2	1090						5.0	1.4		2 shaft fragments
U1/U2	1091						3.9	2.2		heavily concreted. shaft fragment
U1/U2	1093		527	√			5.1	2.1	3.2	
U1/U2	1094		527				7.2	1.1		3 shaft fragments join
19	1095		430	√			8.0	1.0	1.4	shaft w/clench bend very high up
U2	1096						4.1	2.1		2 shaft fragments; concretion basket
U3	1097		444A	√			9.1	1.6	2.9	long nail
U3	1098		444B				7.3	1.4		shaft fragment
U4	1099		501			√	1.5		0.8	
U4	1099.01		501				3.5	0.5	0.7	tack?
U2	1100						2.2	0.7		heavily concreted. shaft fragment; found in concretion basket
20	1102		500			√	1.0	0.6	0.7	
20	1102.01		500	√			1.5	1.4	2.1	
20	1102.02		500	√			2.2	1.8	2.9	
20	1102.04		500		√					splintered fragments
20	1103		488			√	1.2	0.8	0.9	diamond-shaped profile
19	1105.01		464				2.5	0.9		shaft splintered fragments
U2	1106	NU2.01	519	√			7.7	1.0	2.0	2 shaft fragments and head
U4	1107.01		501				3.0	0.8		shaft fragment
U1	1110.01						3.2	0.7		bag of fragments
U1	1111	NU1.10	497	√			7.0	1.5	2.8	
U1	1111.01	NU1.10	497				2.7	2.2		shaft fragment
17	1114		467	√			9.8	0.6	1.7	complete very flat head square section
17	1116		433				5.2	0.5		

U1	1121		482				5.0	1.5		shaft fragment
U1	1121.01		482				4.4	0.9		shaft fragment
U3/U5	1122						5.3	1.4		heavily concreted. shaft w/ possible head; concretion basket
U1	1124.02		482				2.2	0.4		2 fragments
U1	1124.03		482		√					bag of fragments
U6	1125	NU6.08					3.4	1.5		shaft splintered fragments
U4	1126		493				4.1	1.0		3 shaft splintered fragments
U6	1133	NU6.07		√			3.9	1.7	2.8	
U2	1134		536				2.5	1.0		shaft splintered fragments possible tack
19	1139		404	√			2.3	1.8	2.8	
U3	1140		3 cm SW of 3005	√			3.6	1.6	2.2	partial head and shaft
U3	1141	3003		√			3.8	1.6	2.6	
C	1145		522	√			5.6	0.8	1.1	
C	1145.01		522				5.2	0.5		
U7	1146.01		E of U7				4.0	1.6		shaft fragments
U6	1147.04	6007.02					4.0	0.6		shaft w/ clench bend
U2	1148		518				2.6	0.5	0.9	tack, complete
U6	1149		427	√			5.0	1.8	2.8	
19	1150		537				5.1	1.0		shaft splinter
U6	1151	NU6.11					4.4	1.5		shaft fragment
U3	1152.01		on BAT	√			13.1	1.6	2.3	head w/ 2 shaft fragments
U1	1154		520				2.2	0.6	0.8	tack
U1	1155.01		526	√			5.1	1.9	3.3	
U1	1155.03		526				3.8	1.7		shaft fragment
U1	1156		459				5.3	1.6		bent shaft frag
19	1159		517		√					bag of splintered fragments
19	1160		454		√					
19	1162		537	√			5.0	2.0	2.7	head and shaft fragments
19	1162.01		537	√			4.7	2.5	3.0	
U3	1167	NU3.01		√			7.6	1.7	3.0	head and 2 shaft fragments
U3	1168	NU3.06					3.0	1.6		shaft fragment
U3	1170	NU3.05		√			3.5	1.8	3.1	head and splintered shaft fragments
U3	1171	NU3.04					5.2	1.0		splintered shaft fragments w/ clench bend
U2	1172.02				√					
19	1174		531				1.8	1.6		shaft fragment
19	1175		514				0.9	2.2		shaft fragment
U3	1176	NU3.07					4.2	1.2		shaft fragment
U3	1177	NU3.08		√			4.2	1.2	2.2	

U3	1178	NU3.09					5.7	1.0		shaft fragment
U6	1181	NU6.15					6.8	1.2		shaft w/ clench bend
U6	1182	NU6.16					3.6	2.0		shaft fragment
U6	1183	NU6.17					3.8	1.6		shaft fragment
U3	1187	NU3.10					10.1	1.1		shaft fragment square section
U4	1189.03		534				4.2	2.1		shaft fragments
U3	1191	NU3.11		√			4.3	1.6	2.6	
U3	1192.02	NU3.12					6.5	1.3		shaft fragment
U3	1194		453	√			6.1	0.7	1.9	possibly complete, heavily deteriorated-
U3	1194.01		453				4.6	1.0		shaft splintered fragments
U1	1195.01		480				2.7	1.2		3 shaft fragments
U5	1201		NW corner of BAP	√			4.0	1.4	2.1	head and partial shaft
U5	1202.01		426		√			1.4		splintered shaft frag
U3	1203.01		W corner of BAR	√			3.2	1.8	2.7	2 fragments no join
U2	1204		574	√			4.2	1.5	2.6	3 fragments w/ head and shaft
U5	1206.02		5001.01	√			4.9	2.2	2.8	heavily concreted.
U5	1207.08		5002	√			4.2	2.2	3.1	heavily concreted. w/ attached wood
U5	1207.09		5002				6.9	1.2		3 shaft fragments
U5	1208.03		5003.03				7.0	1.6		shaft fragment
U5	1209.01		5004.03				2.2	1.0		shaft fragment
U5	1212.05		5008				4.2	1.5		shaft fragment w/ attached wood
U5	1213.01			√			4.1	1.5	2.4	head and shaft fragments
U5	1214		426				4.1	0.8		heavily concreted. 2 fragments
U5	1215.02			√			4.7	1.6	2.5	
U5	1215.03						3.6	1.3		splintered shaft
U2	1216		402				6.5	2.2		shaft fragment
U2	1217		569	√			3.5	1.8	3.1	heavily concreted. shaft fragments and fragments
19	1218		537	√			4.9	2.0	3.2	
U1	1219		535	√			2.4	0.5	1.5	nice tack; ferro-magnetic
U1	1219.01		535	√			4.8	2.0	2.9	
U1	1219.03		535				4.0	1.5		4 shaft fragments
U1	1219.04		535				9.2	1.4		shaft fragments
U1	1219.05		535				4.8	1.6		shaft fragments
U1	1219.06		535		√					bag of fragments
U3	1223		574		√					bag of tiny splintered fragments
U6	1224		loose		√			1.3		shaft fragment, deteriorated
19	1227		512				10.0	1.2		shaft fragment
U4	1229		452				4.3	1.2		shaft fragment

U6	1231	NU6.18					4.2	0.9		shaft fragment
U1/U3	1231.01						5.6	1.4		shaft fragment
U4	1232		550		√					shaft fragment
U4	1233		553		√					
U1	1235		507				2.3	0.5	0.7	tack
U1	1235.01		507				2.4	0.5	0.9	tack
U4	1236	NU4.10	553	√			2.9	1.3	2.2	partial nail head
U4	1239		552		√					flattened casing
U4	1240	NU4.13	553	√			3.9	1.5	2.4	partial nail head
U6	1241	NU6.19					6.5	1.0		shaft fragment square section
U6	1243	NU6.20					3.4	0.7		clench tip
U4	1244	NU4.14		√			4.9	1.5	2.7	heavily concreted.
U4	1246	NU4.12	553		√					concretion
19	1250.01		558				3.9	1.5		casing of shaft
19	1250.02		558				3.6	1.1		tip?, iron staining not magnetic
U4	1251		576	√			3.8	1.2	1.9	partial nail head
U5	1252.01		5001		√					splinter
U1	1262	NU1.15			√					shaft fragments
U2	1264		562				5.2	1.3		shaft fragment
U3	1266.01		on BAT/3007		√					splintered fragments
U5	1269		551	√					2.5	top only partial
U2	1272		562				4.1	1.4		shaft fragment square section
U3	1273		loose		√					splintered fragments
U4	1275	NU4.05	576	√			4.3	1.8	2.5	partial nail head square section
U1	1276	NU1.16					3.8	1.7		shaft fragments
U4	1279		576	√			4.5	1.6	3.0	head and 2 fragments no join
U4	1279		576				8.9	1.1		
U1	1280	NU1.17		√			5.0	1.4	2.0	
U1	1280	NU1.17					7.1	1.2		shaft from above
U6	1281	NU6.21		√			1.1		1.7	partial head
U6	1281.01						4.8	1.6		shaft fragment
U6	1281.02	NU6.27					3.5	1.4		shaft fragment
U4	1282		575				3.5	0.8		tip
U4	1284	NU4.16	576		√					splintered fragments
U6	1285	NU6.28			√					splintered fragments
U5	1286		5011		√					heavily concreted.
U4	1289	NU4.19	550		√					splintered fragments
U4	1290	NU4.20	550				4.7	1.2		shaft fragment

U4	1291	NU4.18	550		√					4 tiny splintered fragments
U4	1291.01	NU4.17	550		√					2 small splintered fragments
19	1292.01		528		√					splintered fragments
19	1293.02		540		√					
U2	1294		582				6.0	1.0		2 shaft fragments no join
U2	1296		582	√			4.3	1.6	2.3	
U5	1297		557				3.4	1.1		shaft fragment
U5	1298						14.3	1.1		2 shaft fragments
U5	1299		571				7.4	1.0		shaft fragment
U3	1300	NU3.13	559		√					
U3	1300.01	NU3.14	559				3.9	1.6		heavily concreted.
U3	1300.02	NU3.15	559	√			15.4	1.7	2.7	14.0cm from bottom of nail head to clench bend
U3	1300.03	NU3.16	559				4.8	1.9		
U3	1300.04	NU3.17	559	√			4.3	1.7	2.5	splintered fragments only head measured
U3	1300.05	NU3.18	559	√			4.6	1.6	3.0	
U5	1301.01		ass w/5005				13.6			shaft w/ clench bend
U4/U5	1305				√					splintered fragments
U5	1305.06		563/next to 5012					0.9		shaft fragment
19	1306.01		531	√					1.8	nail head only
U5	1307		564	√			3.8	1.5	2.1	
U4	1311		583/next to 5012				2.7	1.6		shaft fragment
U4/U5	1312		587/next to 5012	√			4.8	1.7	2.7	head and shaft fragments
U1	1317	NU1.18					5.0	1.5		shaft fragment
U5	1318		426	√					2.6	head only
U6	1320	NU6.29		√				1.5	2.2	head only
U1	1321		535		√					shaft fragments
U6	1322.01	NU6.30					4.2	0.8		clench bend
U3	1328		601	√			5.6	1.8	2.8	
U3	1329	NU3.19	588	√			26.9	1.5	2.4	4 sections (head 4.4cm/mid 14.0cm/ end 6.1cm/clench 2.0cm), complete reconstructed
U4	1332		561		√					
U2	1333		ass w/ 2001		√					splintered fragments
U2	1336	NU2.01			√					
U6	1337	NU6.31	6005.05		√					splintered fragments
U3	1339.03		ass w/ 3003.03				7.8	1.4		
U3	1341.02		in 3003.01	√			11.6	1.6	2.6	broken at 4.3 from head
U3	1342.02		loose in U3		√					
U6	1344.04		6005.03A		√					

U6	1344.05		6005.03				4.0	1.0		shaft fragment
U6	1344.09		6005.05				4.8	1.4		shaft fragment
U4	1347.02		ass w/ 1000.01		√					
19	1354.01		510		√					
U1	1358		loose in U1				2.5	1.0		clench bend
U1	1358.01		loose in U1				3.5	1.0		shaft fragment
U1	1358.02		loose in U1				3.1			shaft fragment
19	1359		515		√					
19	1359.01		515				7.0	0.6	1.3	tack
U1	1362	NU1.19					4.5	1.2		shaft fragment
U1	1363.01		554				6.5	0.9		2 fragments join
U4	1365	NU4.22		√			3.5	1.6	2.5	
19	1368		515	√			4.7	1.9	2.1	head casing
U4	1371	NU4.21		√			4.1	1.6	2.5	heavily concreted
U4	1372		604							
U4	1373		611		√					
19	1374		515-515.4		√					splintered fragments
19	1375.01		609				2.8	0.8		shaft fragment
U2	1376	NU2.02					4.7	1.5		heavily concreted.
U4	1377	NU4.24					3.5	1.4		shaft fragment
U4	1378		585				6.2	0.9		shaft fragment
U4	1379	NU4.27			√					
U4	1380	NU4.28			√					
U4	1383	NU4.24B					3.6	1.3		shaft fragment
U4	1384	NU4.25		√			4.3	1.6	2.1	
U4	1385.01		ass w/ 4001				4.8	0.9		shaft fragment
U4	1385.02		ass w/ 4001				3.6	0.8		shaft fragment
U4	1385.03		ass w/ 4001				2.8	0.7		shaft fragment
U4	1386	NU4.26		√			2.4	1.6	2.6	
U3	1389.01		ass w/ 3001	√			4.8	1.6	2.4	
U3	1389.02		ass w/ 3001	√			2.5	1.6	2.1	
19	1391		506		√					
U5	1393.01		567				3.0	1.5		
U8	1394		568		√					
U1	1395.01		ass w/ 1000.04		√					
19	1396.02		592	√			4.5	1.6	2.5	partial head, blue patina
U5	1397		U5LL		√					
U5	1399.01		ass w/ 5011		√					

19	1402.02		586		√					
U5	1404			√			2.2	1.7	2.7	partial head
U5	1405.04		ass w/ 5013.02				5.4	1.4		shaft fragment
U2	1406		615	√			6.0	1.8		heavily concreted.
U2	1409		542		√					
U3	1412.22		ass w/ 3007				9.0	0.8		2 shaft fragments
19	1413		591		√					
U4	1414.01		ass w/ 4002		√					
19	1415.03		608	√			7.8	1.1	1.4	head not from same nail, likely tack
19	1416		606				12.6	0.3		wire thin deterioration
U3	1417		BAT	√			4.5	1.6	2.9	
U6	1419	NU6.24		√					2.1	shattered head
U6	1421	NU6.26		√			3.9	1.6	2.8	
U6	1422	NU6.36					3.6	0.9		clench tip
U6	1423	NU6.23		√			5.9	1.7	1.9	2 joining fragments
U6	1424	NU6.34		√			3.3	1.4	2.0	
U6	1425	NU6.33					10.5	1.1		joining fragments
U6	1426	NU6.22		√			4.6	1.6		heavily concreted.
U6	1427	NU6.20			√					Cu/Cu alloy stained concretion
U6	1428	NU6.25		√			3.0		2.3	
U5	1432.06		ass w/ 5014		√					heavily concreted. shaft fragment
U5	1432.07		ass w/ 5014	√			1.8		2.4	
U5	1432.08		ass w/ 5014	√			2.3		2.4	
U5	1432.1		ass w/ 5014				2.7	0.9		shaft fragment
U5	1432.11		ass w/ 5014		√					
U1	1434	NU1.21			√					
U1	1435	NU1.20		√			14.1	1.6	2.6	5 fragments, 4 join
U2	1439		616	√			8.4	1.4	2.1	3 joining fragments
U2	1439.01		616	√			10.3	1.1	2.2	head w/ shaft
U2	1439.02		616	√			5.7	1.6	1.8	head w/ shaft
U2	1439.03		616		√					
U2	1439.04		616				4.8	1.2		shaft fragment
U6	1443.07		ass w/ 6009.02				4.1	0.9		clench bend, S shape
U6	1443.08		ass w/ 6009.02				3.4	0.8		clench bend, L shape
U6	1444.07		ass w/ 6010.05				5.9	1.0		shaft fragment and splintered fragments
U6	1444.08		ass w/ 6010.05				5.9	0.9		shaft fragment and splintered fragments
U1	1445.1		ass w/ 1004		√					
U5	1447		602	√			4.0	1.4	2.2	

U5	1448.03			√			4.1	1.4	2.6	head and splintered fragments
U6	1449		loose in U5				9.4	1.3		shaft fragments
U4	1450	NU4.29					6.6	1.0		shaft fragments
U3	1452		ass w/ 3010				7.7	1.1		shaft fragment and splintered fragments
U3	1455.03		ass w/ 3009		√					
U3	1468		loose	√			3.4	2.0	2.7	heavily concreted.
U6	1473	NU6.41		√			5.1			concreted head w/ wood attached
U6	1474	NU6.40		√			3.1	1.4	2.2	
U6	1475	NU6.42		√			4.3	1.6	2.1	
U3	1477.01		635				4.7	0.9		shaft frag
U1	1481	NU1.23					3.4	0.4	1.0	tack
U1	1482	NU1.24		√			5.6	0.7	0.9	tack, complete, bend near head
U1	1483	NU1.25		√			5.5	0.7	1.1	tack- complete
U6	1485	NU6.45					5.6	1.1		shaft fragment
U1	1488		622	√			3.8	0.9	1.7	heavily concreted.
20	1500		691			√	1.8		0.7	
U5	1502	NU5.02		√			3.3	1.5	2.2	
U6	1503	NU6.48					3.1	1.0		shaft fragment
U6	1504	NU6.47					3.5	0.8		shaft fragment
U6	1505	NU6.49			√					
U6	1506		loose		√					
U5	1507		loose				6.5	1.2		shaft fragment
U4	1508	NU4.32		√			5.7			heavily concreted. head nud
U4	1509	NU4.31	665				6.0	1.0		shaft fragment
U2	1510	NU2.04		√			4.3	2.0	2.5	heavily concreted.
U2	1511	NU2.05		√			3.4		2.2	
U4	1513	NU4.30					4.3	1.4		shaft fragment
U4	1514	NU4.34					5.1	0.9		2 fragments
U2	1520	NU2.07		√			7.1		2.2	
U2	1521	NU2.06		√			4.2	1.7	2.2	
U6	1522	NU6.51					3.2	1.2		shaft fragment
U6	1523	NU6.50					6.2	1.1		2 fragments
U4	1525		665		√					
U3	1526	NU3.25		√			5.0	1.9	3.1	heavily concreted.
U6	1527	NU6.43		√			4.6	2.1	2.7	heavily concreted.
U6	1528	NU6.44					11.0	1.2		clench bend
19	1529		670			√	1.4		0.6	
U4	1531	NU4.35	680		√					

U6	1535.01		ass w/ 6014				1.6	2.0		shaft fragment
U6	1538	NU6.46		√			5.1	1.9	2.6	wood attached
U3	1542	NU3.25					7.5	1.2		3 fragments join
U3	1546		695				11.6	1.6		2 fragments
20	1547	N20.100					10.1	1.3		2 shaft fragments
U6	1549	NU6.53		√			2.4	1.6	2.5	heavily concreted.
U4	1551	NU4.36	690	√			2.2			head in concretion
U6	1556	NU6.52					3.2	1.1		shaft fragment
U4	1566		concreted to drum 4		√					
U6	1567	NU6.54					4.5	1.0		shaft fragment
U5	1570	NU5.01		√			3.1		2.2	
U5	1575		loose	√			3.5	1.6	2.4	
U5	1576		683				15.4	1.7		shaft fragment
U1	1577						10.5			shaft fragments
U5	1580	NU5.03		√			4.3		1.6	
U4	1583	NU4.33		√			5.0	2.0	2.9	
U4	1584		664				2.0	1.8		3 small fragments
U4	1585		702		√					
U6	1587	NU6.55		√			3.6	1.4	2.1	
U6	1588		loose				3.1	2.1		smashed shaft frag
17	1590		659				16.0	2.2		clench bend
U2	1594	NU2.08		√			4.1			heavily concreted.
U1	1595	NU3.21		√			10.5		1.9	
U1	1596	NU3.22		√			4.7	1.5	2.4	square section
U1	1597	NU3.20					5.7	1.2		shaft frag
U1	1598	NU3.23		√			5.7	1.6		heavily concreted. head nud
19	1599	N19.100					3.6	0.6		tip
U2	1601	NU2.09					4.6	0.5		
U4	1602	NU4.38			√					
U4	1603	NU4.39		√			4.8	1.6	2.2	
U1	1607	NU1.26		√			4.7	1.4		head nud
20	1608	N20.101		√			3.8			heavily concreted. head nud
U2	1612	NU2.10					5.5	1.2		shaft fragment
U1	1613	NU1.27		√			5.3	1.9	2.7	heavily concreted.
U1	1616	NU1.28			√					
U2	1619	NU2.12		√			4.3	1.4	1.9	
U2	1620	NU2.11		√			5.0	2.3		head nud
U2	1621		loose	√			4.9	2.2	3.1	2 fragments

20	1625		748				4.5			shaft fragment
U4	1627	NU4.41			√					shaft splinter
U4	1629	NU4.40					2.3	1.4		shaft fragment
U4	1630	NU4.37		√			6.1	1.8	3.3	2 fragments w/ head, non-joining
U1	1634	NU1.29					4.1			L shape clench
U1	1639	NU1.30		√			4.8		2.6	
U1	1644			√			6.7	2.2	2.9	heavily concreted.; found in concretion basket
U3	1650	NU3.27	661	√			5.1	2.0	2.8	
U4	1651		loose		√					
U2	1654	NU2.16		√			4.6	2.1	2.4	
U2	1655	NU2.14					4.9	0.9		shaft fragment
U2	1656	NU2.13		√			6.8	2.1	2.7	2 fragments non-joining
U2	1657	NU2.15		√			7.4	1.0	2.5	complete-flat head
U1	1659	NU1.31		√			3.8	1.5	2.0	
U1	1660	NU1.32		√			4.5	1.6	2.2	heavily concreted.
U2	1674	NU2.17		√			5.1	2.0	2.6	heavily concreted.
U2	1675	NU2.18					9.9	1.1		2 joining fragments
U1	1677	NU1.35		√			4.8	2.2	2.7	heavily concreted.
19	1680		669		√					shell w/ Cu/Cu alloy staining
19	1694.01		759		√					shaft fragment
17	1695		677				6.6	0.4		shaft fragment
U3	1697	NU3.28		√			5.7	2.5	2.0	heavily concreted.
20	1699		loose				8.7			heavily concreted. shaft frag
U8	1700			√			2.8	1.7	2.6	found in concretion basket
U5	1724	NU3.29	750		√					found under keel with head down
U5	1739		loose				6.3			
U3	1741	NU3.30					3.2			shaft fragment on concretion
U3	1742	NU3.31						1.5		found under keel with head down
U2	1750		733		√					
U1	1760		739		√					
U3	3012		3012				12.8	1.6		2 joining shaft fragments, bad lot no.

APPENDIX C
WOOD IDENTIFICATION AND QUESTIONS OF PROVENIENCE

All wood identification within was graciously performed by Nili Liphschitz of the Institute of Archaeology – The Botanical Laboratories at Tel Aviv University.

Determining wood choice for shipbuilding can be very informative in the analysis of a hull. Results suggest that when specifically chosen, wood types were selected primarily for specific qualities. However, results also suggest that there were often no purposeful wood type selection as shipbuilders were forced to primarily utilize locally accessible or even readily available woods. Shipbuilders may have been so limited in the available wood for shipbuilding that many different types of wood were employed for the same function on a ship, while others may have purposely chosen a wood type for distinct elements of a vessel. Wood type identification may also be useful in eliminating or suggesting a specific area or potential areas in which a ship may have been constructed.[226] Occasionally an unusual or exotic wood can be identified in a ship that may offer clues about wood importation if the area of construction can be determined or hypothesized with a high degree of certainty.[227] Information may also be gleaned about the economy of the ship's builder if imported woods were chosen for construction and there is no evidence for the exceptional timber being a repair made in transit.[228] Other cases may simply demonstrate an unusual wood choice. In order to suggest such hypotheses it is often necessary to identify wood to the species level, as one species may have a distinctly different growing environment or structural qualities not shared with species of the same genus. As Frost notes, "...if a ship is considered an artifact then the woods in it have a structural meaning that will increase as

[226] Liphschitz and Pulak 2009, 74, 78.
[227] Liphschitz 2004, 156; Liphschitz and Pulak 2009, 74.
[228] Steffy 1990, 41; 2000, 264-5.

further comparisons become available, each newly excavated ship contributing to the explanation of its predecessors."[229]

Although wood type identification of shipwrecked hull remains has been a topic of discussion and exploration since nautical archaeology's early days, species-level identification of waterlogged wood from shipwrecks is a relatively recent undertaking and can be problematic as it is often not possible to accomplish identification at this level.[230] However, by using structural features of the Kızılburun wood examined microscopically in conjunction with comparative collections and anatomical atlases, many species level wood identifications have been achieved, enabling questions to be addressed that could not be considered otherwise (e.g., were certain wood species sought rather than the more general genus or families of timbers?).[231]

Beyond the difficulties of species-level identification, an ancillary problem that can occur with respect to comparative interpretation is inadequate sampling. Often, only a single or few samples are taken (e.g. one frame sample, one planking sample, etc.), or sampling strategies are not published and general conclusions are drawn about a vessel's overall construction when a more comprehensive sampling methodology might have resulted in a dramatically different understanding of wood use. This is a difficult problem to trace, as the number of samples taken from specific parts of a vessel are not often included in reports or published analyses. For example, an excavated hull may contain 30 frames, yet only two are sampled. These two samples may be of the same wood type, but happen to be repairs made of wood(s) that are different than many or all of the other frames. Further, results may show two different wood types, yet had the frames been sampled comprehensively the results would have shown that many different wood types were chosen for the vessel. Many variables and possibilities exist without a comprehensive sampling strategy. Fortunately, researchers are beginning to realize the limitations of interpretation when sampling of ship's timbers is selective or less than comprehensive.

[229] Frost 1981, 69.
[230] Liphschitz and Pulak 2009, 74.
[231] Liphschitz 2007, 11-3.

To this end, all distinct, definable timbers and many features such as pegs, tenons, and treenails were sampled for purposes of botanical identification to the species level, whenever possible. Over the course of three years, 135 samples have been sent for analysis. The results are listed by Wood Number at the end of Appendix C.

Samples were approximately 1 cm^3 in size. Thin transverse, tangential, and radial sections were made of each sample with a sharp razor blade. The samples were then stained with safranin to make anatomical features more prominent and immersed in glycerol to prevent the samples from desiccation. Identification was accomplished by microscopic examination of the thin-sectioned samples based on the three-dimensional anatomical structures of wood compared with reference wood specimens prepared from systematically identified modern living trees and with the use of floral anatomical atlases.[232]

Keel

Four wood samples were taken from the 3-meter long keel section for species identification. No evidence exists to suggest this section of the keel is made of more than one piece of timber. All samples collected were of European Black Pine (*Pinus nigra*).

Planking

Hull planking and ceiling planking have been identified as two distinct species of pine. Twenty wood samples were collected from 17 sections of hull planking. Thirteen of these were identified as *Pinus nigra*, while the remaining seven are of Turkish Pine (*Pinus brutia*). Additionally, wood samples were taken for species identification from both the upper and lower portions of the garboard prior to confirmation of the garboard consisting of a single piece of sculpted or shaped timber. Both samples have been identified as *Pinus nigra*, matching four samples taken from the keel. Five of the six ceiling planks were also examined, with four planks being of *Pinus nigra* and one of *Pinus brutia*.

[232] Personal communication Dr. Nili Liphschitz 2009. For sampling methodology see Liphschitz 2007, 11-3; Liphschitz and Pulak 2009, 74-5. For a more general sampling methodology see Hather 2000, 11-9.

Tenons

Four wood samples were collected from tenons embedded in the keel. Two were of Kermes Oak (*Quercus coccifera*) (5011.05 x 2) and two were of Sessile or Durmast Oak (*Quercus petraea*) (5011.09 x 2). From the hull planking, 13 tenon samples were collected. As with the tenons in the keel, they were exclusively of oak although of a different species, where that level of identification could be achieved. Eight were of Turkey Oak (*Quercus cerris*) while five were of an indeterminate oak species.

Tenon Pegs

Eleven tenon peg samples were collected; one from the keel and ten from the hull planking. The one sample from the keel was found to be of Persian Walnut (*Juglans regia*). Of the remaining ten peg samples two are of oak (indeterminate species), two are of pine (one of *Pinus brutia* and one of an indeterminate species of pine) and six are of European or Common Ash (*Fraxinus excelsior*).

Plug-treenails

Fitzgerald demonstrated that the archaeological record of woods used for treenails is far from illuminating patterns of wood choice or even suggesting that ancient shipwrights favored hardwoods or softwoods for this purpose,[233] but he also showed that softwoods are favored for the purpose of *plug-treenails* in Graeco-Roman shipbuilding.[234] Five plug-treenails were sampled from the Kızılburun ship. Three were of *Pinus brutia* while two were of *Pinus nigra*, offering further support for Fitzgerald's claim. I mention this as the Kızılburun ship dates to the period when the use of plug-treenails is most prevalent in ancient shipbuilding.[235]

Frames

Twenty eight samples were taken from 26 separate frame fragments for wood identification. Of these, two samples (5020 and timber 6004) were of elm (*Ulmus campestris*).

[233] Fitzgerald 1995, 104-10.
[234] Fitzgerald 1995, 157-8.
[235] Fitzgerald 1995, 162.

These two samples present somewhat of a problem as timber 6004 was re-sampled with the second identification being of ash (*Fraxinus excelsior*), suggesting either a misidentification or more likely that the original identification was from a separate piece of wood attached to the frame that was not recognized at the time of sampling. This situation was seen several times in the sampling process of other frames that retained bits of pine hull and ceiling planking compressed and formed to frame timbers by the extreme weight of the column drums, and therefore seems entirely feasible in this case also. Misidentification seems unlikely as the 5020 sample was also of elm and is not obviously part of the 6004 timber. The remaining 26 samples were identified as *Fraxinus excelsior* or Common Ash.

INTERPRETATION

Some interesting data can be gleaned from the identification of timber use. The keels of Graeco-Roman ships are not known for being made of pine according to ancient written sources, yet the presence of a pine keel on the Kızılburun vessel is not totally surprising as a survey of excavated Graeco-Roman vessels yields several examples constructed with pine keels (Table C.1).[236] What is interesting is the choice of *Pinus nigra* for the Kızılburun keel as this particular species of pine has not been identified in any other wreck for which pine was used for the keel, albeit the number of wrecks is low compared to the total number of known Graeco-Roman vessels located to date.

Hull planking, ceiling planking, and plug-treenails were all found to be of two species of pine. Concerning pine and other softwoods for planking, Fitzgerald states, "The virtually standard use of pine, fir, and other softwoods for the planking of small and moderate-sized vessels must be in part a reflection of Graeco-Roman shipbuilding methods."[237] In other words, the use of pine for planking is common among Graeco-Roman period ships and therefore unsurprising.[238] What is intriguing with respect to hull planking, ceiling planking, and plug-treenails is that the shipbuilder(s) tended to treat each softwood tree equally in

[236] Parker (1992a, 26) notes the predominant use of oak, but notes that only 59 shipwrecks in his catalog of 1259, contained information about wood identification.
[237] Fitzgerald 1995, 109.
[238] Bass 1972, 71; Casson 1969, 194; Fitzgerald 1995, 91, Table 1; Parker 1992a, 26; Steffy 1994, 54.

construction applications, with no differentiation in functional properties of the raw material, seemingly using the two species interchangably.

Tenons made of oak are another common feature of Graeco-Roman shipbuilding.[239] As with the pine species used in the hull, the shipbuilder(s) seems to have shown no preference between oak species used for tenons, treating each species equally with regard to function. Oak is also a common material for the manufacture of tenon pegs of the period.[240] The use of ash for tenon pegs is somewhat unexpected, but is likely the result of having left over wood following the preparation of the frames. Persian Walnut (*Juglans regia*) is a large growth tree[241] and therefore presents a conundrum as there is no other evidence for its use in the vessel besides one small peg. Of course absence of evidence is not evidence of absence so it can only be stated that the single walnut identification is anomalous only in regard to the available material remains from the vessel.

Shipwreck	Date	Location	Species
Ma'agan Mikhael	400 BCE	Israel	*Pinus brutia*
La Tour Fondue	300-250 BCE	France	*Pinus halepensis*
Kyrenia	305-285 BCE	Cyprus	*Pinus halepensis*
Athlit Ram	190 BCE	Israel	*Pinus* sp.
Roche-Fouras	150-100 BCE	France	*Pinus* sp.
Chretienne A	150-100 BCE	France	*Pinus silvestris*
Cavaliere	ca.100 BCE	France	*Pinus leucodermis*
Kızılburun	**99-25 BCE**	**Turkey**	***Pinus nigra***
Miladou	99-1 BCE	France	*Pinus halepensis*
Cap de l'Esterel	125-75 BCE	France	*Pinus halepensis*
Titan	50-45 BCE	France	*Pinus* sp.
Tradelière	20-10 BCE	France	*Pinus silvestris*
Barthélémy	25-50 CE	France	*Pinus halepensis*
Saint- Gervais 3	149-154 CE	France	*Pinus halepensis*

Table C.1. Graeco-Roman vessels with pine keels.

[239] CasFtableson 1969, 194; Fitzgerald 1995, Steffy 1994, 46.
[240] Bass 1972, 71; Casson 1969, 194.
[241] Hather 2000, 132-3.

Two questions arise when attempting to interpret the shipbuilder's material choices for tenon pegs. First, were there not enough usable ash branches cut from the framing timbers to produce all of the pegs for the vessel? If not, this may have implications for the timbers being imported or transported to the construction site as branches may have been purposely removed or accidentally broken off in transit. Why is only one peg of walnut? Does this signify a repair for which no other evidence survives? Was this just another branch lying around the construction site and used simply because it was available? These questions remain, likely forever, unanswered, but it is clear that the material for tenon pegs was of little importance to the shipbuilder as pegs were crafted from at least four distinct genera of wood. Conversely, the near homogenous use of ash for the frames of the vessel does appear to have been important to the shipwright. The use of ash in the ship is unusual as it has been found to be an unusual wood for shipbuilding of the period.

SHIPWRECKS WITH IDENTIFIED ASH TIMBERS

Ash was known in antiquity[242] and is known among modern authors[243] to be a strong yet flexible wood. Theophrastus even records ash as a good timber for shipbuilding,[244] yet supporting archaeological evidence is sparse. One possible reason for this inconsistency is that only in the last 15 to 20 years has it become standard methodology for investigators to distinguish wood genera of ship components beyond that of simple visual identification. Thus far, 19 wrecks dated from the early 6th century B.C.E. to the 4th century C.E. have had ash wood identified as a material of construction in their hulls (Table

[242] See Meiggs (1982, 110) for examples; Plin. *HN* 16.24; Vitr. *De arch.* 2.9.11.
[243] Edlin 1956; Rival 1991, 66-7.
[244] Theophr. *Hist.pl.* 7.3. Hort (1916) translates the passage as follows; "The work of bentwood for vessels is made of mulberry manna-ash or plane; for it must be tough and strong. That made of plane wood is the worst, since it soon decays. For triremes some make such parts of Aleppo Pine because of its lightness. The cutwater, to which the sheathing is attached, and the catheads are made of manna-ash mulberry and elm; for these parts must be strong. Such then is the timber used in ship-building." Translation of this passage would benefit from a more modern translation as several problems are prominent. First, Hort specifically names Aleppo pine, which is not named in the passage. Second, Hort notes that τορυεία, (which he translates as "bentwood") is likely a corrupt word and should refer to a part of the vessel. From the contexts of the passage, I would suggest a better translation as "framing." Next, the word στερέωμα is translated as cutwater. Hort notes that this is apparently the fore part of the keel, therefore it most certainly refers to the stem of a ship. Finally, Hort refers to catheads; an item that is not known to the author to have existed in iconographical representations of ships until at least the 16th century C.E. These may have been through-beams used for towing Classical period ships.

C.2); 12 of which are known from the waters of the French coast. This bias in location toward wrecks in French waters is likely owing to relatively recent revisit studies undertaken to look specifically at wood-type identifications. Six of the 19 wrecks are found in Italy, with the sole remainder coming from Israel. All of the shipwrecks are of cargo vessels. What follows is a chronologically arranged short catalog of the ash timbers from each shipwreck with corresponding information about sampling where such information is available.

Shipwrecks	Date	Element	Location	Species
Giglio	600-590 BCE	unspecified no. of lacing pegs	Italy	*F. excelsior*
Ma'agan Mikhael	ca. 400 BCE	1 tenon peg		
Miladou	125-75 BCE	at least 1 frame- likely repair	France	*F. excelsior*
La Roche-Fouras	125-75 BCE	unspecified no. of planking tenons	France	*Fraxinus* sp.
Kizilburun	**99-25 BCE**	**frames**	**Turkey**	***F. excelsior***
Comacchio Valle Ponti	14-1 BCE	1 of 14 sampled lacing dowels	Italy	*Fraxinus* sp.
La Giraglia	99-1 BCE	71.5% of planking pegs, 5.25 % of tenons	France	*F. excelsior*
Madrague de Giens	70-50 BCE	3 deck stanchions, at least 1futtock, 3 planking pegs	France	*Fraxinus* sp.
Plane 1	50 BCE	unspecified # of wedging elements	France	*Fraxinus* sp.
La Tradelière	20-10 BCE	1 of 5 sampled planks, 2 floor timbers, 1 futtock, 1 half frame	France	*Fraxinus* sp.
Grand Ribaud D	10-1 BCE	1 unidentified timber	France	*Fraxinus* sp.
Saintes Maries 24	40-90 CE	unspecified no. of frames	France	*Fraxinus* sp.
Baie de l'Amitie	70-80 CE	2 of 22 frames	Adge, France	*Fraxinus* sp.
Pisa C	1-99 CE	13 of 28 frames, treenails, mast carling, vert. prow element	Italy	*F. excelsior*
Pisa F	100-199	4 of 21 frames, treenails	Pisa, Italy	*F. excelsior*
Marseille 2	160-220 CE	6 of 135 frames samples	Marseilles, France	*F. excelsior*
Fiumicino 3	100-199 CE	unspecified # of tenon pegs	Fiumicino, Italy	*Fraxinus* sp.
Laurons 2	175-200 CE	unspecified # of tenon pegs	France	*Fraxinus* sp.
Laurons 1	200-300 CE	unspecified # of tenon pegs	France	*Fraxinus* sp.
Fiumicino 2	300-399 CE	unspecified # of tenon and tenon pegs	Fiumicino, Italy	*Fraxinus* sp.

Table C.2. Use of ash in Graeco-Roman ships.

CATALOG OF ASH (Fraxinus excelsior) USED IN ANCIENT SHIPS

Giglio, Italy

The wreck at Giglio, Italy is the earliest discussed here. Dating to the early sixth century B.C.E., the wreck had nine wood species used in its construction, with only a limited amount of ash. Ash was used for at least some of the pegs that secured the lacing ligatures in the planking of the vessel.[245] Whether all the pegs used in the Giglio vessel are of ash is unclear, as sampling frequency was not indicated.

Ma'agan Mikhael, Israel

Excavators of the Ma'agan Mikhael ship of the fifth-century B.C.E. collected 128 wood samples from the hull for analysis. Many wood types were incorporated into the vessel, with only one example of ash; a tapered peg used in securing the ship's ligatures. Five other tapered pegs were sampled, all of which were of oak.[246] It would be easy to presume that the single peg of ash was a product of repairs made to the vessel. However, caution must be expressed here as investigators believe that the vessel was newly constructed when it sank.[247] The Ma'agan Mikhael vessel is one of the most comprehensively sampled Classical period vessels known to the author.

Miladou, France

The vessel at Miladou, France is dated between the late second and the early first century B.C.E. and has at least one frame of ash. As there were four other species of timber identified among the frames, including alder, Aleppo pine, poplar and fig,[248] the ash timber was likely a repair piece, a product of poor sources of homogenous timbers at the area of the ship's construction, or its use may be due simply to utilization of readily available or on-hand resources. Neither the number of samples, nor the sampling strategy was published for the vessel.

---

[245] Bound 1991, 34.
[246] Liphschitz 2004, 156-61.
[247] Kahanov and Linder 2004, 3.
[248] Dumontier and Joncheray 1991, 174.

La Roche-Fouras, France

Contemporaneous with the Miladou wreck is the wreck at La Roche-Fouras, France. The shipwrights made use of ash for the tenons that connected the hull planking.[249] Interestingly, ash was not identified among the pegs that held the tenons in place. Presumably, if the ash trees were plentiful enough to produce tenons, there were likely branches, twigs, or scrap wood that could have supplied the material for the pegs, yet the shipwright chose an evergreen oak (*Quercus ilex*).[250] This may suggest that the shipwright chose ash for the tenons due to some quality of the wood (presumably the flexibility), or that oak was in short supply. There may also be unrecognized reasons for the shipwright's wood choices or these conclusions may simply be based on a limited sampling strategy. Neither the number of samples, nor the sampling strategy was published for the vessel.

Comacchio, Italy

From the first century B.C.E., there are six shipwrecks in which ash wood has been identified as part of construction materials. The first is the wreck at Comacchio, Italy. Investigators sampled 14 pegs apparently used to secure the laced planking; similar to the use described for the Giglio shipwreck. Of the 14 samples, one was identified as ash.[251] Comprehensiveness of sampling is not discussed.

La Giraglia, France

The next wreck was located near the small island of La Giraglia, France. The vessel is a dolia carrier of the first-century B.C.E. in which the shipwright used ash for 71.5% of the sampled mortise-and-tenon pegs, as well as for 5.25 % of the sampled treenails. The actual number of samples is not given in the description. As recorded in the published report, "It is believed that the shipwright used ash for the pegs simply because it was available to him, rather than for any special quality," [252] yet the shipwright chose oak for the tenons. Although not in concordance with Marlier and Sibella, this may suggest that when

[249] Guibal and Pomey 2003, 41; Pomey 1998, 436.
[250] Dumontier and Joncheray 1991, 137.
[251] Castelletti et al. 1990, 149-50; Sciallano and Marlier 2004, 71.
[252] Marlier and Sibella 2002, 167.

given a choice of woods, ash may make better pegs and treenails than tenons, as oak timbers large enough to produce tenons were presumably available and therefore the associated branches and twigs would also likely have been available. The situation is opposite that of the La Roche-Fouras wreck. However, there were six distinct genera identified in the construction of the La Giraglia vessel, all of which are low altitude varieties, thus substantiating Marlier and Sibella's idea of the use of readily available local materials.

Madrague de Giens, France

The mid-first-century B.C.E. shipwreck at Madrague de Giens has ash utilized for at least one futtock,[253] at least three deck stanchions, and at least three planking mortise pegs.[254] There is no homogeneity among the three construction elements. There were three genera identified among the frames, two among the deck stanchions, and at least three among the mortise pegs. Again, this likely suggests a use of readily-available local materials, or a lack of homogenous more desirable materials.

Plane 1, France

The Plane 1 shipwreck, also of the mid-first-century B.C.E., is described as having "wedging elements" of unstated quantities made of ash.[255] The number of samples taken versus the overall number of wedging elements is not published. These wedging elements are presumably the chocks placed between the keel and the mast step or chocks placed between full floors and the keel, although this remains unclear. Relevant to this discussion is the fact that there is use of ash only for the wedging elements and a generous use of three other genera (*Pinus*, *Quercus,* and *Populus*) identified in major features of this ship suggests once again the use of readily available materials.

---

[253] Guibal and Pomey 2003; Pomey 1998, 434, 436. Rival (1991, 86) reports three of 18 frames were of *Fraxinus excelsior*.
[254] Tchernia et al. 1978, 110. Actual numbers of ash elements used in the ship may be greater as there was limited sampling.
[255] Wicha and Girard 2006, 113.

La Tradelière, France

The late first-century B.C.E. shipwreck at La Tradelière presents another anomaly in that the shipwrights used ash in the planking. At least five samples were taken from the planking with four being identified as Scots pine (*Pinus silvestris*) and one sample identified as ash. Additionally, of at least 13 samples that were taken from the framing elements. Ash was used for two floor timbers, one half-frame, and one futtock,[256] but in association with oak, chestnut, and walnut.[257]

Grand Ribaud D, France

The remains of the Grand Ribaud D shipwreck had a single well preserved, but functionally unidentified ash timber from the bow extremity containing one square section fastener. No other ash was identified from this late first-century B.C.E. vessel. [258] Neither the number of samples, nor sampling strategy was published.

Saint Maries 24, France

Four wrecks, dated to the first century C.E. have ash elements in their construction. The wreck at Saintes Maries 24 had ash for framing, along with six other genera of wood.[259] Sample numbers are not published, but the large number of timber types identified suggests a utilization of available resources and not a purposeful choice of homogenous materials.

Baie de l'Amitie, France

The wreck at Baie de l'Amitie dates from the last quarter of the first century C.E. The shipbuilders incorporated a minimum of two frames of ash, while seven distinct genera of timber were identified among the remaining 20 frames in which wood type was identified.[260] Once again, this suggests utilization of readily available timbers.

[256] Guibal and Pomey 2003, 37, 39; Guibal and Pomey 2004, 37.
[257] Quantities and associated materials were clarified by personal communication with Dr. Patrice Pomey 01/06/2009.
[258] Hesnard et al. 1988, 111-2.
[259] Long et al. 2005, 69-70; Wicha and Girard 2006, 113.
[260] Muller 2004; Wicha and Girard 2006, 113 table 19.1.

Pisa C, Italy

Two ships of the 19 vessels excavated from the ancient harbor at Pisa have ash components. Pisa C is dated to the first century. This is certainly the most comprehensively sampled vessel among all that are included in this catalog. The investigators state, "More than one sample from each element of the ship's structure was taken. About 500 samples from ship C and 150 samples from ship F were collected and analyzed."[261] Portions of 13 frames of the vessel are of ash. However, at least 28 partial frames survive and portions of at least 15 are of *Ficus carica* (common fig) with other portions being of *Juglans regia* (walnut), *Ulmus* sp. (elm), and *Quercus ilex* (evergreen oak). Further, treenails used to join frames to planks are also reported to have been of *Fraxinus* sp., but the number of treenails sampled and how many of them were of ash was not indicated.

Pisa F, Italy

Also from the Pisa excavations is a vessel from the second century C.E. (Pisa F) that had several frame sections identified as ash. The exact number is not given in print, but the published colored wood plan suggests that of at least 21 frames on the ship, at least four were of ash. The ship is also said to have had treenails of ash, but their exact numbers were not published.[262]

Marseille 2, France

Of 135 sampled frames from the late second century C.E. Marseille 2 shipwreck, only six were not pine (*Pinus halepensis*). The remaining six were of ash (*Fraxinus excelsior*).[263] Given the great number of pine frames and overall homogeneity of its use for frames, it is difficult to discern if the use of ash was for repairs, or if they were installed at the time of construction. The investigators do not advance any opinion for the use of ash in the vessel.

[261] Giachi et al. 2003, 270.
[262] Giachi et al. 2003, 270-3.
[263] Gassend and Cuomo 1982, 130; Rival 1991, 250, plate 10.

Fiumicino 3, Italy

At Fiumicino, Italy, Wreck 3, likely of the second century C.E., was discovered in the excavation of the Claudian harbor. The ship had an unknown number of ash pegs that were used to secure tenons in the mortises of the planking.[264] The number of samples versus identified ash components does not appear in publication.

L'Anse de Laurons 1 and 2, France

Two wrecks at L'anse des Laurons are reported to have ash used in their construction. Laurons 2, dating to some point between the late second century and the late third century C.E.[265] and Laurons 1,[266] dating to the third century C.E., both have planking mortise pegs of ash. Multiple genera of wood have been identified in the construction of these ships; again suggesting that shipwrights used available resources or that there may have been a shortage of large quantities of certain woods.[267] This information was presented in chart form without indicating sampling numbers or strategies.

Fiumicino 2, Italy

The final wreck of importance to this catalog is Fiumicino 2. The shipwreck is dated to the fourth century C.E. and had planking mortise pegs of ash. In addition, the planking tenons were of ash, although it is not clear how many samples were taken or if ash was homogenously used for pegs and tenons.[268]

---

264 A summary of the wreck with details of construction materials and pictures can be found on the Navis Project website, http://www2.rgzm.de/Navis/Home/Frames.htm. A search for ash under materials provides links to all the wrecks on the website that have ash identified in their construction. This site is a searchable database, therefore each report does not have a separate URL. Also see Boetto 2001, 124.

265 Pomey 1995a, 35. For more on the dating of the shipwreck seeXiménès and Moerman (1991, 222); Gassend (1998, 197).

266 Guibal and Pomey 2003, 41; Pomey 1998, 434.

267 Pomey 1995a, 35.

268 A summary of the wreck with details of construction materials and pictures can be found on the Navis Project website, http://www2.rgzm.de/Navis/Home/Frames.htm. Also see Boetto 2001, 124.

Discussion

Evidence suggests that ash was of little importance to Graeco-Roman shipwrights for major structural components. Unlike pine, typically used for planking, and oak, typically used for frames, pegs, and tenons, ash has no convention in typical Graeco-Roman ship construction. Sporadic use of ash for pegs and frames are, however, seen in archaeologically documented shipwrecks. Although only twelve distinct frame timbers have been identified in the Kızılburun wreck, it appears that this is a near homogenous use of ash and offers a deviation from the archaeologically documented pattern of sporadic use of the wood type. Alternatively, this may be a preference of Eastern Mediterranean shipbuilders as opposed to Central or Western Mediterranean shipbuilders as most of the shipwrecks cataloged here were located in, if not originated from, Western or Central Mediterranean locales. As more shipwrecks are systematically and comprehensively sampled from Eastern regions of the Mediterranean, more definitive conclusions may be revealed.

PROVENIENCE OF THE KIZILBURUNHULL

There are several factors to consider when attempting to determine the provenience of the Kızılburun vessel. The most obvious, and likely the most telling, is the distribution of timber used in its construction, but one must also consider ancient written sources and any data discovered throughout the excavations. For instance, in the course of research and analyses of the cargo of the vessel, both the origin and destination of the final voyage have been discovered with a high degree of certainty and may be suggestive of the ship's provenience when coupled with data supplied from the identification of the wood used in its construction.

The native distribution of the identified arboreal species here is based on flora literature for Turkey and the Mediterranean region, predominately that of Davis' eight-volume publication, *Flora of Turkey and the Eastern Aegean Islands*.[269] These volumes cover not only the modern country of Turkey, but also the remainder of Southwest Asia and the Eastern

[269] In personal communication Dr. Nili Liphschitz (2009) she stated that her main source of timber distribution is Davis, 1965-82, vols. I-VIII.

Mediterranean Region. Based on the information gained from the marble cargo of the vessel this seemed a logical starting point to trace the timber habitats. However, a ship is not restricted by seas and therefore a large area must be considered when attempting to ascertain the provenience of a vessel based on the timbers used in the construction of its hull. Therefore, distribution atlases have also been utilized from European and Balkan regions.

Pinus brutia (Turkish pine) and *Pinus nigra* are sporadically available all over central and western Turkey, the Aegean Islands, and Mainland Greece.[270] *P. nigra* grows at elevations from 250 -1800 meters, while *P. brutia* tends to grow at elevations from 100 – 1500 meters, but seen at higher elevations in southern Anatolia and at much lower elevations in northern Anatolia, making these two species of limited use in determining a provenience for the ship's construction as neither one species is exotic or from a distinct and limited geographical region.

Quercus coccifera is an evergreen oak that ranges all across the Mediterranean basin,[271] and is generally of small growth limited to about 10 meters in height.[272] *Quercus petraea* is wide ranging, stretching across southern Europe and throughout Turkey.[273] This is one of the most common trees in Turkey, often forming pure stands.[274] *Quercus cerris* or Turkey Oak is common in Italy, Greece, and in the Near East,[275] particularly in Turkey from which it takes its common name, except in the eastern and northeastern parts of the country.[276] It can grow in mixed forests with other oaks (*Quercus* sp.), *Pinus nigra, Pinus brutia* or in pure stands. Again, all the species in this genus are indistinct in regards to suggesting a narrow provenience for the Kızılburun vessel.

---

[270] Davis 1965, 73-5; Meiggs 1982, 44; Polunin and Everard 1976, 16; Strid and Tan 1986, 42; Turland et al. 1993, 63.
[271] Meiggs 1982, 45; Polunin and Everard 1976, 54; Turland et al. 1993, 90.
[272] Davis 1982, 681-2; Meiggs 1982, 45.
[273] Hather 2000, 48; Polunin and Everard 1976, 57.
[274] Davis 1982, 668.
[275] Meiggs 1982, 45; Polunin and Everard 1976, 67.
[276] Davis 1982, 674.

Ulmus campestris is yet another timber that is available throughout Turkey, particularly in its northwestern portion,[277] as well as in southern Europe.[278] The tree tends to favor streams and rivers or open slopes, a trait that is shared with *Fraxinus excelsior*. *Juglans regia* is found throughout Turkey, the Balkans, as well as extending eastward to China.[279] This tree is heavily cultivated for its fruit and timber and easily disseminated by animals as well as humans, voiding any distinct or even natural growth area.

In addition to having a habitat covering northern Turkey, western Turkey, and south-central Turkey,[280] European or Common ash (*Fraxinus excelsior*) takes its name from its widespread availability across Europe.[281] It tends to grow in coastal areas or by streams, but can survive almost anywhere. The trees tend to grow sporadically in environments that harbor oaks as well.[282] This statement may suggest that in order to have enough trees to produce all the frames of a ship, the timber was likely intentionally sought or purposely cultivated.

Species-level identification has shown that the frames of the Kızılburun hull are predominantly *F. excelsior*. As with the other wood types found in the vessel, *F. excelsior* has a widely spread distribution that offers little information to help distinguish a possible area of construction for the vessel. Of prime importance for this discussion is the apparent purposeful and primary use of ash timbers that challenges the available evidence suggesting a sporadic pattern of use during the Graeco-Roman period. Muller states that, "If the systematic use of noble woods essentially reflects technical preoccupations, the use of lower-quality woods indicate the exploitation of local sources."[283] Although ash has not been historically known as a lower-quality wood, its seemingly unparalleled use as primary material for the Kızılburun frame timbers suggests that it was either the shipbuilder's best available local timber or that the choice of ash has some other significance.

---

[277] Davis, 1982, 647; Fitzgerald 1995, 111.
[278] Hather, 2000, 132-3; Polunin and Everard 1976, 62.
[279] Davis 1982, 654; Polunin and Everard 1976, 41.
[280] Davis 1978, 149-51; Polunin and Everard 1976, 161.
[281] White et al. 2005, 409; Polunin and Everard 1976, 161.
[282] Davis 1978, 149-50; Rival, 1991, 66-7; White et al. 2005, 408-14. Ash is reported to grow sparsely in open, low lying areas with damp, alkaline soils and plentiful light.
[283] Muller 2004, 348.

Shipwreck investigations in which the origin and destination of the final voyage are known with some certainty are rare, yet such is likely the case with the Kızılburun ship.[284] Unfortunately, this information suggests little about where the ship was constructed. In considering the question of the ship's construction area, one must look at the specific types of noble or exotic woods used in the vessel or for types that grow in distinct areas. As shown, the wood types found in the Kızılburun hull are found commonly throughout the Mediterranean region and both in the area of the ship's final origin and destination, thus making discussions of the specific area of construction fruitless insomuch as both areas have the same access to these timber resources.[285] Although it is entirely feasible that the vessel could have been constructed at either end of its final voyage or at any point in between based on the wood types used in the ships construction, there is no way to suggest that it must have been so. As Carlson notes, "The presence of several cooking pans of the *orlo bifido* type invites speculation about the possibility that the voyage originated in a western port; this may have interesting implications for theorizing about the person or persons responsible for this marble shipment,"[286] as well as the area of the ship's construction.

If the area where the ship was built could be further refined, it may suggest clues to the ship's ownership. Was it owned by the community of Claros, the quarry at Proconnessus, or was it of private ownership? Did the ship in fact originate in a western port? The inability to narrow the area of construction hampers the ability to address the question of ownership. That is if a connection could be implied between the area of construction and the owner of the vessel. However, there may be pertinent literary evidence, when reviewed in light of the wood identification data that may shed light on this very important question. The

[284] The rough-cut marble components have been sourced to the quarries of Proconnessus and stylistically matched to architectural components making up the Temple of Apollo at Claros (Carlson and Aylward 2010, 145-59).
[285] Davis, 1965; 1978; 1982; Hather, 2000, 120-33.
[286] Carlson and Aylward 2010, 145-6.

community of Claros is known to have had a grove of sacred ash trees in the time of Pausanias.[287]

Making the connection between a historic reference to an ash grove at Claros written approximately two centuries after the sinking of the Kızılburun ship, and the evidence for a relatively large amount of ash used in the vessel is tenuous and should be viewed with much skepticism. However, given the proposed destination of Claros for the Kızılburun ship, the presence of the Temple of Apollo at Claros, and a reported sacred ash grove dedicated to Apollo at the location, the use of *Fraxinus excelsior* may be significant.[288] Further discussion is beyond the scope of this thesis; however, it is my hope to present this potential connection as the basis for future hypotheses to be tested as more archaeological evidence pertaining to open water stone transport is uncovered, particularly pertaining to questions of vessel ownership.[289] If one can demonstrate ownership of such a vessel, then one may be able to more properly discuss the idea of purpose-built stone carriers of antiquity.

[287] Paus.7.5.10: Ionia has other things to record besides its sanctuaries and its climate. There is, for instance, in the land of the Ephesians the river Cenchrius, the strange mountain of Pion and the spring Halitaea. The land of Miletus has the spring Biblis, of whose love the poets have sung. In the land of Colophon is the grove of Apollo, of ash-trees, and not far from the grove is the river Ales, the coldest river in Ionia.

[288] This may be significant as ash is known to grow sparsely (Davis 1978, 149; Rival 1991, 66-7; White et al. 2005, 408-14) Timbers in numbers sufficient enough to produce a ships framing system may suggests cultivation of ash trees such as would exist in a grove.

[289] It remains unclear if vessel ownership belonged to quarry owners, temple constructors, third party merchants, or if there was even a standard mode of operation. Burford (1969, 172) suggests that quarry stone may have been a free resource, with the major financial factors being labor of cutting and transport, while Snodgrass (1983, 21) implies from a single fourth century B.C.E. example that quarried stone transport may have been the responsibility of a third party.

			WOOD SAMPLES	
	Wood No.	**Sampled**	**Timber Purpose**	**Genus & Species**
1	1000.01	timber	frame	*Fraxinus* sp.
2	1000.01	attached	attached to frame 1000	*Pinus brutia*
3	1000.01	attached	attached to frame 1000	*Pinus brutia*
4	1000.01	attached	tenon, attached to frame 1000	*Quercus cerris*
5	1001.05	timber	planking	*Pinus brutia*
6	1002.03	timber	planking	*Pinus nigra*
8	1003.08	tenon	tenon, planking 1003	*Quercus* sp.
7	1003.10	timber	planking	*Pinus nigra*
9	1003.10	tenon	tenon, planking 1003	*Quercus cerris*
10	1004.05	timber	planking	*Pinus nigra*
11	1005.01	timber	planking	*Pinus nigra*
12	1006	timber	UM	*Pinus brutia*
13	1007	timber	UM	*Pinus nigra*
14	1008	timber	UM	*Pinus nigra*
15	2000	timber	NOT SAMPLED	
16	2001	timber	NOT SAMPLED	
17	3000.01	timber	frame	*Fraxinus excelsior*
18	3001.01	timber	frame	*Fraxinus excelsior*
19	3002.01	timber	ceiling planking	*Pinus brutia*
20	3003.01	timber	frame	*Fraxinus excelsior*
21	3003.01	attached	attached to frame 3003	*Pinus brutia*
22	3003.01	attached	attached to frame 3003	*Pinus brutia*
23	3003.01	attached	peg, attached to planking 3003	*Fraxinus excelsior*
24	3003.01	tenon	tenon, attached to planking 3003	*bark of conifer*
25	3003.04	attached	attached to frame 3003	*Pinus brutia*
26	3003.04	attached	peg, attached to planking 3003	*Pinus brutia*
28	3004.01	timber	planking	*Pinus nigra*
27	3004.01	peg	peg, planking 3004	*Quercus* sp.
29	3004.01	tenon	tenon, 3004	*Quercus cerris*
30	3005.01	timber	planking	*Pinus nigra*
31	3006.01	tenon	tenon, planking 3006	**not wood**
32	3006.01	timber	planking	*Pinus brutia*
33	3007	timber	planking	*Pinus nigra*
34	3007	tenon	tenon, planking 3007	*Quercus cerris*
35	3007	tenon	tenon, planking 3007	*Quercus cerris*
36	3007.09	tenon	tenon, planking 3007	*Quercus cerris*
37	3007.10	peg	peg, planking 3007	*Quercus* sp.
38	3007.10	timber	planking	*Pinus brutia*
39	3007.10	peg	peg, planking 3007	*Pinus* sp.
40	3007.11	peg	peg, planking 3007	*Fraxinus excelsior*
41	3007.11	tenon	tenon, planking 3007	*Quercus* sp.
42	3007.12	tenon	tenon, planking 3007	*Pinus* sp.
43	3007.13	tenon	tenon, planking 3007	*Quercus* sp.
44	3007.13	peg	peg, planking 3007	*Fraxinus excelsior*
45	3007.13	tenon	tenon, planking 3007	*Quercus* sp.

46	3007.19	tenon	tenon, planking 3007	*Quercus cerris*
47	3007.24	peg	peg, planking 3007	*Fraxinus excelsior*
48	3007.25	timber	planking	*Pinus brutia*
49	3007.26	peg	peg, planking 3007	*Fraxinus excelsior*
50	3008	timber	NOT SAMPLED	
51	3009.03	timber	frame	*Fraxinus excelsior*
52	3010.01	timber	UM	*Pinus nigra*
53	3011.01	timber	planking	*Pinus nigra*
54	3011.01	timber	planking	*Pinus nigra*
55	3012	NAIL	NOT SAMPLED	
56	3013	timber	frame	*Fraxinus excelsior*
57	3014		NOT SAMPLED	
58	3015	timber	UM	*Fraxinus excelsior*
59	3016	timber	UM	*Fraxinus excelsior*
60	3017	timber	UM	*Pinus brutia*
61	4000	timber	frame	*Fraxinus excelsior*
62	4001		NOT SAMPLED	
63	4002	timber	frame	*Fraxinus excelsior*
64	4002	attached	attached to 4002	*Pinus nigra*
65	4002	pitch		
66	4003	timber	UM	*Fraxinus excelsior*
67	5000.06	timber	frame	*Fraxinus excelsior*
68	5000.06	treenail	treenail, frame 5000	*Pinus brutia*
69	5000.06	timber	frame	*Fraxinus excelsior*
70	5000.06	treenail	treenail, frame 5000	*Pinus brutia*
71	5000.12	timber	planking under BAP	**Unidentifiable**
72	5001.01	timber	frame	*Fraxinus excelsior*
73	5001.01	attached	attached to 5001	*Pinus brutia*
74	5002.01	treenail	treenail, frame 5002	*Pinus nigra*
75	5002.01	treenail	treenail, frame 5002	*Pinus nigra*
76	5002.03	timber	frame	*Fraxinus excelsior*
77	5003.01	timber	frame	*Fraxinus excelsior*
78	5004		NO SAMPLE FOUND	
79	5005	timber	frame	*Fraxinus excelsior*
80	5005	timber	frame	*Fraxinus excelsior*
81	5006.02	timber	ceiling planking	*Pinus nigra*
82	5007.01	timber	frame	*Fraxinus excelsior*
83	5007.04	attached	tenon, attached to frame 5007	**Unidentifiable**
84	5007.04	attached	attached to frame 5007	*Pinus brutia*
85	5008.05	timber	ceiling planking	*Pinus nigra*
86	5009.06	timber	frame	*Fraxinus excelsior*
87	5010.03	timber	planking	*Pinus nigra*
88	5010.03	peg	peg, planking 5010	*Fraxinus excelsior*
89	5010.03	attached	attached compressed frame	*Fraxinus excelsior*
90	5011	timber	keel	*Pinus nigra*
91	5011	timber	keel	*Pinus nigra*
92	5011.05	tenon	tenon, keel	*Quercus coccifera*
93	5011.05	tenon	tenon, keel	*Quercus coccifera*
94	5011.06	timber	keel	*Pinus nigra*

95	5011.09	peg	peg, keel	*Juglans regia*
96	5011.09	tenon	tenon, keel	*Quercus petraea*
97	5011.09	tenon	tenon, keel	*Quercus petraea*
98	5011.23	timber	keel	*Pinus nigra*
99	5012	timber	garboard strake	*Pinus nigra*
100	5012.05	timber	garboard	*Pinus nigra*
101	5012.05	timber	garboard	*Pinus nigra*
102	5013.03	timber	ceiling planking	*Pinus nigra*
103	5014.05	timber	frame	*Fraxinus excelsior*
104	5015	timber	UM	*Quercus petraea*
105	5017	timber	UM	*Pinus brutia*
106	6000.04	timber	planking	*Pinus brutia*
107	6000.04	attached	tenon, attached to 6000	*Quercus cerris*
108	6001.01	timber	tenon, planking 6001	**not wood**
109	6001.04	timber	planking	*Pinus brutia*
110	6002.01	timber	frame	*Fraxinus excelsior*
111	6003.01	timber	planking	*Pinus nigra*
112	6004.02	treenail	treenail, frame 6004	*Pinus brutia*
113	6004.03	attached	attached to 6004	*Pinus brutia*
114	6004.03	timber	frame	*Ulmus campestris*
115	6004.05	attached	attached to 6004	*Pinus brutia*
116	6004.05	attached	attached to 6004	*Pinus brutia*
117	6004.05	timber	frame	*Fraxinus excelsior*
118	6005.02	timber	frame	*Fraxinus excelsior*
119	6006.06	timber	planking	*Pinus brutia*
120	6007.04	timber	ceiling planking	*Pinus nigra*
121	6008.01	attached	tenon, attached to 6008	*Quercus* sp.
122	6008.01	treenail	treenail, frame 6008	*Pinus brutia*
123	6008.04	attached	attached to frame 6008	*Pinus brutia*
124	6008.05	timber	frame	*Fraxinus excelsior*
125	6009.04	attached	attached to frame 6009	*Pinus nigra*
126	6010	timber	frame	*Fraxinus excelsior*
127	6010.07	attached	attached to 6010	*Pinus nigra*
128	6011	timber	UM	*Pinus nigra*
129	6012.01	timber	UM	*Pinus nigra*
130	6013	timber	UM	*Pinus nigra*
131	6013	timber	UM	*Pinus nigra*
132	6014	timber	UM	*Pinus nigra*
133	6015.01	timber	UM	*Pinus nigra*
134	6016	timber	UM	*Pinus nigra*
135	6017	timber	UM	*Fraxinus excelsior*
136	6018.02	timber	Frame	*Fraxinus excelsior*
137	6019	timber	UM	*Pinus nigra*
138	6020	timber	UM	*Fraxinus excelsior*
139	6021	nail	NOT SAMPLED	
140	6022	timber	UM	*Pinus nigra*
141	6023	timber	UM	*Pinus nigra*
142	Lot 1473	nail	UM	*Pinus nigra*
143	Lot 157.06	timber	UM	*Ulmus campestris*
144	Lot 213	tenon	UM	*Quercus* sp.

145	Lot 229	timber	UM	*Pinus brutia*
146	Lot 655.04b	timber	UM	
147	Lot 723	timber	frame from 2006	*Fraxinus excelsior*
148	Lot 804	timber	frame from 2006	*Fraxinus excelsior*
149	Lot 804.01	timber	frame from 2006	*Fraxinus excelsior*
150	Lot 903	timber	frame from 2006	*Fraxinus excelsior*
151	Lot 931	timber	frame from 2006	*Ulmus campestris*