THE SHIPWRECK OF SANTA MARIA IN PADOVETERE (COMACCHIO-FERRARA)

Archaeology of a riverine barge of Late Roman period and of other recent finds of sewn boats

edited by

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with the collaboration of
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foreword by Sauro Gelichi

All'Insegna del Giglio

Foto di copertina: Santa Maria in Padovetere shipwreck *in situ* with digital reconstruction of its hull shape (elaboration: E. Costa).

Retro: Santa Maria in Padovetere shipwreck *in situ* (photo: E. Costa).

Finanziatori

Questo libro è stato stampato grazie al finanziamento PRIN 2017
per il progetto FOOD&S.T.O.N.E.S. (CUP H74I17000170003)

ISBN 978-88-9285-198-6
e-ISBN 978-88-9285-199-3

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Stampato a Sesto Fiorentino (FI)
febbraio 2023, BDprint

FOREWORD

In Arles, in 2004, a 1st century AD boat was discovered in the Rhône River. The perfectly preserved hull was recovered and immediately restored: since 2013, Arles Rhone 3 (the name given to the wreck) has been exhibited in the new Musèe Arles Antiques. Less than ten years elapsed between the discovery and the final exhibition while taking care of the excavation, recovery, and restoration. It has been a remarkably speedy process. Unfortunately, we cannot report similar time frames for many marine and fluvial wrecks discovered in our country. A lack of meticulous masterplans and programming prevents their correct recovery and, sometimes, correct documentation.

In this panorama, the maritime and river navigation knowledge of the Italian Early Middle Ages is even more penalized. We know only a few hulls dated to the 8th century; almost all are log-boats (vessels made from a single tree trunk), which were erroneously dated at the pre- or protohistoric era for a long time. Likewise, the picture for the pre-medieval period is not so optimistic, although some more late antique wrecks are known. However, even when identified and investigated, the path that leads from the excavation to the critical edition is not always fast and complete. This volume represents an exception in the Italian national context: both for the speed of the team reaching a publication after the excavation and for the quality and exhaustiveness of the critical edition, not penalized by such prohibitive timing.

First of all, the critical edition of the hull should be highlighted, excavated in an excellent way and expertly studied by the best specialists in the sector. Then, we must point out the different analyses and studies that move in different directions, all aimed at accompanying the study of the vessel and understanding its functions and context, including the environment in which it moved. These types of analysis are also associated with studies on the cargo and modelling, attempting to design not only on the quantity of 'goods' it could carry but also on their typology. The reconstructions based on hydrodynamic calculations gave surprising results, offering valuable data to better understand the duration and techniques of river navigation in the late ancient era.

The boat is dated to the 5th century, and it has been found in Motta della Girata, near the famous archaeological ecclesiastical complex of Santa Maria in Padovetere, excavated during the last century. We can assume that the boat embodies the same type of vessel that even the milites comaclenses *must have used in their navigation along the Po river and its tributaries, as we know from written sources from the 8th century (Motta della Girata is a few kilometres from Comacchio). Nevertheless, this shipwreck is crucial to better understanding the characteristics of the Early Medieval navy. It is also crucial for its peculiar contribution to the study and analysis of riverboats in a critical transition phase between the Roman era and the Middle Ages. At a local level, it tells us a specific story of an important river in antiquity – the Po di Spina – which had become, precisely in this period, senescent but still navigable. Accompanied by the archaeological research conducted in the area of the ecclesiastical complex – first directed by Fede Berti, then by Mario Cesarano and, recently, taken up by the Ca' Foscari University of Venice – the story of this vessel acquires a more explicit meaning, starting to shed light on a still little-known phase of this river space.*

Fundamentally, the barge seems to relate very well to the specific functions of this area before it was cancelled and hidden by the bulky ruins of the church and its baptistery. We are delighted that the Superintendence desired to renew the investigations in the area and that these researches have started a new season. This publication may represent a first step of a new era.

A barge is an essential testimony for understanding not only the history of nautical technology but also the economic and social history of the past. In recent years, outside Italy, maritime archaeology has demonstrated how it can be an original and performative tool to address these issues. In recent years, river archaeology has assumed an increasingly central role in landscape studies. No need to highlight how decisive it is in the Po area. We should overcome a superficial archaeological approach characterized by the inexperience of those who practice it. Equally, we must go beyond helpless protection paradigms, blaming the costs and difficulties of dealing with such contexts. The conservation aspect pays the price, and subsequently, these objects cannot be part of museum collections due to a lack of resources and suitable places for their exhibit. We are, therefore, still far from the case we mentioned at the beginning. Waiting for better times to realize the necessary quality enhancement, the Superintendency appropriately ordered the reburial of the vessel to preserve it for the future. Today we do not have material access to the object's remains, but we have this critical edition that returns it to us in all its three-dimensionality, details, and secrets.

Sauro Gelichi
Venezia, February 2023

INTRODUCTION

The aim of this volume is to recount, in the most exhaustive possible way, the study of the wreck of a riverine barge, dated to the 5th century AD, carried out in an ancient riverbed in Santa Maria in Padovetere close to Comacchio.

The archaeological investigation of this barge has been framed in the most interdisciplinary way possible, engaging geologists, archaeobotanists, a chemist and a nautical engineer who were able to contribute to the reconstruction both of the history of this object and of the paleoenvironment where this barge moved. On the other hand, the lack of an evident cargo has stimulated the research of 'fine-grain' indicators able to contribute to the identification of the type of use of this watercraft. This approach, utilized to better contextualise the barge, is one of the newest aspects which we adopted along with using digital documentation, 3D digital reconstruction and hydrostatic and hydrodynamic calculations. Indeed, the shipwreck was documented *in situ* through both digital photogrammetry and laser scanning, and it was used as a case study in order to compare these two techniques. The remains of the barge were completed with a 3D application producing a digital model which was analysed in collaboration with a nautical engineer in order to calculate important aspects such as the tonnage, the seaworthiness, and the speed.

The historical and archaeological importance of this finding was immediately apparent and thus, for multiple reasons, deserving of an in-depth analysis through excavation. First of all, the shipwreck lies a few metres from a site of great importance for the Middle Ages, that is, the parish of Santa Maria in Padovetere with its cemetery, excavated by Alfieri, located in a place which, thanks to the continuation of the investigations, is revealing itself to be a crossroads of waterways which were strategic for the traffic of Comacchio, and beyond. It is clear that the hull represents a precious witness, not only of this water traffic, but also, we believe, of the riverine traffic of the entire Po Valley. Indeed, it is one of the very few riverine shipwrecks of Antiquity found in Italy and the only one of Late Roman period. The discovery of a riverine hull, in a good condition, was an exceptional opportunity to discover ancient navigation in inland waterways. The exceptional condition of the starboard side and of the stern, emerged during the excavation, permitted a 3D reconstruction of the entire barge with minimal approximation. Such discoveries and the possibility to have an almost complete reconstruction are extremely rare.

Furthermore, the ship-building aspect revealed details of great interest, not so much because it is mainly a sewn technique, very well-known and diffused only in the Roman and Early Medieval Upper Adriatic (Beltrame, 2002a), but because, along with the principal technique, the classical 'mortise-and-tenons' and, originally at least for the Mediterranean, the pseudo-clinker techniques are used. These particularities make this item one of the most relevant and original shipwrecks of the Ancient Mediterranean.

The barge which we are presenting has only been documented *in situ* because it has been left where it was found, in anticipation of conditions which make its recovery possible. The abandonment of a hull *in situ* is not always the best solution, neither for research because the wood cannot be documented optimally, nor for its preservation because the conservative conditions of the deposit can change, for example after a fall in the water table. On the other hand, if there is not a credible and well-financed project, which considers documentation, conservation treatment and exhibition, then recovery must always be excluded, or at least when there is no serious need for quick removal. After all, the hull of Valle Ponti (Berti, ed., 1990), found in the 1980s near the wreck of Santa Maria in Padoverete, still awaiting a conservation process in a warehouse in Comacchio, is one of the experiences of managing a nautical project most embarrassing in Italy.

This book is one of the very few critical editions of an excavation of an ancient shipwreck investigated in Italy, whether it be in underwater or other contexts. Moreover, in our country, despite numerous discoveries of ancient ships silted in harbour or littoral contexts, studies and publications are few in number and are often preliminary. While the volumes dedicated to the hulls of Fiumicino by Scrinari (1979), and to the boat of Monfalcone by Bertacchi (1988), of the 1970s and 1980s present important limitations of interpretative and documentary aspects, the catalogue of the exhibition of the Roman ship of Valle Ponti (Berti, ed., 1990) analyses, in an exemplary way, the cargo and the board items, but brusquely, and in few pages, dismiss the study of the hull, with inadequate documentation.

The more recent situation has, of course, not improved. Indeed, in the first years of the 21st century, in Italy, there have been a series of exceptional discoveries of ancient shipwrecks, such as the Medieval galley on the submerged island of San Marco in Boccalama in the lagoon of Venice (Fozzati, ed., 2002-3), the Roman shipwrecks of Pisa San Rossore (Camilli, 2004; Camilli and Setari, eds., 2005) and of Piazza Municipio at Naples (Boetto, Zazzaro and Poveda, 2021), the Roman and Medieval shipwrecks of the harbour of Olbia (D'Oriano, 2002), the Early Medieval shipwreck of the mausoleum of Teodorico at Ravenna (Medas, 2003), but they have sometimes been approached in a superficial way and, in the case of Pisa, without the necessary presence on the field of nautical archaeologists (Beltrame, 2002b). Despite 20 years having passed since these finds, we still know so little about these big excavations, with the exception of Naples, followed by my expert colleagues Giulia Boetto and Chiara Zazzaro, who have already published important scientific communications.

The study of the barge of Santa Maria in Padovetere also presents the first publication of new discoveries of elements of Roman boats built with the sewn-technique, carried out, recently, in Venice, *Altinum* and Grado, which enrich, the already detailed panorama of testimonies regarding this ship-building technique.

Let me close this introduction by thanking my colleague and friend, Sauro Gelichi, because he has stimulated the publication of this book by hosting it in the PRIN project PRIN 2017 Food and S.T.O.N.E.S. (CUP H74I17000170003), as well as through seminars which have allowed the dissemination of the results of this research from the relatively confined circle of specialists in ancient ship-construction, involving historians and archaeologists working on the traffic of goods in Late Roman and Medieval period in the Po Valley. I also thank the former Superintendents Marco Edoardo Minoia and Luigi Malnati who, in agreement with the director of the excavation Mario Cesarano, authorised the study of this barge and its publication.

Carlo Beltrame
Venice, October 2022

Carlo Beltrame

1. SHIPWRECKS AS SOURCES FOR THE STUDY OF ANCIENT RIVERINE NAVIGATION IN ITALY AND ABROAD

The historical reconstruction of the ancient navigation along the Italian rivers suffers from a relative lack of archaeological evidence and of a delay in methodology and in institutional organisation. This delay is much more evident if we compare the data and the scientific literature available from the Italian rivers with the data from the waterways of central European countries.

The institutional activity carried out in Italian rivers has almost always been of rescue archaeology. In most situations, the recoveries correspond to logboats, discovered by chance or during dredging (Asta, 2015), rather than to crafts. But the extremely poor archaeological evidence from rivers is partially balanced by the land discoveries of buried boats in ancient waterways.

Fig. 1.1. Shipwreck of the 15th-16th century AD barge of Porta Paola at Ferrara (courtesy S. Medas).

In this panorama, the available evidence for a construction of a history of navigation in Italy, and especially in the Po Valley, is quite ephemeral. For the Roman period, we can cite, indeed, only a flat-bottom hull, carrying a cargo of tiles, dated in the 1st century AD, which was investigated in the Stella river, close to Palazzolo dello Stella (Udine) (Vitri *et al.*, 2003; Castro and Capulli, 2016). However, there are numerous findings of Roman boats built with the sewn technique and found in land excavations, in buried conditions. Among them, the best-preserved examples are the two boats of Corte Cavanella di Loreo (Rovigo), found in a presumed *mansio* (stage station) and the boat of Marcon/Altinum (Venice) (Beltrame, 2002a; Beltrame and Gaddi, 2013a) (see below).

At Precenicco (Udine), in a, now silted, meander of the nearby Stella river, excavation has allowed the random discovery of a boat, only 8 m long, dated to C 14 to 11th-13th century AD (Capulli, 2017). In the centre of Ferrara (at Porta Paola), in a silted meander of the Po river, which crossed the city, a typical riverine flat bottom barge, dated between the second half of the 15th and the first half of the 16th century AD, was documented during a rescue excavation organised by the local Soprintendenza and was then left *in situ* and buried (Guarnieri, Medas and Pizzarello, 2010) (Fig. 1.1).

Outside the Po Valley, the archaeological evidence of riverine navigation is almost absent, except for the exceptional finding of Pisa San Rossore, where a sort of riverine harbour was discovered in the silted meander of the Auser river. In this site, a great number of ships and boats of very different types, some adapted to riverine navigation and others with maritime shapes, dating from the Hellenistic period to the 5th-6th century AD, have been excavated and recovered (Camilli and Setari, eds., 2005; Peruzzi, 2014).

The activity of research on the topic of riverine navigation in other states, such as France, Holland, Germany, but also Slovenia, is much more intense and the evidence of boats in the rivers is richer. In France, we can mention the project involving the investigation and study of the Port-Berteau 2 shipwreck in the Charente river, a ship dated at the end of the 6th century AD (Lavier, 2001), but there is much richer evidence of riverine boats from the Roman period, such as the Arles-Rhone 3 shipwreck (Marlier, ed., 2014), or the six shipwrecks of Parc Saint-Georges at Lyon from a silted side of the Saone (Guyon and Rieth, 2011). In the Netherlands, in a tributary of the Rhine, De Meern 1, 4 and 6, Woerden 1, 2, 6 and 7, Zwammerdam 2 and 6 Roman shipwrecks were investigated (Holk, 2011; Mees and Pferdehirt, 2002, 30-56). In Germany, at Oberstimm, close the Danube, two military boats were excavated (Bockius, 2002), while at Mainz, close to the Rhine, Mainz 1, 2, 3, 4, 5 and 6 military hulls were studied (Mees and Pferdehirt, 2002, 66-103). In Slovenia, in the Ljubljanica river, Roman and probably Pre-Roman period shipwrecks have been the object of underwater investigation (Gaspari, 2017).

A comparison of the Italian situation with that of the Mittel European countries, presented above, allows the following observations to be made. The scarcity of findings from the Italian rivers can, of course, be attributed, in part, to the scarce attention of the institutions placed on this kind of archaeological evidence. However, it could also be ascribed to the different use of Italian rivers in comparison to those of other countries. Indeed, we cannot ignore the fact that Italian rivers have been deeply dredged and transformed by man and that they are now less natural than rivers in other countries. These activities could, at least in the past (especially in the 1960s and 1970s), have impacted such heritage, leaving us almost no traces of ancient navigation.

The most numerous discoveries of logboats, of different periods, consisting of more than 150 objects from the Po Valley (Lucchini, 2020), rather than assembled boats, is a situation which we can find in other countries, such as France, and which can be attributed, at least in part, to the most numerous chances of conservation that these objects have due to their shape. However, we have to consider the fact that these finds represent a much smaller barrier to ancient and contemporary navigation than a boat made of jointed timbers, which implies that they could be left *in situ* and not removed after sinking (Capelot and Rieth, 2005, 201). In France, already in the 1970s, the presence of numerous logboats in the rivers was discovered, much of which could be dated in the Medieval period (Capelot and Rieth, 2005, 200). A verification of the chronologies of the logboats of the Po Valley, preliminary dated in this period, is now being conducted by Alice Lucchini (2020) who is also carrying out an analytical study of their shape, of their technique of construction, and of their context of deposition.

Carlo Beltrame

2. THE BEGINNING OF THE INVESTIGATION AND THE LOCATION OF THE SITE OF SANTA MARIA IN PADOVETERE

It was summer 2014 when the archaeological officer of the Soprintendenza per i Beni Archeologici dell'Emilia Romagna, Mario Cesarano, called me to propose an interesting collaboration. The former director of the Museo Archeologico Nazionale di Ferrara, Fede Berti, in June 2008, during a trench test (of 13×3.5 m) to investigate the cemetery of the 6th century chapel of Santa Maria in Padovetere, in Valle Pega (Balista and Berti, 2016-2017, 127), excavated in the beginning of the 1960s by Patitucci Uggeri (1970) in the city of Comacchio, had discovered the remains of what appeared to be the section of a boat constructed with the sewn technique of the Roman period. It lay 10 m south of the church at a depth of -1.5 m from ground level. Berti knew this naval technique very well because she had excavated and recovered the Valle Ponti ship (see below), of course the most famous (not only in a positive sense) boat built with this technique. Cesarano, as soon as he arrived in the Soprintendenza, planned to re-open and enlarge that trench-test to study these ship remains in depth. The proximity of Prof. Sauro Gelichi, who had been engaged in research in Comacchio for a long time (Gelichi, Negrelli and Grandi, eds., 2021 and references), had suggested that the officer ask me to lead this investigation as an expert in ship construction and, in particular, in ancient ship construction[1].

Before long, a private company of archaeologists was contracted by the Soprintendenza to begin the first season of excavation and, in autumn 2014, the barge which, lying under the water of the aquifer in an anaerobic environment, was conserved in very good conditions was unearthed. A team from Ca' Foscari University participated in the excavation with the task of studying the barge. This was composed by the research fellow Elisa Costa and two archaeology students (Alice Lucchini and Edoardo Pasotto) under my coordination as professor of Maritime Archaeology. Elisa Costa also followed the excavation during the second season.

The site is located 4.5 km west of the city of Comacchio (Ferrara), in the Emilia Romagna region, on the plain of

[1] A preliminary report of this excavation has already been published as an article (Beltrame and Costa, 2016).

Fig. 2.1. Regional location of the site of Santa Maria in Padovetere.

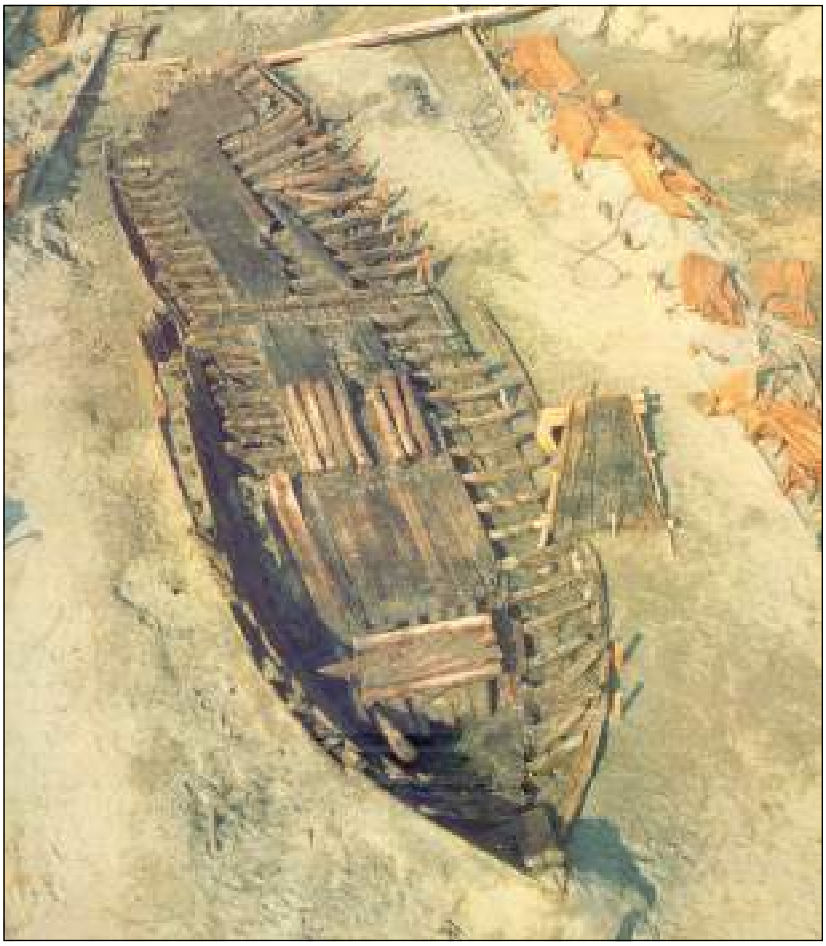


Fig. 2.2. The shipwreck of the Roman ship of Valle Ponti at Comacchio (Berti, ed., 1990, cover).

the Po river Delta that was reclaimed in the 1950s (Fig. 2.1). About 3.5 km from this place, another boat, built with the sewn technique, had been excavated and recovered in the 1980s from Valle Ponti di Comacchio (Berti, ed., 1990). It was a barge, which, at the end of the 1st century BC, sank on the seashore along the littoral after a marine shipwreck. The possibility that it might have come from a river which then ejected it into the sea was not ruled out. The excellent conditions of conservation of this hull and of its cargo were explained by the geomorphologists with the very quick burial of beach sediments and, therefore, by a progradation of the coastline (Bondesan *et al.,* 1990, 22) (Fig. 2.2).

The autumn season of excavation at Santa Maria Padovetere, contracted to the E.P.I.C. snc company of Milan under Mario Cesarano's scientific direction, did not, because of the limited budget, allow the entire hull to be brought to light; it was only entirely exposed, that is, comprehensive of the stern, in 2015. The work, under the direction of Lorenzo Zamboni, began at the end of September and concluded in the middle of December (Figs. 2.3, 2.4, 2.5).

The area, which was excavated in the autumn time, was around 250 m², for a total volume of 300 m³, from a depth, at the ground level, of -0.52 m below sea level, to a maximum depth of -3.60 m below sea level. The very good conditions of conservation were due to the anaerobic conditions of the context, which was a sandy clay layer under the aquifer which inhibited the organic activity. Since the hull was very inclined, with its left side located in a high position over the aquifer, the left side was degraded both by organic and by ploughing activities.

The same condition which allowed the good conservation of the wood became a complication during the excavation because it was necessary to use pumps. Walkways were used to work over the hull without damaging it and geotextiles were used to protect the wood during the work (Fig. 2.6).

The same precautions were also used to protect the two dugouts found over the hull.

A tensile structure was located over the site to protect it from the sun and the rain. The legs of the structure lay over 12 conglomerate cubes which it was necessary to locate in the excavation.

During this campaign, the team of Ca' Foscari University requested the authoritative collaboration of Prof. Francesco Guerra, director of the Laboratory of Photogrammetry of the Università IUAV of Venice, and of his team which followed an important part of the laser scanning digital survey (see below).

Unlike the first campaign, the second campaign, contracted to the Società Cooperativa P.ET.R.A, was carried out between the middle of August and 19th September 2015, an absolutely inauspicious season for the excavation of a wooden hull. Indeed, while the Autumn excavation had been carried out during foggy days and with a very wet climate, without sun rays (thus allowing the exposition

Fig. 2.3. Preliminary phase of the first excavation of the barge (photo: C. Beltrame).

Fig. 2.4. Preliminary phase of the first excavation of the barge (photo: C. Beltrame).

Fig. 2.5. Final phase of the first excavation of the barge (photo: L. Zamboni).

Fig. 2.6. Tensile structure covering the excavation and use of walkways (photo: C. Beltrame).

Fig. 2.7. Preliminary phase of the second excavation of the barge (photo: E. Costa).

Fig. 2.8. Final phase of the second excavation of the barge (photo: E. Costa).

of the wreck without the wood drying out), the summer excavation, under the sun, made it very difficult to keep the wood moist despite attempts of watering with techniques used on gardens (Figs. 2.7, 2.8).

Not even the presence of a tensile structure was sufficient and the wood, despite it being protected from the sun rays, quickly got wet with obvious serious consequences for its conservation. This situation created a conflict between myself, who asked for the immediate covering of the hull after its documentation, and the scientific director, who postponed the covering to allow the continuation of the public visits of the site which had already started during the previous weeks.

After formally dissociating myself from the consequences which the wood was suffering, the Superintendent, Luigi Malnati, was convinced to resolve the dispute by ordering the immediate covering of the wreck.

After it was covered with geotextile and sandbags, the shipwreck was left *in situ* waiting for idoneous conditions for its recovery.

THE SITEWRECK

Carlo Beltrame

3. CHRONOLOGY, FORMATION OF THE DEPOSIT AND HISTORICAL AND ARCHAEOLOGICAL CONTEXT

The available information for the dating of the hull and of its construction are of different nature and come both from finds and from radiocarbon dating.

The excavation has revealed the presence of small copper coins directly in contact with the inner side of the external planking (into layer US 619, see further) (Fig. 3.1). According to Tommaso Lucchelli (pers. comm. 2016), professor of numismatic at the University of Ca' Foscari, although they are not legible, they can be dated to the 4th-5th century AD from their dimensions. The excavation has also brought to light fragments of amphoras, mainly of the Keay LII type (Pacetti, 1998) (Fig. 3.2), and *terra sigillata africana*, within the light blue lime-clay layer (US 619) covering and in direct contact with the hull. This type of amphora can be dated to the second half of the 5th century AD (Cesarano and Corti, 2017, 362).

A radiocarbon dating made on a piece of rope from the sewing of the hull, which was sampled in 2008 during the barge's accidental discovery (Balista and Berti, 2016-2017, 127), gave the following result: 1625 ± 45 BPor 332-545 cal AD.

Geomorphological studies in the zone of Santa Maria in Padovetere, carried out by Paolo Mozzi (University of Padova) with archaeologists Alessandro Alessio Rucco and Claudio Negrelli from the Ca' Foscari University of Venice (Rucco, 2015, 23; Rucco, Mozzi and Ninello, 2015, 95-104) (see below), have proved that between the first quarter of the 5th and the last quarter of the 6th centuries AD the *Padus* river flooded leaving a 2 m-thick deposit. This dating is further limited to the beginning of the 5th century AD by the absence of archaeological finds predating this period in the area covered by the flooding (Grandi, 2015, 8-9; Rucco, 2015, 23). This geological event has been confirmed by the excavation where the flood layer has been identified and dated through the finds we have just mentioned and through the same barge.

Here, the northern bank of an ancient river, has been identified. It is one of the many rivers that disappeared in the Middle Ages in the Po Delta area; the land reclamation of the 20th century (Balista, Bonfatti and Calzolari, 2007, 19) also contributed to the total transformation of the area from the Roman period to the present.

The hull, as mentioned above, was covered by a lime clay layer (US 619) (Fig. 3.3) containing the above quoted pottery and coins. This layer, in turn, was covered by the sandy layer US 614 which lay on top of the first logboat (Fig. 3.4). This logboat, containing fragments of an amphora of the Keay LVII type, and dated by radiocarbon to between the 380 and the 580 AD, had to be lost between the 5th and the 6th century AD (Cesarano and Corti, 2017, 354). It had an almost flat bottom and almost round sides; one extremity was not excavated while the other appeared truncated (Fig. 3.5).

The sandy layer covering this dugout, with fragments of amphoras, was a second flood event (US 613) which probably sank the small watercraft in this place, almost over the barge. This layer, in turn, was covered by other sandy clay layers, containing fragments of amphoras, which testify other flood events (US 612, US 611) which, between the 6th and the 7th century AD, contributed to the movement of the bank of the river toward the south, perhaps also reducing the width of the riverbed (Cesarano and Corti, 2017, 362) (Fig. 3.3). One of these events also brought into the site a second dugout which was not excavated and was simply seen in a side section of the excavation. This logboat was dated by radiocarbon to between 410 and 620 AD (Cesarano and Corti, 2017, 354).

The upper layers testify phases of reclamation, dated by pottery and by a wide layer of fragments of reused bricks and tiles of the Roman period to the 8th century AD (Cesarano and Corti, 2017, 352-354). These activities of reclamation were made, perhaps, also burning the vegetation of the bank.

Between 1956 and 1962, Nereo Alfieri excavated the remains of the abovementioned chapel, tentatively identified as Santa Maria in Padovetere, located over a small mound a few metres north of the boat (Alfieri, 1966; Grandi, 2015, 3; Rucco, 2015, 20) (Fig. 3.6). The church was founded in 520/521 AD by the Bishop of Ravenna (Holger-Egger, 1878, 315). Other finds brought to light above the flood deposit, during Alfieri's excavation, are dated to the 5th century (Grandi, 2015, 4). The same archaeologist, East of the church, excavated also two cemeteries dating their use from, at least, the 5th century AD, although finds recovered in the area, among which there were coins, suggest a secular occupation of the site from the half of the 5th to the 7th century (Corti, 2007; Grandi, 2015, 3-6).

All these markers suggest us to date the moment of the end of the barge's life before the second half of the 5th century AD and the hull's construction some years earlier. As we will see, on the barge's bottom-planking, there is a repair which means that the hull was not new, although we have no other elements to say if it was very old.

In the Roman period, before the climatic changes of the Early Medieval period that affected the region of the Po Delta, this littoral area was crossed both by navigable rivers in an east-west direction, which connected the Adriatic Sea and those Roman cities that didn't face the sea, and by canals, such as the *Fossa Augusta*, connecting the rivers. The canals permitted the movement of watercraft between cities on inland routes, parallel to the maritime route (Uggeri, 1990, 179-182) (Fig. 3.7). Erodiano (VIII, 7, 1) describes a route which connected Aquileia and Ravenna through marshes and shallows in the 2nd or 3rd century AD. The shallows, produced by the Eridano river, which was perhaps the Po, emptied into the sea through seven outlets called the Seven Seas. A similar description was made in the 6th century AD by Procopius in the *Bellum Gothicum* (1, 1, 19-22) where he mentions the use of the high tides to sail with cargo boats from Ravenna to Aquileia.

Considering the particular morphology of the western Adriatic coast with sandy beaches, which were not suitable for the construction of harbours and anchorages, and which were very dangerous because of the shallows facing the rivers' entrances, this alternative 'coastal' route must have been a strategic solution, especially in the winter season.

The river where the barge was found is identified as the ancient *Padus* (Padovetere), a navigable river probably connecting the harbour of *Vaetranus*, north of Ravenna, with the Late Roman city of *Voghenza* (close to Ferrara). A tributary of the river, located a few kilometres south of the site, perhaps also connected the sea and the city of *Forum Cornelii*, the Roman *Imola* (Calzolari, 2007, 162-163). About 1 km from the site of the wreck, the aforementioned *Fossa Augusta* connected the *Padus* with Ravenna and was perhaps still in use in the Late Roman period (Calzolari, 2007, 159).

South-east of the church of Santa Maria in Padovetere, a canal has been identified that is orientated in a north-easterly direction and connects the *Padus* and Santa Maria in Padovetere with the lagoon harbour at Comacchio. The canal, known as *Motta della Girata* (*motta* meaning 'motte' or 'small mound' and *girata* meaning 'curve'), was perhaps constructed in the 7th century AD (Rucco *et al.*, 2015, 103). The harbour of Comacchio was identified by Sauro Gelichi, in the neighbourhood of Villaggio San Francesco,

Fig. 3.1. Small copper coin over the hull (US 619) (photo: E. Costa).

Fig. 3.2. Fragment of amphora Keay LII type from the excavation (photo: C. Beltrame).

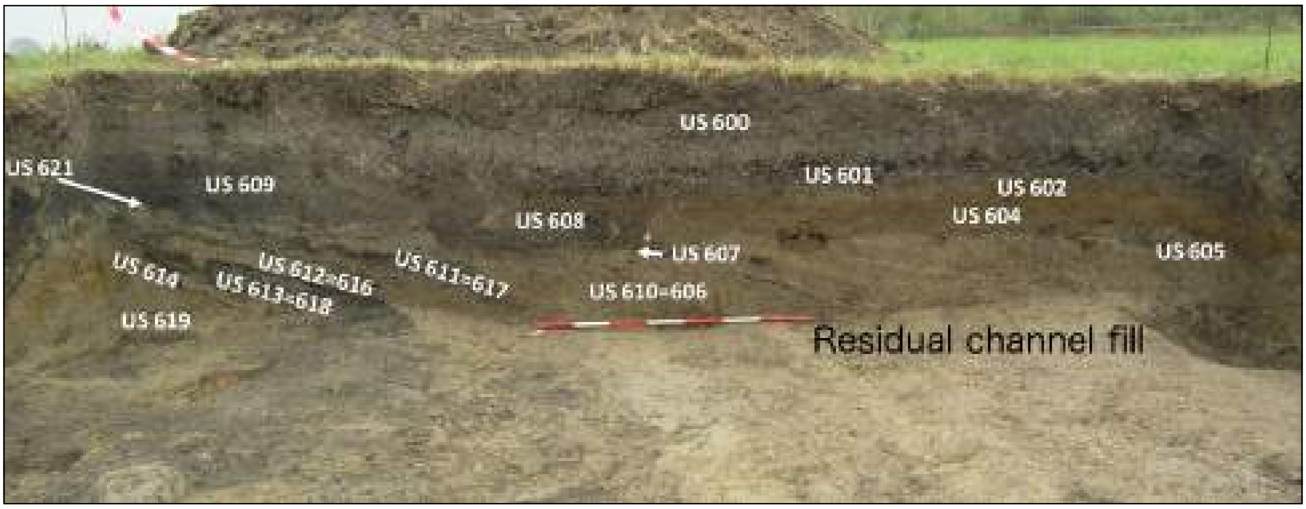


Fig. 3.3. North-south oriented eastern section of the excavation (photo: C. Beltrame).

and was dated between the 7th and the 8th century AD (Gelichi *et al.,* 2021).

Both the historical reconstruction of the coastal area in the Roman period and the recent geoarchaeological investigations of the *Motta della Girata* canal suggest that the barge laid close to a strategic junction of waterways leading in several different directions, although the chronologies of the waterways have still not been defined. Although it seems that the *Motta della Girata* was not yet present when

Fig. 3.4. The logboat over the barge (photo: C. Beltrame).

Fig. 3.5. The logboat over the barge (photo: C. Beltrame).

Fig. 3.6. Chapel of Santa Maria in Padovetere (photo: A.A. Rucco).

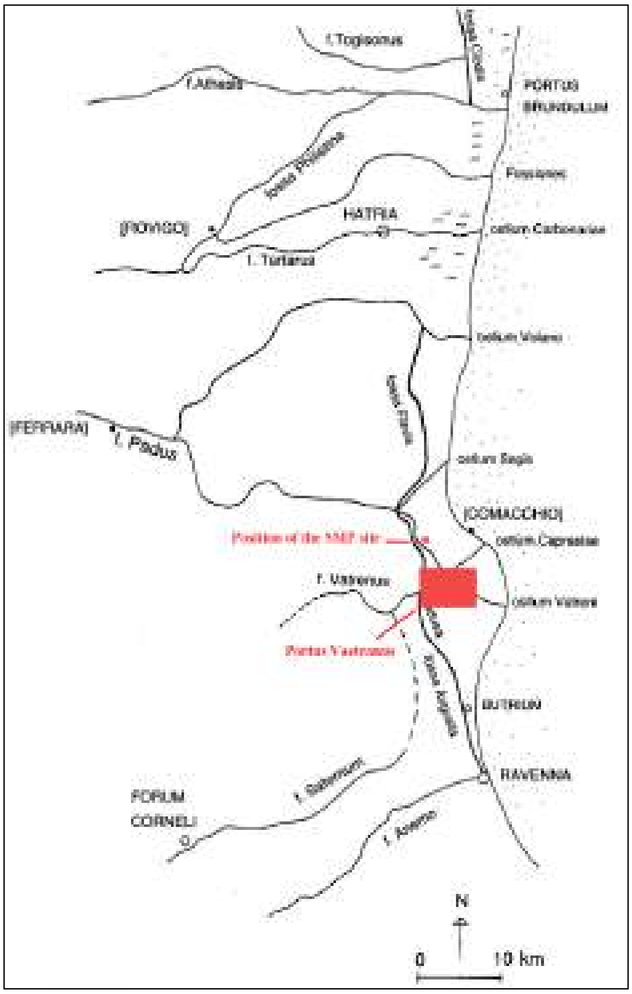


Fig. 3.7. Roman-period harbours, rivers and canals along the coast close to Comacchio (Calzolari, 2007, fig. 1).

the barge sank, the place of the discovery of this hull was probably a place of rest. Perhaps a small riverine harbour? Indeed, it is important to note that over the barge, a second later major flood also buried two wooden logboats, made of *Quercus robur*, which have been found at a higher level in the stratigraphy. Was it a chance occurence? Or are we led to think that in this place there is a concentration of barges and logboats which were moored on a, yet to be found, bank? In this case we would be able to explain the end of the life of the barge (and of the logboats) with a flood which sank the watercrafts in the 'harbour' as also happened, more or less, at the site of Pisa San Rossore (Camilli, 2004). In Pisa San Rossore, there was not only a single flood, but various violent floods, in different periods, which sank the watercrafts and buried the wood in a very small area. We might postulate that, as in Pisa San Rossore, also at Santa Maria in Padovetere two floods covered the barge and the logboats and that, as in Pisa San Rossore, here the riverbank that was used to moor the watercrafts was not monumental and that it either has been lost or it is in a yet to be excavated section of the area.

In the Roman period, this landscape around Santa Maria in Padovetere was characterised by forests interspersed with sparse occupation located along the *Padus* and the *Fossa Augusta* (Balista *et al.*, 2007, 27). The economy of the region comprised agriculture and animal breeding, and the production of building materials (Calzolari, 2007, 172). In the Early Medieval period, after the transformation of the landscape caused by coastal progradation from the coast into a lagoon, or perhaps earlier, saltworks and fisheries became components of the local economy (Grandi, 2015, 19-20; Rucco, 2015, 16-20).

Claudio Negrelli

4. After the shipwreck: artefacts and pottery between 5th and 6th century AD

4.1 *Introduction*

This section deals with the circulation of ceramic artefacts in relation to the shipwreck of Santa Maria in Padovetere. However, as the barge itself has not yielded any directly related items, nor are there any sequences of earlier materials, we are forced to address this topic by talking about the 'after'. The 'after' is represented, firstly, by some objects deposited in the alluvial layers within the Padovetere canal in which the shipwreck was found, placed above it, and secondly, by the settlement sequence (the settlement of Santa Maria in Padovetere) that developed, in strict consequentiality, on the bank of the riverbed, once it had grown and stabilised after the alluvial events mentioned above (Fig. 4.1). As for the first point, it should be pointed out that these materials are currently being studied by other scholars (Cesarano and Corti, 2017), while for the second, directly analysed contexts are available.

4.2 *Late Antique and Early Mediaeval materials*

It can be argued that it is precisely the data from the shipwreck sequence (Cesarano and Corti, 2017, 362-364) that are among the oldest recorded data at the Santa Maria in Padovetere site. The stratigraphies immediately after the barge's burial return an African red slip patera attributed to Hayes 61B, type 3, a late variant, and Keay LII amphorae

Fig. 4.1. Topographical overview of the Padovetere area in relation to the church and settlements of Santa Maria, between the 5th and 6th centuries (taken with modifications from Balista, Bonfatti and Calzolari, 2007, Tab. 3 and 4).

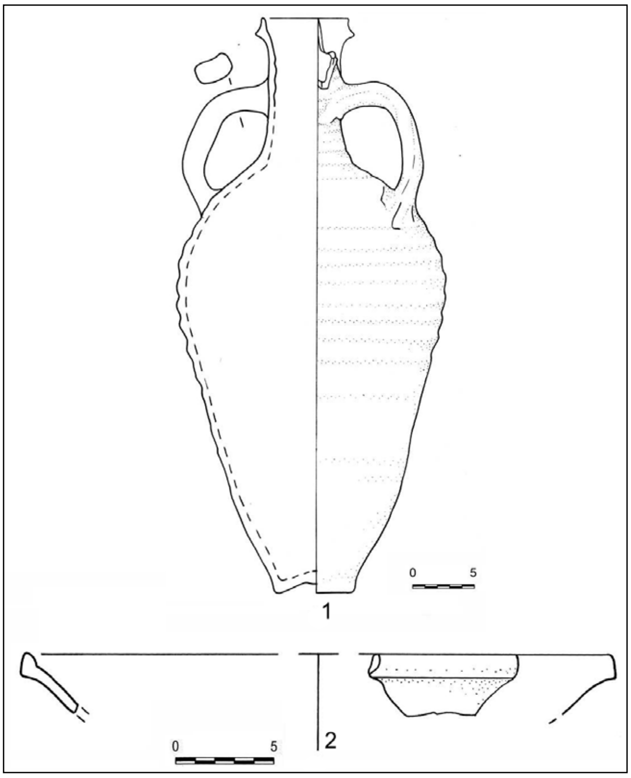


Fig. 4.2. Keay LII amphora (1) and ARS H61B type 3 (2), from the 2014-2015 excavation of Santa Maria in Padovetere (Cesarano and Corti, 2017, Fig. 7.3 and Fig. 10.1).

from deposits in direct contact with the hull (Fig. 4.2). According to these attributions, the context of reference seems to be approximately ascribable to the late 5th century (Cesarano and Corti, 2017, 362-364). While plausible, this framing is at the very least uncertain. Indeed, it seems to me that the African red slip patera is not fully ascribable to the late variant (Cesarano and Corti, 2017, 362) of the H 61B3 form, but rather generically to the more general B3 family, cautiously ascribable to the mid-5th century. The wall of the piece, according to the drawing proposed in Cesarano and Corti, 2017, fig. 7.3, is not very sloped, as would be required for the late variant of HB3 (according to the typological identification of Bonifay, 2004, 170). For this reason, we prefer a more cautious classification in the generic HB3, in which category the shape of the lip would also fall.

Even the Keay LII amphorae, known productions from the Calabrian-Peloritanian area (Straits of Messina), cannot be dated *per se* to the second half or the end of the 5th century, appearing here in morphological variants attested, in truth, throughout the whole 5th century. On the contrary, comparison with Roman sequences would lead one to believe that these pieces still belong to the middle of the 5th century, with a certain tendency towards neck shortening only occurring later on (Pacetti, 1998, 197). It is interesting to note that the materials recovered from the old excavations in the area of the church apparently did not yield large quantities of Keay LII amphorae, and that these specimens are either not typologically recognisable, or refer to later types (e.g. a piece defined as 'related' to Keay LII in Corti, 2007b, 575) than those found above the wreck (Fig. 4.3). A sign that the stratigraphy inherent in the burial of the wreck perhaps seems to indicate a slightly earlier chronology than the settlement that developed on the left bank of the Padovetere (see below).

Referring again to the sequences of the 2014-2015 excavations, the preliminary study mentions some elements from levels connected with a pair of monoxilic dugouts found in even higher positions than the shipwreck (again, within the alluvial filling levels of the Padovetere canal). In particular, these are an African amphora, ~~a~~ some small *spatheia* and an African red slip patera, which can be ascribed to a period between the late 5th and early 7th century (Cesarano and Corti, 2017, 362). These elements, together with another series of oriental imports (including Phocean red slip, LRA series 1-4 and 5/6, as well as supposed 'Thessalonian amphorae': Cesarano and Corti, 2017, 362-367), offer in a nutshell the more general picture that emerged from those same excavation campaigns which, in addition to the stratigraphy of the shipwreck, covered the areas inside the church and its immediate surroundings. Although there is no lack of ceramics that can be placed between the 7th and 8th century, it seems that the peak of the evidence concerns the period between the late 5th and the first half of the 6th century. This, in turn, substantially coincides with the panorama previously proffered in 2007 in relation to the study of materials from the old excavations, which, however, had almost no stratigraphic contextualisation (Fig. 4.4, Corti, 2007a and Corti, 2007b).

Confirmation, above all in the form of new data, has come from the most recent campaigns undertaken by Ca' Foscari University of Venice[1] (Fig. 4.5), which have helped to identify a sequence that can be better defined in relation to structures preceding and contemporary to the church of Santa Maria in Padovetere[2]. Significant amounts of material came to light during the 2021 campaign, within a chronological range from the late 5th to the 8th century.

With regard to the earliest periods (Period 1, in association with traces of wooden buildings) there are pieces that mostly belong to amphoric fragments of the most widespread Late Antique oriental types, such as LRA 1, or LRA 4, as well as a series of ribbed walls of uncertain identification, which could be ascribed to late Cretan productions (see below). However, the presence of the Agora M273 types, precursors of the LRA8 *'sous module'* (Pieri, 2005, 132-137), i.e. the *Samos cistern type*, particularly common in later periods, cannot be excluded. In addition to the Aegean and Eastern Mediterranean material, there are many non-diagnostic African amphora fragments, while, among the coarse wares, at least one rim recalls the *ollae* with a hexagonal lip and rounded rim, with a slight

[1] Campaigns directed by Sauro Gelichi, Medieval Archaeology. Some mention will be made below of the 2021 excavation campaign, which is entirely preliminary (like 2022), in that it is still being studied.

[2] On the church building of Santa Maria *in Padovetere*, which was supposedly built under the episcopate of Aurelian, archbishop of Ravenna in 520-521, there exists extensive literature. See most recently Gelichi, 2021, 646 et seq. with previous bibliography.

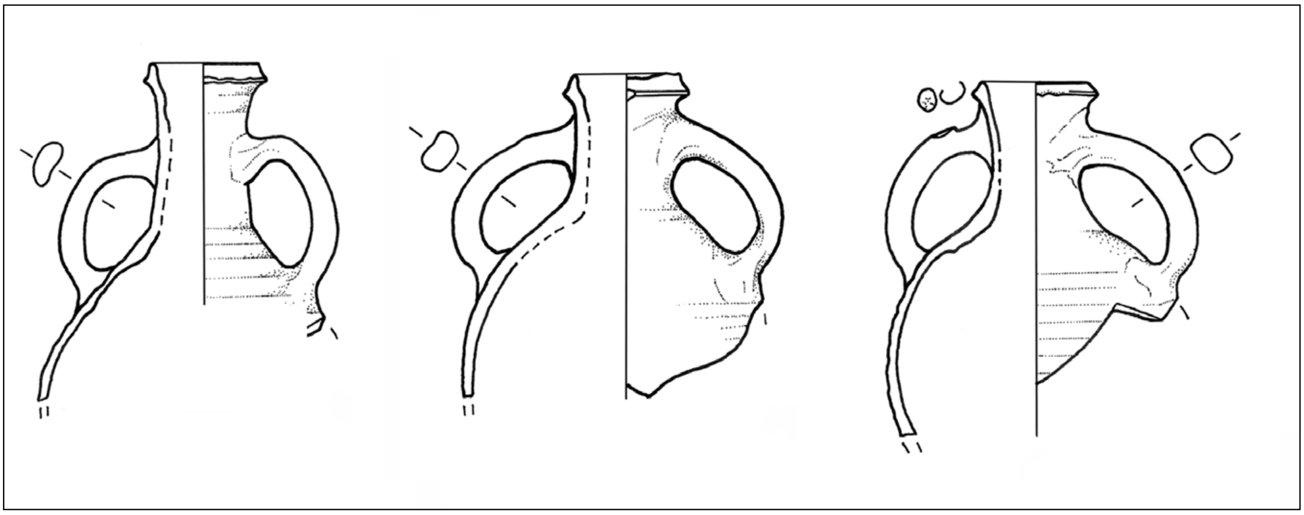


Fig. 4.3. Keay LII amphoras from Santa Maria in Padovetere (Corti, 2018, Fig. 3.2-5).

Fig. 4.4. Amphora from the old excavations at Santa Maria in Padovetere: probable Cretan production (Photo: C. Negrelli).

internal hollow, typical of regional contexts of the Gothic or slightly later period (see, for example, Negrelli, Bracci and Rucco, 2016, 109). These pieces are compatible with a late 5th-early 6th century horizon.

In the initial phase of the later Period 2, pertaining to the plundering of the pile building (and thus containing material dating to its last occupation), the material remains have greatly increased, as is often the case with the distribution of finds in this type of sequence. Among the diagnostic pieces used for preliminary dating[3], there are a few African red slip forms, including an almost whole plate, type H 87 A2, dating from the late 5th to early 6th century (Bonifay, 2004, 173-175)[4]. Phocaean red slip, fairly frequent in the southern Adriatic, but rarer in the northern Adriatic, is attested by a fragment of a patera, Form 3 E/F, rounded on the outside, also datable between the end of the 5th and the first half of the 6th century (Martin, 1998, 116). Late antique glazed ceramics also appear, albeit in modest numbers, predominantly as open forms, most probably flanged bowls (little mortaria) (Gelichi and Maioli, 1992, 250-253, 271; Brogiolo and Gelichi, 1992, 25-26). The rare painted pottery also seems to belong to the 6th century. These are closed vessels, characterised by wide paintings and thickly and regularly ribbed bodies, according to a tradition that may be typical of the central-northern Adriatic (Negrelli, 2015, 140-146).

Among the cooking pots there are already *ollae* similar to the Classe types, datable at least in the 6th century, and to 'Aegean' types, such as the 'Fulford casserole 35' (Cavalazzi and Fabbri, 2010, 625, Fig. 5-3, for comparisons in Ravenna) with a hooked lip, datable between the 5th and 6th centuries. An African common ware mortar, Bonifay type 13 (Bonifay, 2004, 255-258), can be related to the 5th century.

As can be seen from the illustrative graphs of some of the US samples from Period 2 (Graphs 4.1 and 4.2, US 1076 and 1077), most of the ceramic material consists of African and, above all, Oriental amphorae. The formers are documented with mostly non-diagnostic pieces, while the latter represent the overwhelming majority. Among the best known and most recurrent types in Late Antiquity, such as LRA1, 2, 3 and 4, of eastern import from the Aegean, western Anatolia and Syria-Palestine, LRA1, from the southern coast of Anatolia, northern Syria and Cyprus, as well as Rhodes, prevail in a slight majority (Pieri, 2005, 79-85).

However, it is important to emphasise the presence of a particular amphora type, which stands out from the usual picture of eastern imports into the Adriatic (Auriemma and Quiri, 2007). It consists of a series of pieces (Figs. 4.6, 4.8), probably of Cretan origin, characterised by presumably ovoid shapes (more or less expanded), with walls thickly and regularly grooved from the shoulder to the bottom (red clay – orange or light brown, with lightened surfaces at some parts, slightly granular fractured or flat, hard. Fine white lime inclusions, and dark). There are two prevailing types: the first concerns rather narrow cylindrical necks, with wide arched handles with an elliptical or slightly squared cross-section, with externally enlarged and rounded lips; the second concerns flattened and squat truncated necks, also with similar lips to the previous ones, and handles that are

[3] Only US 1076 and 1077 are considered here, to be regarded as two guiding contexts that are emblematic of the entire period sequence.

[4] This shape in D is believed to be contemporary to the C5 group, dating from the second half of the 5th century to the early 6th century.

Fig. 4.5. Location of the excavation of Santa Maria in Padovetere 2021 in relation to the excavations of 2014-2015.

Fig. 4.6. US 1077, fragment of Cretan amphora (Photo: C. Negrelli).

Fig. 4.7. US 1077, fragment of Cretan amphora (Photo: C. Negrelli).

Fig. 4.8. US 1076, fragment of Cretan amphora (Photo: C. Negrelli).

less developed and closer to the shoulder. The bottoms are rarely preserved, but it appears that they must have been simply concave and without a tip, but with a simple umbilication on the outside. In US 1077, these types are well represented by at least seven specimens (NMI), but there could be many more, as this is the most attested amphoric category if the total number of fragments is considered. Typologically, an initial examination indicates that they belong to types TRC1 and TRC 2 (Portale and Romeo, 2001, 302-306)[5] from Gortina, datable between the 5th and 6th century (Fig. 4.9), although the identification proposed here should be regarded as hypothetical, pending the completion of studies.

The end-use and abandonment levels of the pile structure can be placed between the Gothic and very early Byzantine ages, up to the mid-6th century. Identifying a 'batch' of Cretan amphorae in such a context is not a trivial matter. Firstly, because they help to paint a slightly different picture from the usual panorama, consisting of a series of amphorae that are now recurrent and 'canonical' (I refer to the African-produced amphorae and the Oriental products of the LRA 1-7 series). Secondly, because an identity is given, or at least a partial identity, to that fraction of products that

[5] With special reference to Tables XLIII.c-d and XLIV.b, f, g.

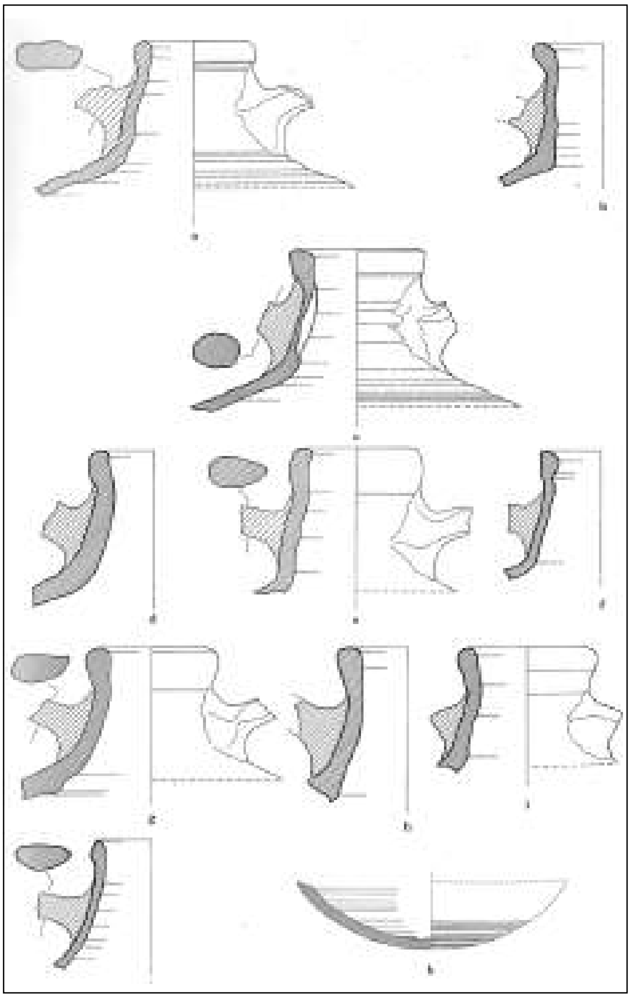


Fig. 4.9. Cretan amphorae of type TRC2, rim variants (Portale and Romeo, 2001, Tab. LII).

generally fall within the "unidentified" category in amphora studies, often the largest percentage of amphorae in Late Antique and Early Medieval excavations.

Another probable Cretan amphora fragment, incidentally, is perhaps morphologically discernible in Corti, 2007b, 575 and fig. 5.6, here identified as an LRA2 (unfortunately, descriptions of the fabric are missing, Fig. 4.4).

4.3 *Notes on circulation and consumption in the Padovetere area between the Gothic and early Byzantine ages.*

The spread of Cretan amphorae in the Adriatic is traditionally noted as sporadic (Auriemma and Quiri, 2007, 45), although there is no lack of evidence throughout the Imperial and later Late Antique periods. For example, in Rimini some pieces appear in the 'domus del Chirurgo', in phases datable to the second half of the 3rd century (Giovagnetti and Negrelli, in press). Even in Ravenna, at urban excavations of residential buildings, various Cretan productions do not seem to represent a negligible element, at least in phases datable to the early imperial age (Tempesta, 2018, 136-139). Further north, it is sufficient to refer to the rich synthesis framework highlighted between Trieste and Aquileia, as well as for Veneto and Apulia, with reference to the Early and Middle Imperial age, up to the 3rd century (Auriemma, Degrassi and Quiri, 2015, 146-147)[6].

Moving on to the Late Antique period proper, it seems important to emphasise the Cretan presence in Butrint (Reynolds, 2010, 96 and fig. 5c): here, a type very similar to the above-described pieces from Santa Maria in Padovetere appears in the stratigraphy of the early 6th century. In Butrint, this would be evidence of a resumption of contacts with Crete, during the 5th and 6th centuries, at least on a par with what was already happening in the Middle Imperial age (Reynolds, 2010, 96 and fig. 5c). If we consider Butrint not only from a southern Adriatic perspective, but also as a stage in a maritime communication system directed towards the northern Adriatic and thus towards Po Valley, it follows that the evidence from the Comacchio area could represent more than just occasional presences. In this regard, the excavations at the episcopal centre of Padua add a comparison to the picture of TRC1 and TRC2 present in the Upper Adriatic, within a chronology spanning the 6th century[7]. A date between the mid-5th and mid-6th century is also confirmed by a well-dated context in Aquileia, "Fondo ex Cossar" (Dobreva and Riccato, 2016, 438, table 2.1-2)[8].

The data deriving from this 'Cretan' presence at Santa Maria in Padovetere therefore completes an extremely varied panorama of imports during the final phase of the 5th century and the first half of the 6th, in which the eastern component now seems to represent the clear majority, as compared to the African product (Fig. 4.10). This is a variety, quantity and specificity of products (not only amphorae) that I do not believe can be restricted to the single category of an 'intermediate site' along the great lagoon communication route that united the Middle Adriatic, particularly Ravenna, with the great cities of Veneto. Yet, traditionally, the site of Santa Maria in Padovetere is included in this category, as it is essentially interpreted as a stopover, albeit an important one, along the *Fossa Augusta* (Corti, 2007a; 2007b, Cesarano and Corti, 2017).

On the contrary, I believe that the topographical situation of Santa Maria in Padovetere, together with its economic structure, precludes adhering entirely to this interpretation. In fact, this area should not be so much explained in relation to the strip represented by the *Fossa Augusta*, which appears to pass significantly further to the west[9] (Fig. 4.1), as much

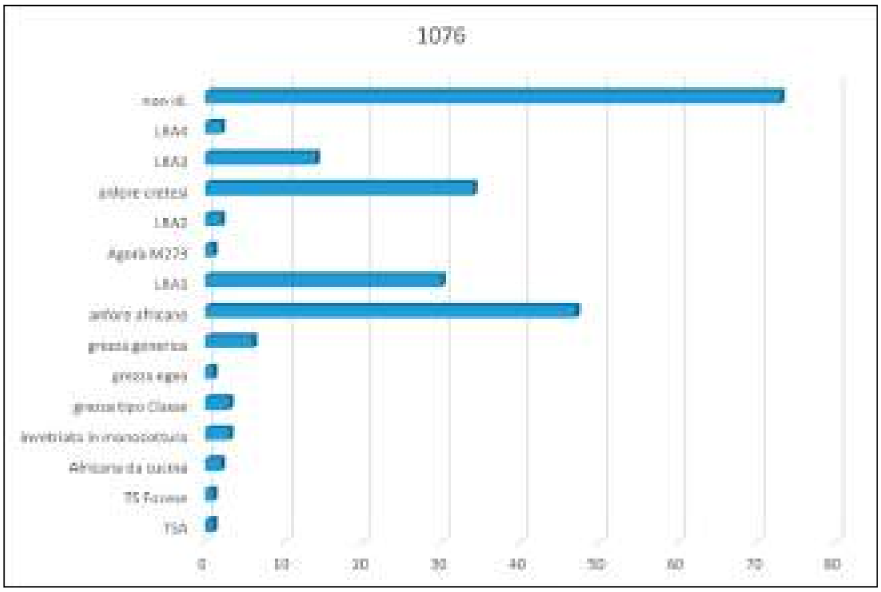
[6] For Altino: Cipolato, 2018, 143.

[7] Ganzarolli, 2017, 200-205, recognizes particularly an amphora (Table V.9 and Figs. 2-3) with parallels to Gortina, of a nonrecurring type, datable to the first half of the 6th century, and another specimen that can be catalogued within TRC1 (Table 5.10 and Fig. 4), datable within the late 6th century.

[8] Amphora type TRC1 within a context dated archaeometrically between the mid-5th and mid-6th centuries.

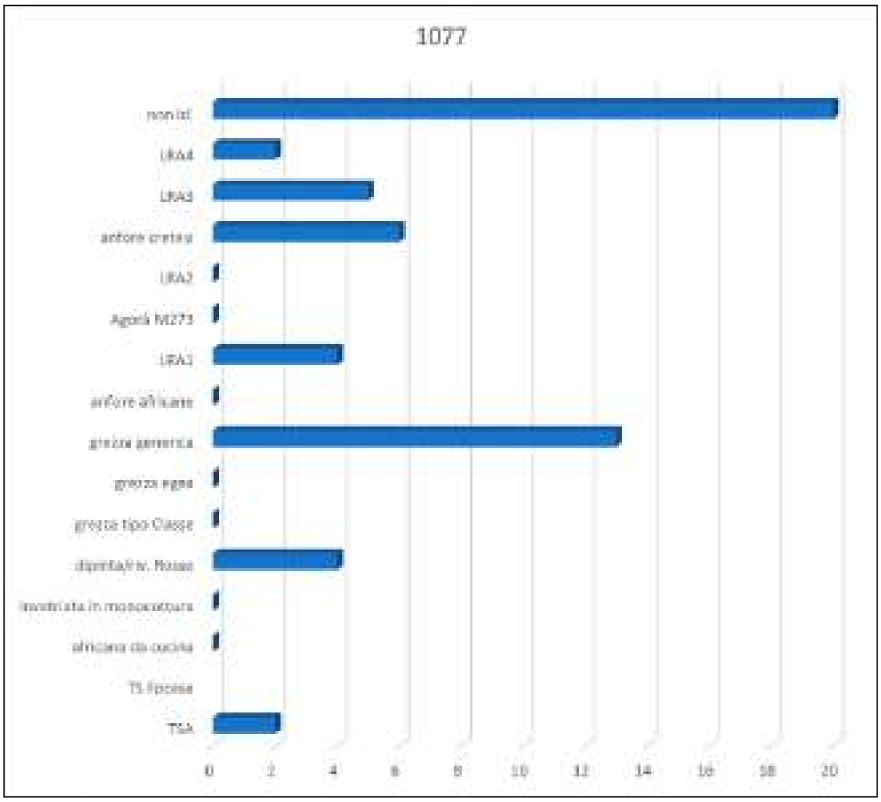
[9] On the lagoon route from Ravenna to Aquileia, supported by the *fossae*, there is an endless literature. See a quick summary of it, from an Upper Adriatic perspective, in Negrelli, 2018. For the route of this road and the Fossa Augusta in the Comacchio territory, the most reliable reconstruction remains that of Balista, Bonfatti and Calzolari, 2007.

Fig. 4.10. Amphoric imports from the Mediterranean evidenced in Comacchio.



Graph 4.1. NTF quantities of ceramic materials in US 1076.

as in relation to Padovetere itself, as recent excavations have irrefutably shown. In essence, this could be a so-called 'port on a river mouth' (in the meaning used by Arnaud, 2016, subject, of course, to appropriate relations with more urban situations), capable of performing a nodal function directly opening up the Adriatic inputs on the one hand and the Po Valley penetration on the other. It is no accident that materials very similar to the Cretan ones mentioned above also appear along the same river route inland (Rossetti, 2020, 125, n. 29, tav. 4.1: amphora identified as 'globular' rather shows morphological and fabric characteristics that are much more similar to late Cretan products), within a



Graph 4.2. NTF quantities of ceramic materials in US 1077.

context referable to a small Late Antique-medieval river port (Bucci, 2020) located in the "Verginese" territory (Basso Ferrarese region, near Voghenza).

If such an arrangement were proven, the 'Ravenna bias', as it might be defined, would also be dispelled, i.e. the tendency in Late Antique and Early Medieval local studies to always attribute to the nearby capital the function of a governing place in relation to this territory. Instead, the development of the site of Santa Maria in Padovetere as a port may have taken place in relative economic and logistical autonomy with respect to Ravenna and its ports of call, even assuming that the *Fossa Augusta* continued to function in some way during the Gothic age and beyond[10].

4.4 *Conclusions*

In strictly economic terms of the history of the diffusion of Mediterranean products (Fig. 4.10), the case of Santa Maria in Padovetere seems to reflect rather sudden rhythms of change, at least judging by certain 'emblematic' categories of ceramic materials.

The mid-5th century is well represented by the Keay LII immediately following the shipwreck. They denote a precise connection with the area of the Straits of Messina, in addition to the more usual presence of African and Oriental products. At the same time, or immediately after these depositions, towards the late 5th century, up to the beginning of the 6th century (probably in the Gothic period), the settlement of Santa Maria in Padovetere seems to take hold suddenly and intensively at the same time, in the sense that the sequence does not contain a specific precedent[11]. This substantially 'new' site immediately qualifies as a place of exchange and sorting of African and eastern goods – to a much lesser extent of regional/Padanian or southern Italic products – among which the presence of a 'batch' of Cretan amphorae stands out, in addition to the more usual types. Variety, specificity and quantity of the product (cargoes seem to arrive here in some ''primary" way, little affected by intermediate sorting) would seem to delineate the characteristics of a port, not simply a fluvial one, but more or less directly accessible also from the Adriatic and tending to be autonomous with respect to the logic of the lagoon route from Ravenna to the Venetian regions. In essence, there would be a shift from a fluvial horizon (represented by the shipwreck and not characterised by a settlement on site), to a more decidedly maritime horizon, represented by a demesne pole characterised in the port sense.

During the 6th century, things changed further, both in terms of the type of settlement (foundation of the church of Santa Maria in Padovetere), and in the circulation of products, until, in the 7th century, it was the development of Comacchio that dictated a profound change in the organisation of this area: but that is another story[12].

[10] Gelichi, 2021, for an updated summary on the late antique territorial arrangements of these territories.

[11] The materials cited in the area for the 4th century (Corti, 2007a, 535) do not seem indicative of an already established and stable settlement. It should be added, moreover, that they present some elements of doubt with regard to possible residuality.

[12] For a summary of the events of the entire sector in its early medieval outcomes, see again Gelichi, 2021. For the circulation of ceramic artifacts in Comacchio, Negrelli, 2021.

Elisa Costa

5. THE SURVEY METHODOLOGY

A precise and accurate survey methodology has been employed to replace the real object and it has proved to be necessary to obtain metric information and visualisation of the shipwreck and to investigate it during and after the excavation. In nautical archaeology, due to the perishable nature of the wood once it is removed from its original environment, a precise and fast technique is very important; this branch of archaeology also requires specialised skills, motivated by the peculiar characteristics of the hull that can only be correctly interpreted by a naval archaeologist or an expert on the topic (Carandini, 2001, 12-14; Bianchini, 2008, 13; Beltrame, 2017, 159-174).

The digital and three-dimensional models can be considered the best and the closest representation to the reality of the documented object, allowing a data archive to be obtained without loss of details and information and without personal interpretation that might occur with a direct survey by the illustrator.

Regarding the Santa Maria in Padovetere barge, the decision by the Superintendency not to recover, restore and host it a museum was an important factor in the choice of the survey methodology and three-dimensional digital documentation; once the excavation was completed it would no longer be possible to carry out a direct study on the hull.

The digital techniques employed, such as photogrammetric and laser scanning or topographic surveying, allow fast documentation and complete acquisition of data, providing a quantity of data at high resolution useful for various analyses and measurements, even after the reburial of the hull under a protective layer of sand (Lemée, 2006, 82; Kocabas, 2012).

5.1 *The topographic survey*

During the excavation campaigns, a topographic survey was used as a best practice for the creation of a local reference system (Guyon, 2010, 26). The topographic network was created with the total station consisting of seven station points, connected to the zero-reference point of the site. Then, the local reference system was roto-translated to a global reference system with a differential GPS which conferred global coordinates to targets and points on the excavation. Some benchmarks are closely connected to the excavation area corresponding to the riverbank where the boat was found; from these stations, the various excavation phases, the stratigraphic units, and the findings were documented. Furthermore, the whole station was employed for the survey of the photogrammetric and laser scanning targets. From one of the stations, the survey of the detail points of the barge was carried out, using a well-known technique previously used in archaeology until the advent of the most modern digital techniques (Bruseth *et al.,* 2006, Lemée, 2006, 82-102). Through a series of measurements of the hull size, seam holes, frames, and planking boards, it was possible to document the entire craft. Each wooden element was detected with a series of points at regular intervals between 5 cm and 10 cm depending on the characteristics of the construction element and the details on the surveyed part of the hull (Fig. 5.1). In the survey of the planking, the points were acquired by following the holes of the sewing given that the edge of the boards is hidden by the presence of the caulking rolls. In this way, by measuring the holes, the simultaneous description of the various construction elements of the hull was carried out: the seam channels, the wooden pegs, the caulking rolls, and the planking.

The documentation obtained is metrically correct, with millimetric accuracy in relation to the topographic network and the accuracy of the instrument. On the other hand, this technique remains conditioned by the interpretation of the detector and only represents the object by lines and points and not 'continuously' as with the new available digital techniques (Fig. 5.2). It could be considered a basis of comparison for the metric and geometric control of the three-dimensional model obtained through the photogrammetric survey.

5.2 *The photogrammetric survey*

The technique mainly used for the survey of the boat was multi-image photogrammetry, a fast and accurate technique that allows maximum precision without touching and stressing the boat any further. The aerobic environment in which the boat is located after excavation jeopardises the solidity of the wood, requiring immediate documentation so as not to lose construction details of the hull. In recent years this technique has been widely used in almost all archaeological excavations, due to its ease of use and versatility in different and complicated areas and thanks to its cost-effectiveness.

In the complex subject of a wooden hull, characterised by multiple elements and small details, the choice of three-dimensional documentation is clearly advantageous. The photogrammetric technique produces a metrically correct three-dimensional model, and, at the same time, it is faithful in photographic rendering and texturing, removing

Fig. 5.1. The survey of the detail points of the Santa Maria in Padovetere boat (photo: C. Beltrame).

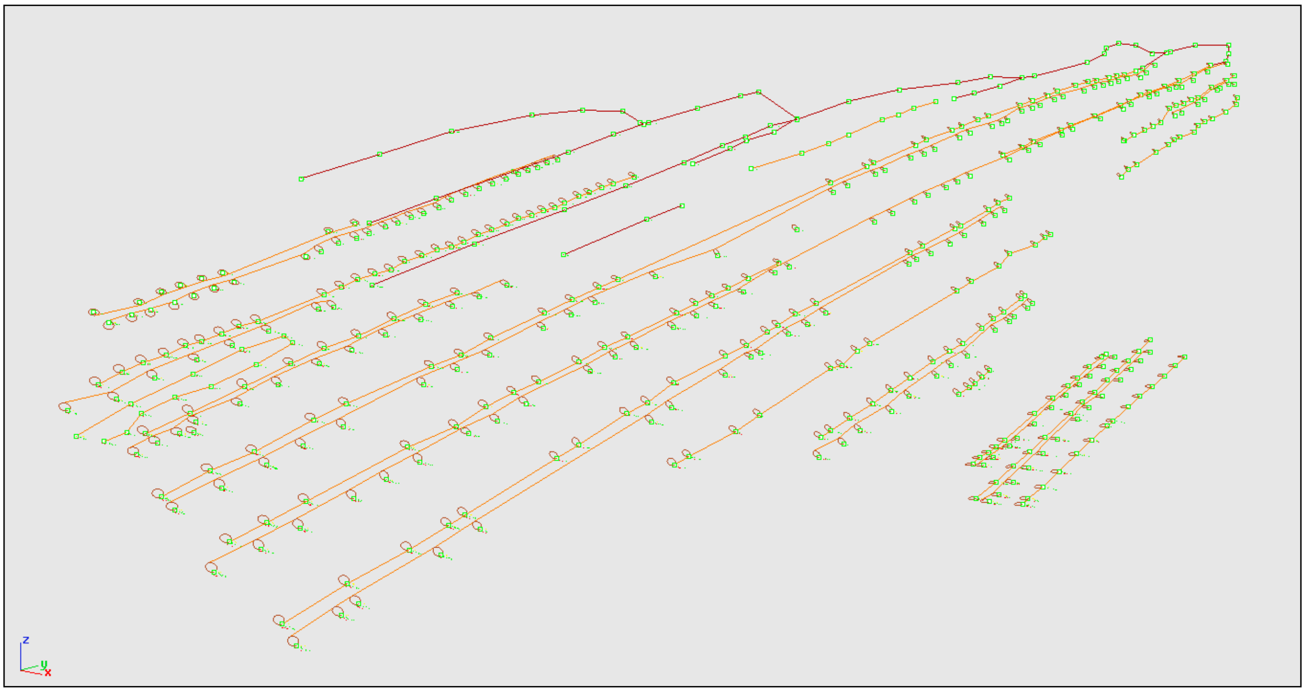


Fig. 5.2. Partial result of the detailed survey carried out with the total station (elaboration: E. Costa).

any kind of physical contact with the boat and problems related to timing (Crumlin-Pedersen and Olsen, 2002, 51; Marlier, ed., 2014, 56).

The surveys were carried out regularly during the excavation, through various photogrammetric surveys during the archaeological campaigns and daily photographic documentation in order to document both the excavation phases and the vessel. Some of the main problems encountered during the survey were related to the low quantity and quality of light present in the site and the type of material that does not have substantial chromatic differences between the different construction elements, sometimes making it difficult to recognize them in an image. In the shooting phase, great attention must be paid to light, white balance, and exposure, especially when you are in wet wood contexts where the subject can be very dark (Dostal, 2017, 163).

To carry out the survey, the usual photogrammetric practices were followed: the overlap of 60% between the images, the longitudinal and transversal parallel strips to the hull with an overlap of 20%, and the maintenance of the same distance from the subject, are only some of the aspects that must be followed for an accurate result of the photogrammetric model[1]. The result was satisfactory as regards both

[1] For photogrammetric theory see Fangi, 1997; Guidi, Russo and Beraldin, 2010; De Luca, 2011; Cannarozzo, Cucchiarini and Meschieri, 2012.

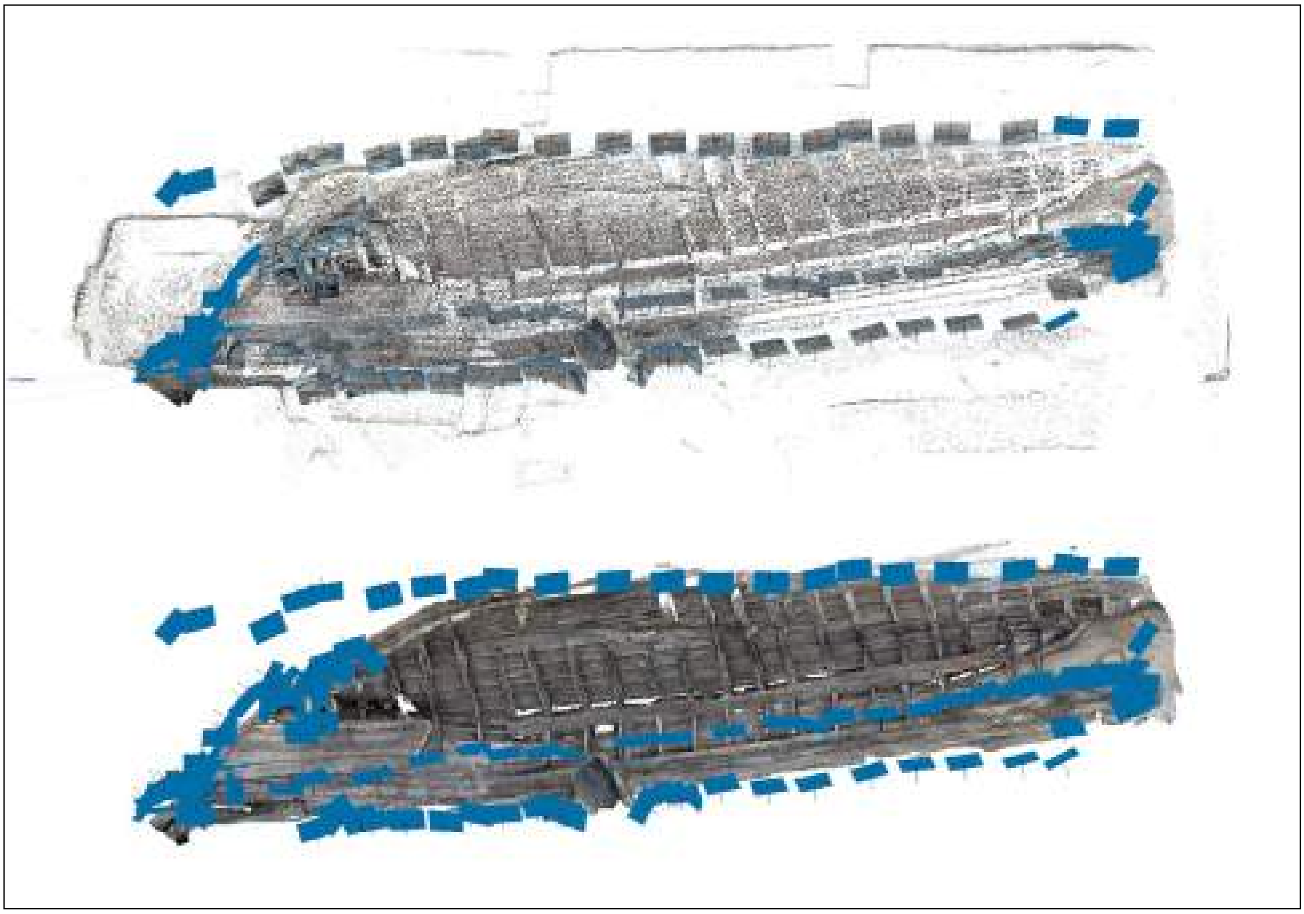


Fig. 5.3. Dense point cloud and camera position; photogrammetric survey September 2015 (elaboration: E. Costa).

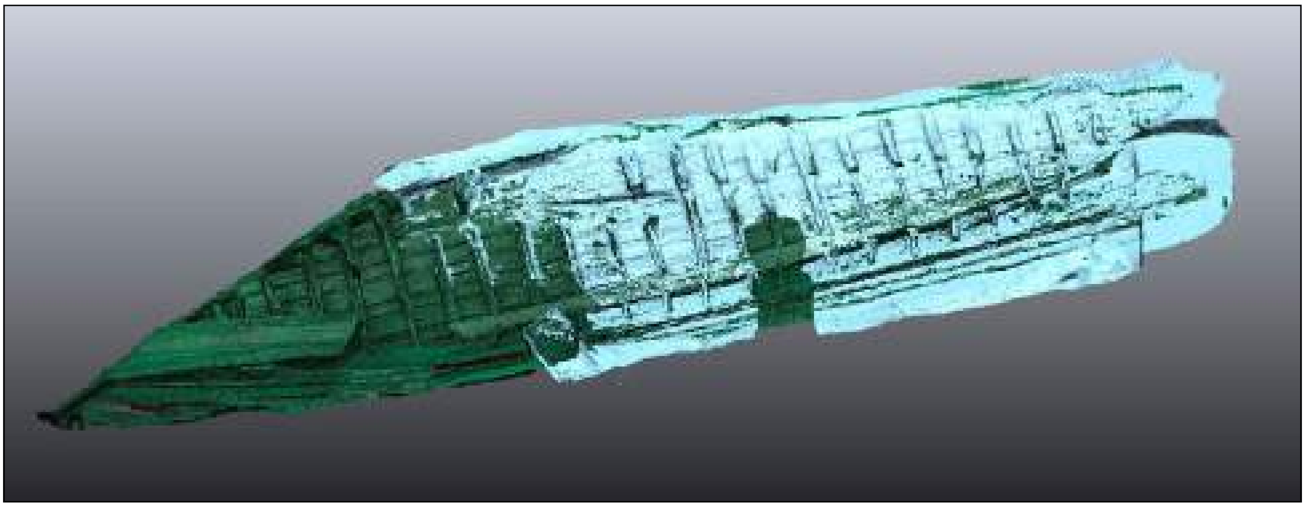


Fig. 5.4. Comparison of the point clouds from the two photogrammetric surveys: 2014 in light blue and 2015 in green (elaboration: E. Costa).

field operations, data processing on the computer, and the final model acquired. Portability on laptops is one of the main peculiarities of today's photogrammetric software, as it allows you immediate control of the acquisition and data processing phase in the field, allowing you to correct and integrate the images or methods of the survey.

An important factor in the photogrammetric survey is the identification of the distance from which the photos have to be taken in order to produce a model at a given nominal scale, which is the correct scale to print a drawing or an orthophoto. The principle of the nominal scale is linked to the concept of graphic error, which is conventionally assumed to be equal to 0.2 mm (the smallest thickness of the tip of the drawing inks) multiplied by the scale factor. For example, the typical archaeological scale for a hull is the 1:10 scale; multiplying 0.2×10 mm gives a result equal to 2 mm, determining that in a drawing on a scale of 1:10, everything that is smaller than 2 mm is not represented.

It is possible to obtain accurate documentation with digital techniques if the employed tools have high instrumental accuracy; the quality of the professional cameras combined with the reduced shooting distance from the subject, and the minimal errors of the network obtained with the total station, allow us to achieve high precision of the digital model.

In the photogrammetric process of the *Agisoft Metashape* software, the value of the pixel equivalent to the graphic error of our scale is inserted in the extraction phase of the orthophoto of the model, which is thus scaled correctly, allowing us to measure the objects represented in the image.

For the final photogrammetric survey of the first excavation campaign in 2014, the boat was thoroughly washed and cleaned of sand and clay residues. The first strips of images were taken following an orthogonal camera position with respect to the subject along the complete length of the boats, the same strips have been realised keeping the camera in an oblique position in order to be able to represent the vertical details of the hull, and some of the images were taken from a greater distance according to a radial pattern around the excavation.

The second excavation campaign in 2015 took place in the summer period when the natural light was not optimal for photographic documentation since the sunlight created areas of full light in contrast with shadow areas in the parts of the excavation under the roof.

The first photogrammetric survey in 2015 took place as soon as the excavation of the boat was completed, even though the last plank of the side was at the deepest level of the excavation, submerged by the water of the exceptionally high aquifer and the suboptimal natural light conditions. However, it was essential to document the hull at the end of the day and at the end of the work to obtain the virtual model of the clean barge. For this survey, the first strips of the images were taken following the same rules and orientation employed in 2014 and most of the images were realised at a close range and focusing more on the stern area excavated in this second excavation mission.

The second survey was carried out on the whole hull at a homogeneous distance of about 2-3 m, following nadiral and radial streaks around the hull and with some strips with close-up images depicting the details of the boat and the stern area (Fig. 5.3). The survey was carried out on an overcast day, allowing for optimal light conditions throughout the hull. To obtain the final model, the point clouds of the two reliefs were merged into the same reference system; for the texturing phase, only the images with optimal light were used.

The 2015 survey was integrated with the 2014 survey through a series of details of the boat and topographical targets. The insertion of the two photogrammetric models in the same reference system was obtained with a precision of around 1 mm, since the details of the hull, of which we had acquired the coordinates from the photogrammetric survey of 2014, were clearly visible in both models (Fig. 5.4). Once the complete final model was obtained in the correct reference system of the site, the orthophotos relating to the plan and the longitudinal perspective drawing of the boat (Fig. 5.5) and the transversal perspective drawings of every frame (Fig. 5.6) were extrapolated, maintaining the actual inclination of the hull as it was found during the excavation. On the basis of the orthophotos and the 3D model, the plan with the boat in the excavation position, inclined on the right side, and the sections made on the frames were vectorized (Fig. 5.7).

5.3 *Laser scanning survey*

During the excavation campaigns, the laser scanning survey was carried out with Faro Focus 3D, which allows the documentation of the boat and the whole archaeological site at 360°, in an automatic and fast manner (Fig. 5.8). The survey has been realised with the Photogrammetry Lab of IUAV University of Venice by Paolo Vernier and Francesco Guerra.

The Faro checkerboard targets were positioned on still concrete pillars inside the site and on small mobile platforms around the barge so as not to damage it; these are used as GCPs (Ground Control Points) with known coordinates from the topographic survey in order to orient each single scan in a reference system and align them with each other.

In 2014, 11 scans were carried out from a raised position around the wreck, inside the archaeological site and one directly on the ground section from the exact centre of the hull. The survey of the entire archaeological site is a complete point cloud of about 526 million points (Fig. 5.9).

In 2015, a total of 12 scans were made, 6 of which from the highest area around the archaeological site and 6 inside, near the hull; the orientation of the 2015 point cloud in the same reference system of the previous year has been possible with the georeferenced target on the pillars.

In 2015, the laser scanning survey was carried out two days after the photogrammetric survey, as the laser scanner was not present on site every day; in those days, a side of the site collapsed due to heavy rain, damaging some wooden elements of the hull. By comparing the point clouds from the two different survey techniques, the fracture points and the deformations that occurred are evident, confirming how a daily and accurate documentation is necessary in order not to lose important metric information (see further).

5.4 *Comparing point clouds*

A final phase of the processing of the acquired data consists in the analysis of the surveys by comparing the point clouds obtained with the different techniques to evaluate their accuracy, to determine which is the best technique to use in different contexts, and to determine which result must be employed for the reconstruction of the virtual model. The

Fig. 5.5. Orthophotos relating to the plan and longitudinal perspective drawing of the boat from the photogrammetric survey (elaboration: E. Costa).

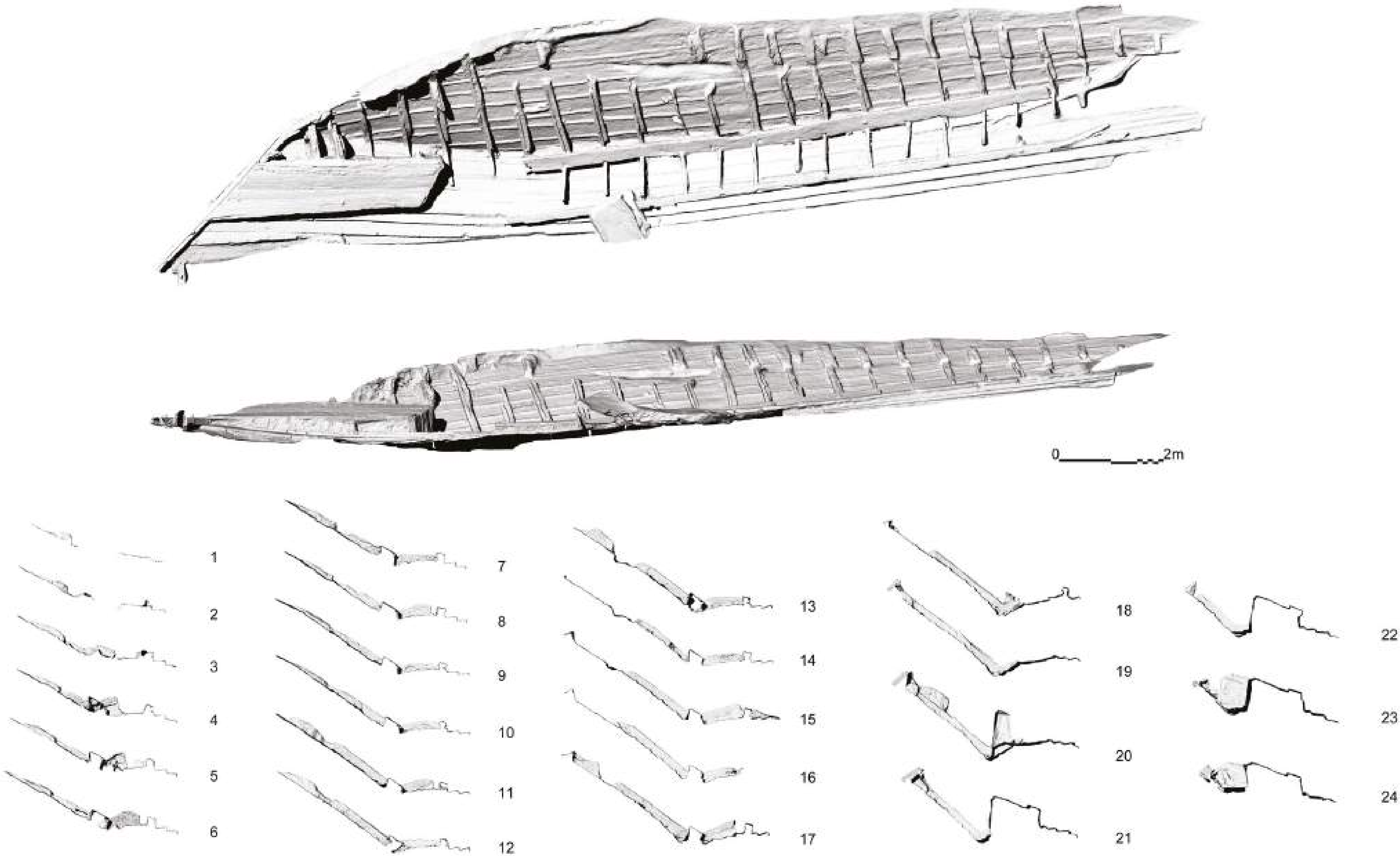


Fig. 5.6. Orthophotos relating to the plan of the boat and perspective drawings of the frames from the photogrammetric survey (elaboration: E. Costa).

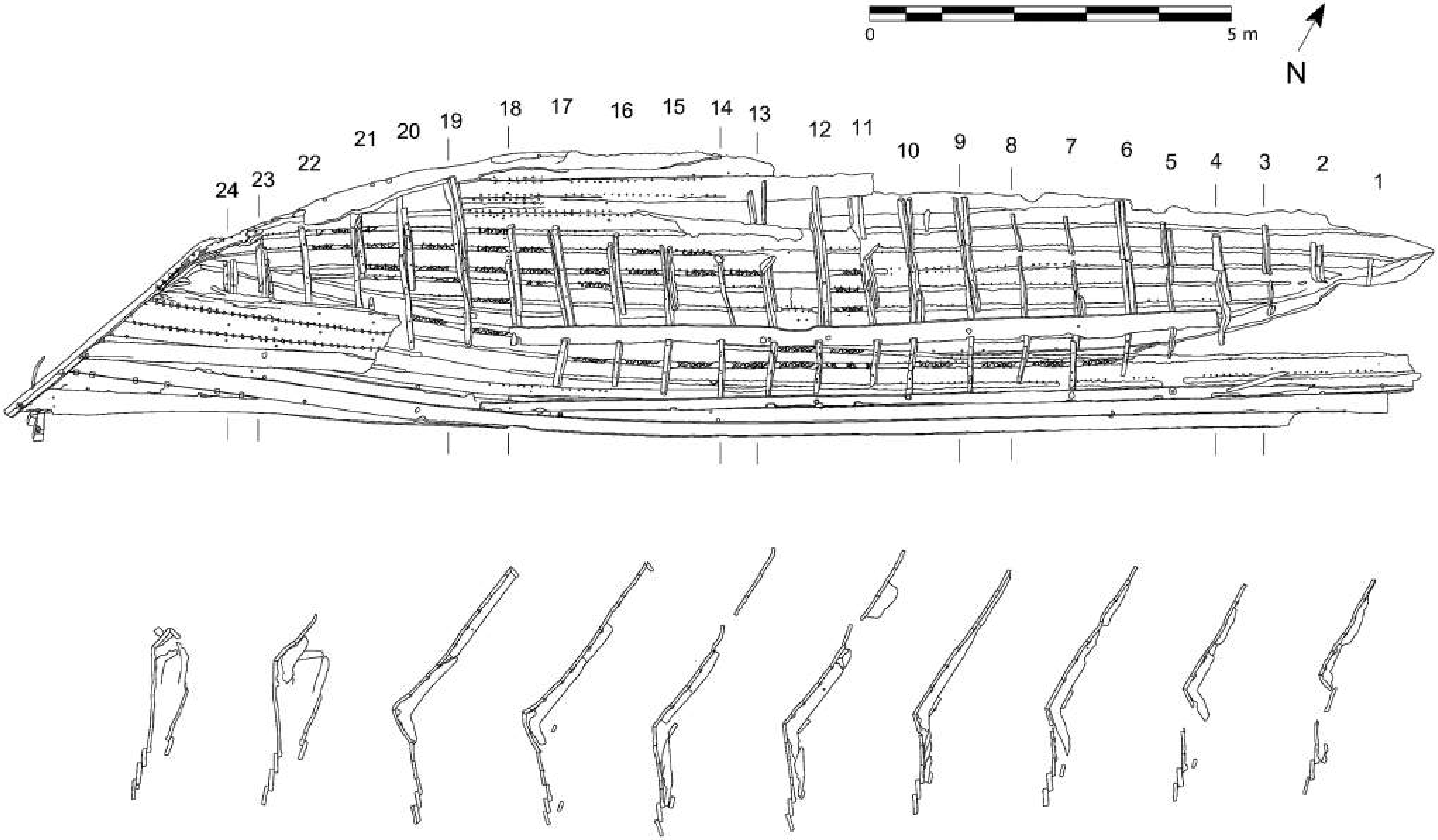


Fig. 5.7. Vectorisation of plan and transversal sections of the boat *in situ* (elaboration: E. Costa).

Fig. 5.8. One of the stations of the laser scanning survey of the stern portion of the boat in 2015 (photo: E. Costa).

overlapping of the clouds from photogrammetric survey and laser scanning has been possible thanks to the georeferencing of the targets in a reference system.

The analysis of the point clouds was carried out with *CloudCompare* software, which allows the point clouds to be aligned, to set the parameters for the comparison and the range of the scale from blue (0 cm error) to red (3 cm or 5 cm error).

Three different analyses were carried out:

– comparison between 2014 and 2015 point clouds from the photogrammetric survey;
– comparison between 2014 and 2015 point clouds from the laser scanning survey;
– comparison between the point clouds from the laser scanning survey and from the photogrammetric survey.

In the comparison of the 2014-2015 photogrammetric clouds, we note the presence of points with an error of around 12-15 mm in two different parts of the boat: the first one, where the wood deteriorated during the first excavation and which deformed between the two campaigns, and the second one, in the western part near the stern that was not deeply cleaned in 2014. The presence of red points, on the other hand, which represent elements with differences greater than 3 cm, denotes a lack of data (Fig. 5.10).

The comparison between the point clouds obtained from the two survey techniques was made on the photogrammetric point cloud in reference to the one produced by the laser scanner; the result is a high accuracy comparison, with a preponderance of points with distance errors according to a standard deviation of 2 mm which defines a nominal scale of 1:10 (Fig. 5.11).

Fig. 5.9. Point clouds from the laser scanning survey of the complete site in 2015 (elaboration: E. Costa).

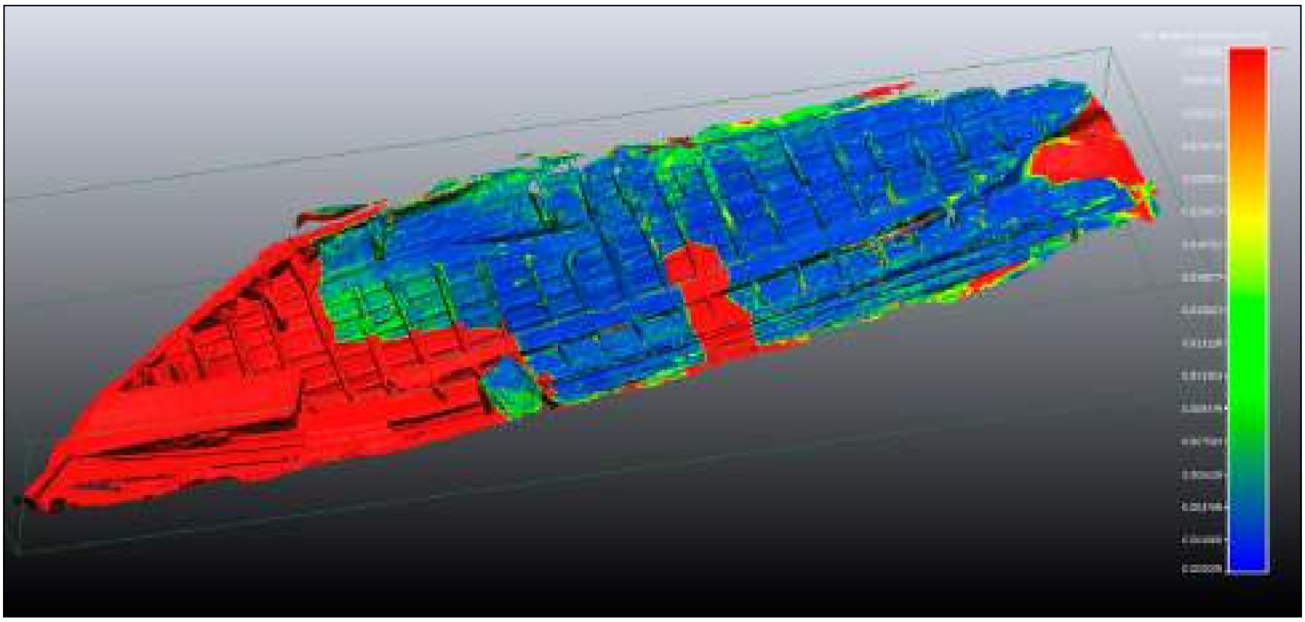


Fig. 5.10. Comparison between 2014 and 2015 point clouds from the photogrammetric survey (elaboration: E. Costa).

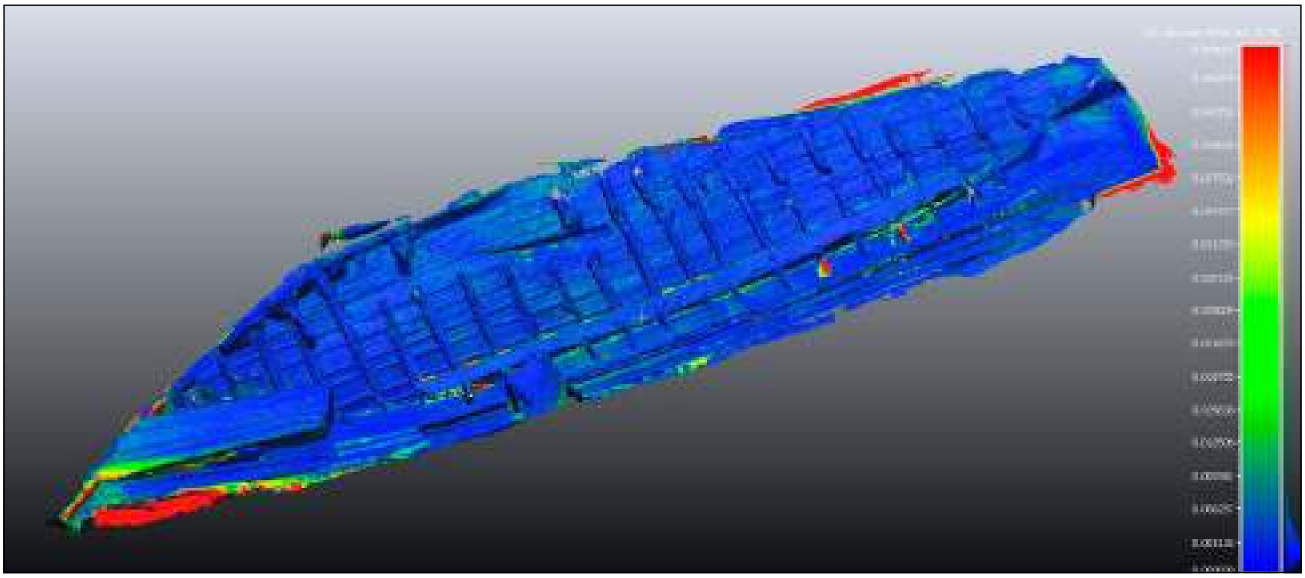


Fig. 5.11. Comparison between the point clouds from the laser scanning survey and from the photogrammetric survey (elaboration: E. Costa).

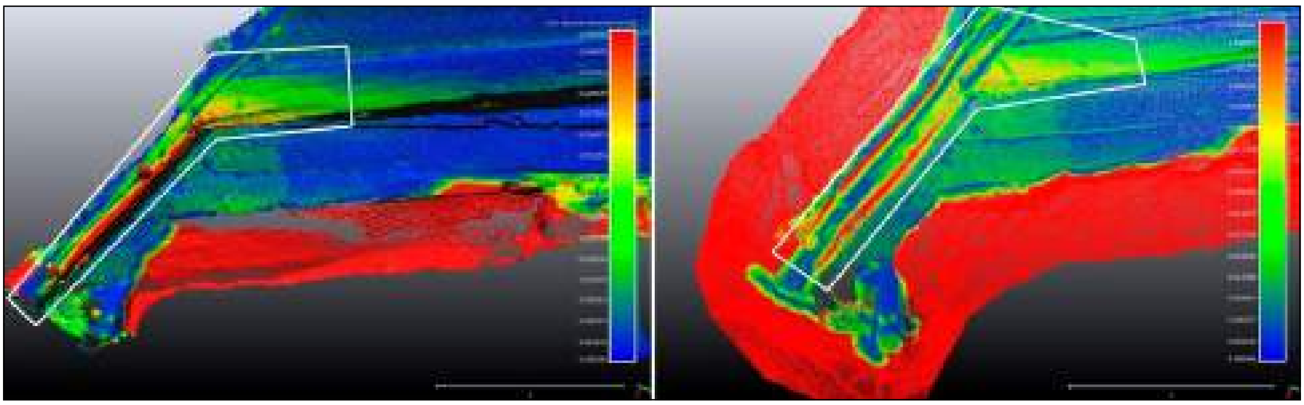


Fig. 5.12. Detail of the stern; comparison between the point clouds from the two survey techniques. On the left, the analysis is computed on the photogrammetric point clouds; on the right, the analysis is computed on the laser scanning point clouds (elaboration: E. Costa).

The photogrammetric survey was carried out immediately at the end of the excavation, while the laser scanning survey was carried out two days later; the comparison of the clouds for this detail of the hull was realised with a scale range of 5 cm to better represent and analyse the damage (Fig. 5.12).

The comparison between the point clouds was useful for the data analysis (to evaluate the metric quality and accuracy of the surveys) and for the production of indispensable daily documentation.

It is important to emphasise that if the photogrammetric survey had not been performed as soon as the excavation was completed, the survey of the barge would have been carried out only after the fracture. It is necessary to keep in mind that the archaeological excavation, especially in wet sites, is a precarious situation, in which unforeseen events of various kinds can modify and compromise the site and the objects. This situation, supported by the comparison of the point clouds, highlights the need to carry out a daily survey in order to acquire a digital model useful for documentation.

THE ENVIRONMENTAL CONTEXT

Carlo Beltrame

6. FOR A MULTIDISCIPLINARY APPROACH IN NAUTICAL ARCHAEOLOGY

The study of this shipwreck has been carried out with a multidisciplinary approach in the awareness that the collaboration with scientists in the study of wooden shipwrecks can lead to more in-depth knowledge about both the boats and their cargos, especially if evident traces of transported goods are not present.

In the recent past, the contribute of archaeobotany to the study of shipwrecks has been mainly limited to dendrological aspects, including the dating, the identification of the areas of the wood's provenance (e.g. Giachi *et al.*, 2003; Allevato *et al.*, 2010; Greck and Guibal, 2011; Guibal *et al.*, 2021) and, much more rarely, the analysis of the technology of the wood working (e.g. Greck and Guibal, 2011). Although, in Italy, the studies where other kinds of organic materials, such as fibres and pollen, have been analysed are still few (Allevato *et al.*, 2010; Arobba *et al.*, 2014; Giachi *et al.*, 2017; Willis, 2017), this approach is becoming to be widespread abroad.

An analysis of biological records (wood and animal remains, pollen, non-pollen palynomorphs [NPP], seeds/fruits, fibres) collected in a shipwreck can provide information about shipbuilding and repair techniques (e.g. Castelletti *et al.*, 1990; Willis, 2017; Wicha and Verlaque, 2019) and the location of the places of its construction (e.g. Cappers *et al.*, 2000; Muller, 2004; Allevato *et al.*, 2010; Barkai and Kahanov, 2016; Giachi *et al.*, 2017; Andrieu-Ponel, Belkacem and Ponel, 2014; Andrieu-Ponel, 2019). The provenance of the materials (not only wood) used for boat construction or repairs can also provide information about the environment in which the boat was built and used (e.g. Cappers *et al.*, 2000; Deforce *et al.*, 2014).

fig. 6.1 – Sampling for palynological analysis on the shipwreck of Santa Maria in Padovetere (photo: C. Beltrame).

More attention should be done also on geomorphological and sedimentary aspects of shipwrecks excavated in wet sites, since we are able to quote only few and not recent works on these topics, such as the works on the Roman ship of Valle Ponti (Comacchio) (Bondesan, Dal Cin and Monari, 1990) and on the ancient wrecks, found at Pisa San Rossore in the coastal plain of the Arno and Serchio rivers, in Tuscany (Benvenuti *et al.*, 2006) or the Early Medieval wreck investigated in a river at Port Berteau (France) (Capelot and Rieth, 2005, 202).

Paolo Mozzi, Alessandro Alessio Rucco

7. THE GEOARCHAEOLOGICAL CONTEXT OF THE AREA OF SANTA MARIA IN PADOVETERE

The archaeological area has been investigated since the late 1950s. Since the beginning, particular attention has been paid to the geomorphological dynamics underlying the foundation of the most representative building in the area, a parish church attributed to the early 6th century AD. In particular, the relationship between the ecclesiastical building and a paleochannel of the Po river which flowed, in Late Antiquity, a few metres south-west of the parish church, has always aroused great interest (Rucco, 2021 and references) (Fig. 7.1).

Much has been written about an artificial canal, traditionally called *Motta della Girata*, originally dated to the Etruscan age but recently attributed, based on radiocarbon dating, to Late Antiquity (Rucco, 2015). This canal branched off from the Po paleochannel about 150 m south-east of the parish church and headed towards the northern outskirts of the nearby town of Comacchio, in a place where archaeological investigations have made it possible to highlight the traces of a port (Grandi and Negrelli, 2021).

The area is thus characterised by a high archaeological value. This value, and the general complexity of the buried archaeological record, was enriched by the discovery of the riverine barge described in this volume.

Very recent archaeological investigations carried out by the teaching of Medieval Archaeology at Ca' Foscari University of Venice have shed light on the very early stages of occupation of the area datable to the end of the 5th century, i.e., precisely coeval to the barge (Fig. 7.2).

Geoarchaeological investigations conducted in the last decade on the entire archaeological area allowed to define the main depositional units that characterise it, leading to the proposition of an overall geomorphological and paleoenvironmental framework for Late Antiquity.

7.1 *The geomorphological setting*

Two major geomorphological units characterise the Santa Maria in Padovetere area (Beltrame *et al.,* 2021) (Fig. 7.3). The first is an almost 500-metre-wide abandoned channel belt of the ancient Po river (*Padus vetus*, 'Padovetere'), running NW-SE and flanking the parish church. The second is the N-S relict beach ridges cut by the Po channel belt and formed between 3500 and 2700 years ago (Stefani and Vincenzi, 2005). Over the following centuries, the coastline shifted about 5 km further east (Castiglioni *et al.*, 1999).

During Late Antiquity, the Santa Maria in Padovetere area was far inland from the coast. Ancient rivers in the area were given different names (*Eridanus*, *Padoa*, *Padus*), but they all correspond to various Po river channels. The shape of the beach ridges suggests that, during the 4th century BC, the main branch of the Po river probably debauched into the sea just 2.5 km southeast of Santa Maria in Padovetere (Cremonini, 1993). Then the river mouth shifted to the northeast and remained in the Porto Garibaldi area until the 4th century AD (Bondesan, 1990; Bondesan and Giovannini, 1994). Available data suggest that, in Late Antiquity, the Po river branch near Santa Maria in Padovetere (*Padus vetus*) was a residual channel (Bondesan, 2001; Balista and Berti, 2016-2017).

The study area is crossed to the east by the early-Medieval *Motta della Girata* canal, which starts from the Po residual channel about 100 m downstream of the wreck site (Figs. 7.4, 7.5). The canal, almost 30 m wide and 2.5 m deep, is filled with fine-grained, organic-rich sediments (Rucco, 2015). Radiocarbon dating of a peat sample collected at the bottom of the sedimentary fill of the *Motta della Girata* Canal some 300 m E of the wreck site was dated to 1260 ± 30 BP (669-779 cal AD, Tab. 7.1). This indicates that the canal was already active in the 7th century AD.

A core drilled outside the canal in 2015, the PEG1 core, indicates that a thin, organic-rich silt level separates the depositional top of the beach ridges from a 2.5 m alluvial succession that consists of sand and silt, and continues to the present topographic surface (location shown in Fig. 7.5, revised stratigraphic log in Fig. 7.6). A charcoal fragment collected from this organic-rich layer was dated 1550 ± 30 BP (423-574 cal AD, Tab. 7.1).

Core and depth (cm)	LabCode	Radiocarbon Age (yr BP)	Calibrated Age AD [start-end] probability%	Material	Elevation (m asl)	Latitude	Longitude
PEG1/PEG1 bis 255-260	Beta-354936	1550 ± 30	[423-574] 95.4%	Charcoal	-3.30/-3.35	44°40'46.1" N	12°07'37.2" E
MDG canal PEG3 160-165	Beta-354937	1260 ± 30	[669-779] 85.3%	Peat	-2.30/-2.35	44°40'44.3" N	12°07'38.6" E
Barge excavation Depth N/A	LTL6271A	1625 ± 45	[332-545] 95.5%	Rope	N/A	44°40'30.1" N	12°07'20.0" E

Tab. 7.1. Radiocarbon dates from Rucco, 2015 (Beta-354936, Beta-354937), and Balista and Berti, 2016-2017 (LTL16271A).

Fig. 7.1. General setting of the study area.

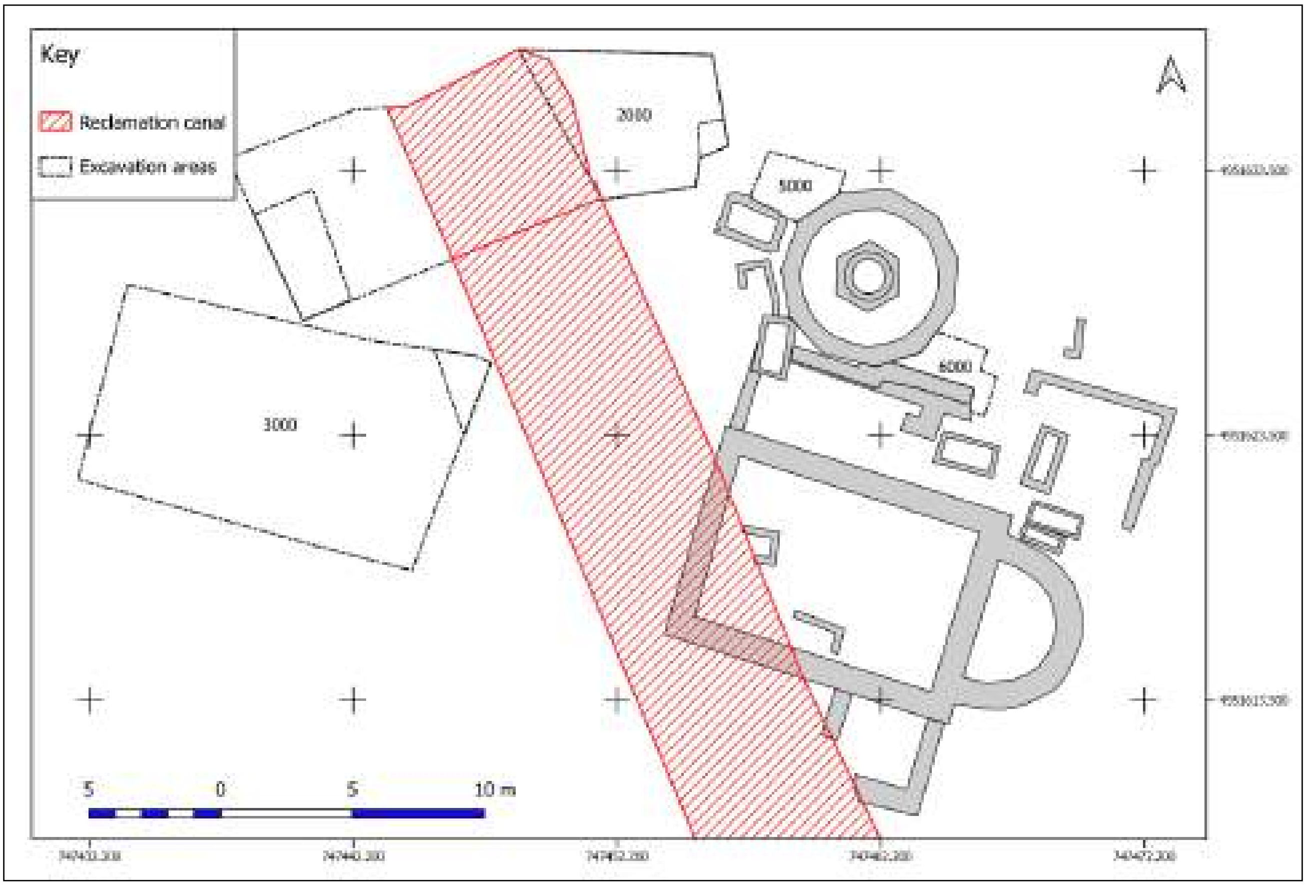
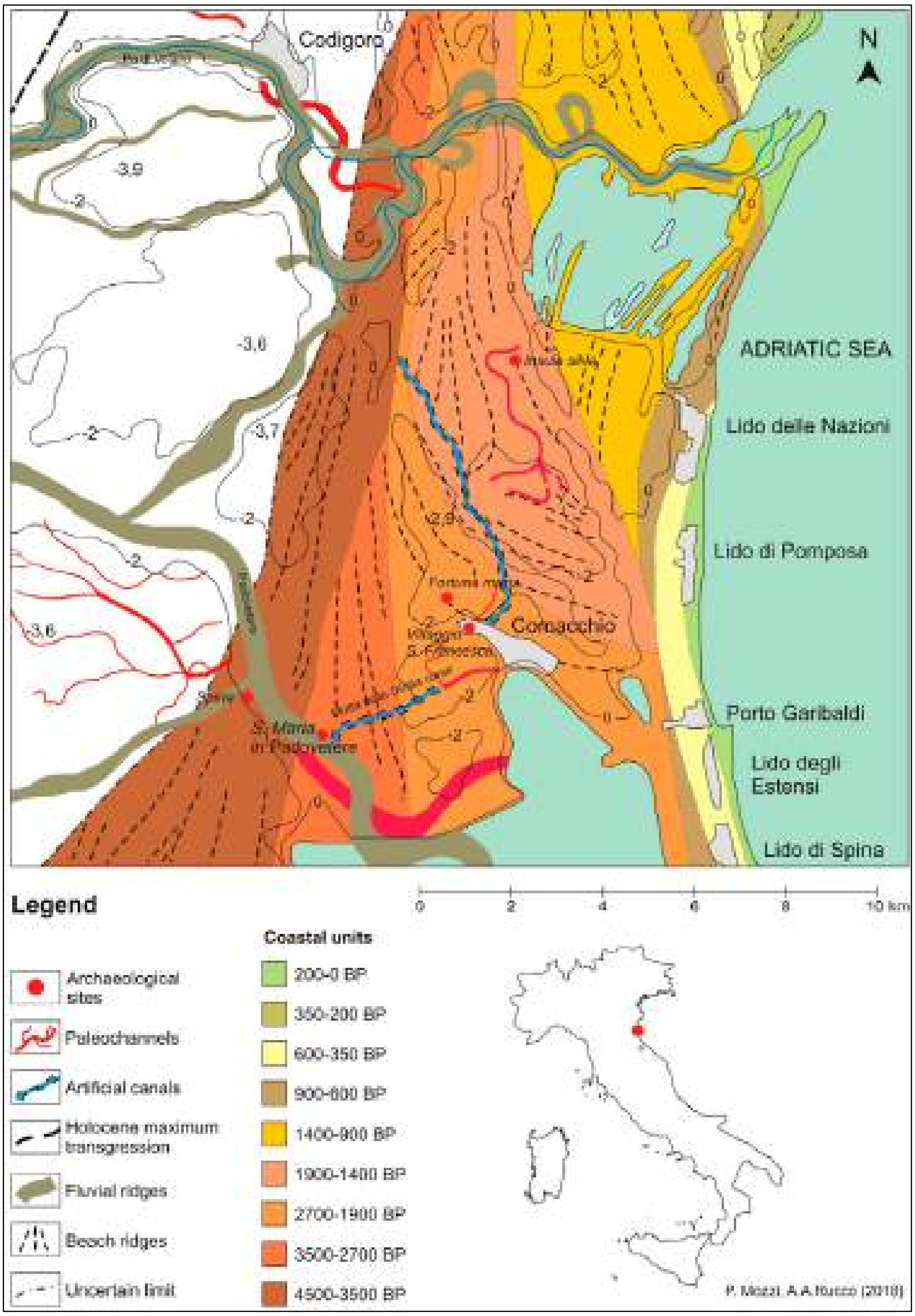


Fig. 7.2. Excavation areas besides the Santa Maria in Padovetere parish church (drawing: A. A. Rucco).



7.3. Geomorphological setting of the study area (modified from Stefani and Vincenzi, 2005).

7.2 *Field methods*

The first step of the research in the archaeological area of Santa Maria in Padovetere involved the creation of a DSM (*Digital Surface Model*) to identify micromorphological anomalies related to both geological and anthropic near-surface structures. To achieve the result, a photogrammetric survey was carried out with a Mavic Enterprise Dual DJI aircraft on 06/16/2021. 346 photographs were taken and processed with *Agisoft Photoscan*. The field topographic survey was carried out with a Geomax Zenith 16 GNSS, based on WGS 84, UTM 32N reference system. Altitude values were calibrated according to the Italy ITG2009 geoid (Fig. 7.7). Coring was carried out using an Edelman combination-type auger. The field description included grain size, sedimentary structures, colours (with reference to the Munsell Soil Colour Charts), pedological features (nodules, mottles) and paleontological content (shells, plant remains,

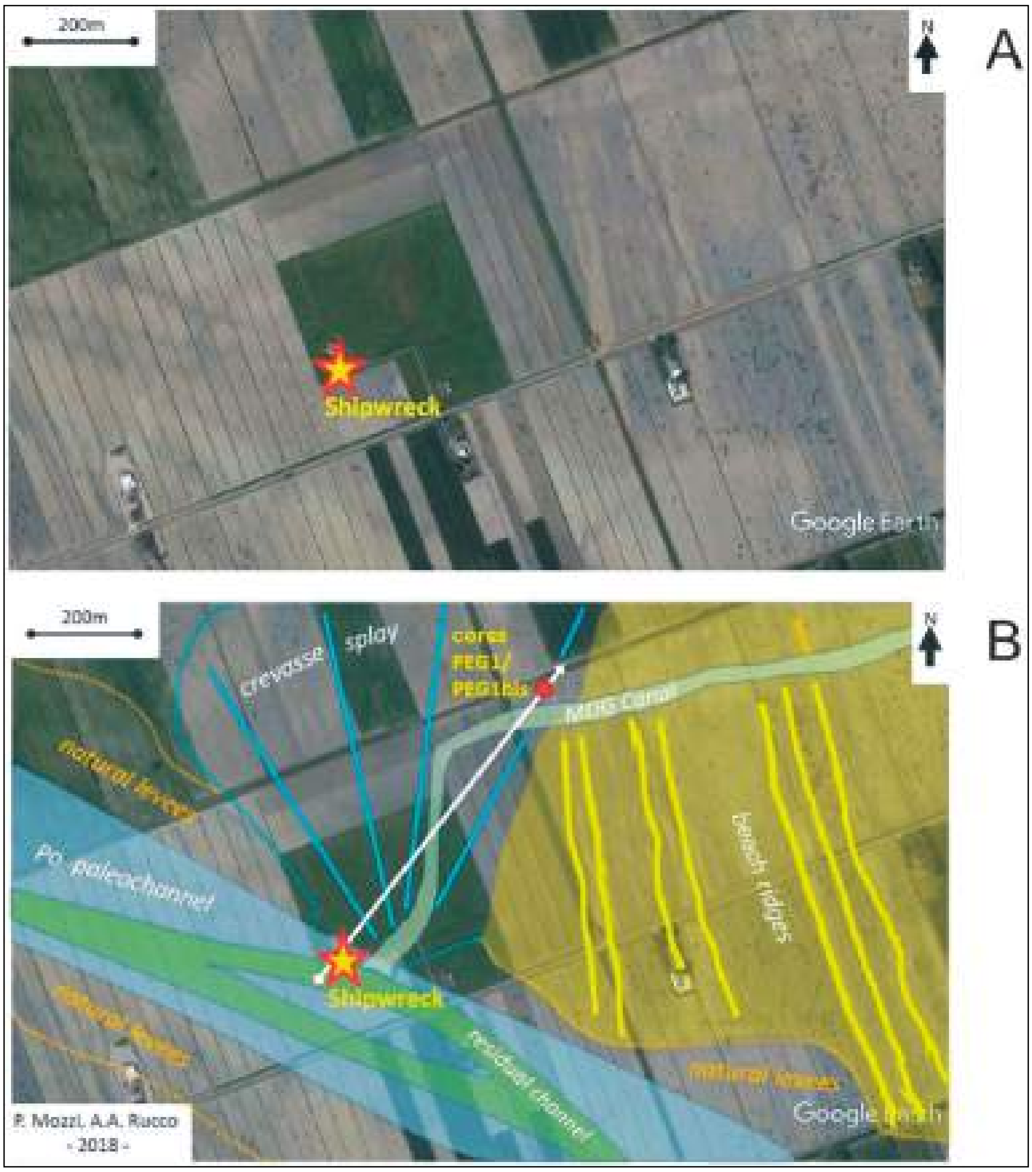


Fig. 7.4. Main geomorphological units in the Santa Maria in Padovetere site.

wood, charcoal). Radiocarbon dates from Rucco (2015) and Balista and Berti (2016-2017) were calibrated using the OxCal 4.3 software (Bronk Ramsey, 2009) and the calibration curve IntCal13 (Reimer *et al.,* 2013) (Tab. 7.1).

7.3 *Results*

It should be noted that the area corresponding to the state-owned space is much more conservative of the original landforms than the immediately external one. As an example, it can be highlighted that elevations are on average 50 cm higher than outside. Undoubtedly, a decisive role in this sense was played by the very early acquisition of the land by the Italian State, which preserved it from the impact of agricultural activities.

The DSM spans approximately between -0.3 and -2 m asl. A major landform is the *Motta della Girata* canal, which crosses the eastern portion of the area in SSW-NNE direction. The DSM has also presented a marked depression just SW of the parish church that corresponds to a trace of the Padovetere palaeochannel. The space immediately surrounding the parish church inherits not only the relief of the natural levee on the left bank of the Padovetere river but also the overall geometry of the crevasse splay on which the whole occupation of the site took place.

In satellite images, the beach ridges in the Santa Maria in Padovetere area appear to be regularly spaced, almost parallel sandy belts (Fig. 7.4). In front of the Santa Maria in Padovetere site, the Po river paleochannel splits into two secondary channels, each about 60-80 metres wide, around what appears to be a fluvial island in remote sensing images. The hull of the sewn-plank barge lies on the left bank of the northern minor channel.

Stratigraphic data from our survey and Rucco (2015) allowed us to define the general stratigraphy of the area (Fig. 7.7). The PEG1/PEG1bis cores were drilled a few metres north of the left bank of the *Motta della Girata* Canal. Beach

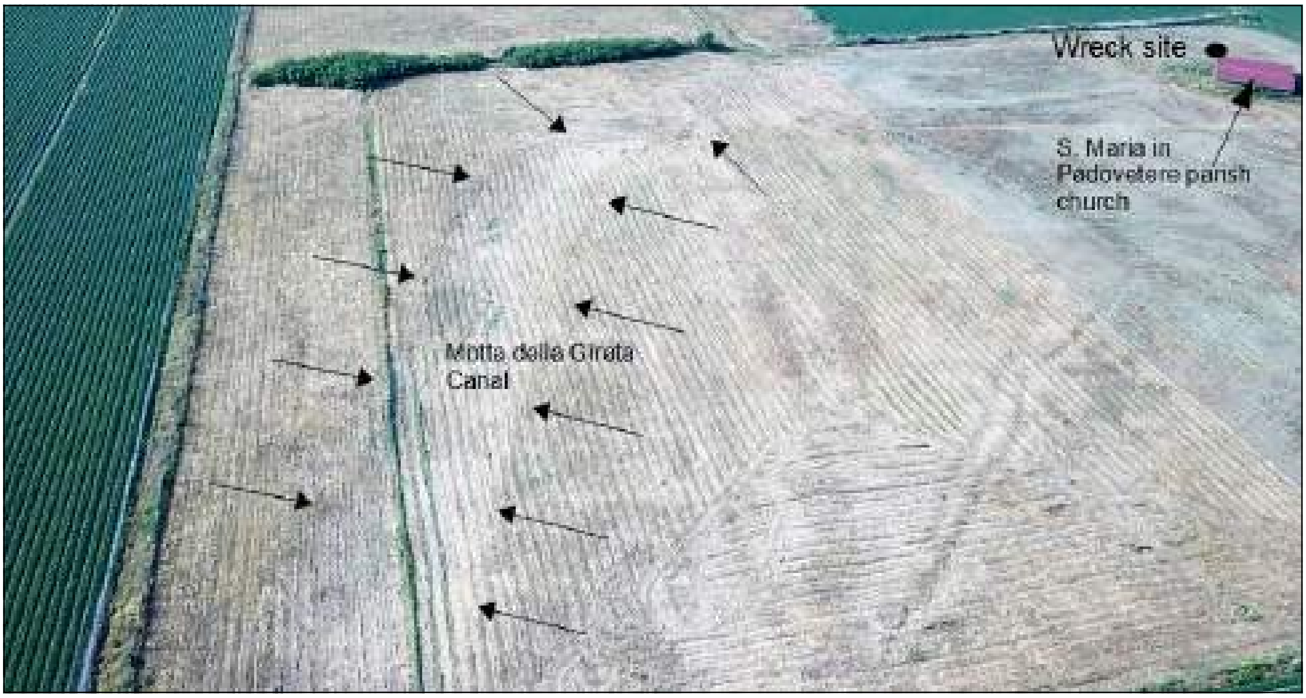


Fig. 7.5. The *Motta della Girata* Canal from a N-S perspective (photo: A.A. Rucco).

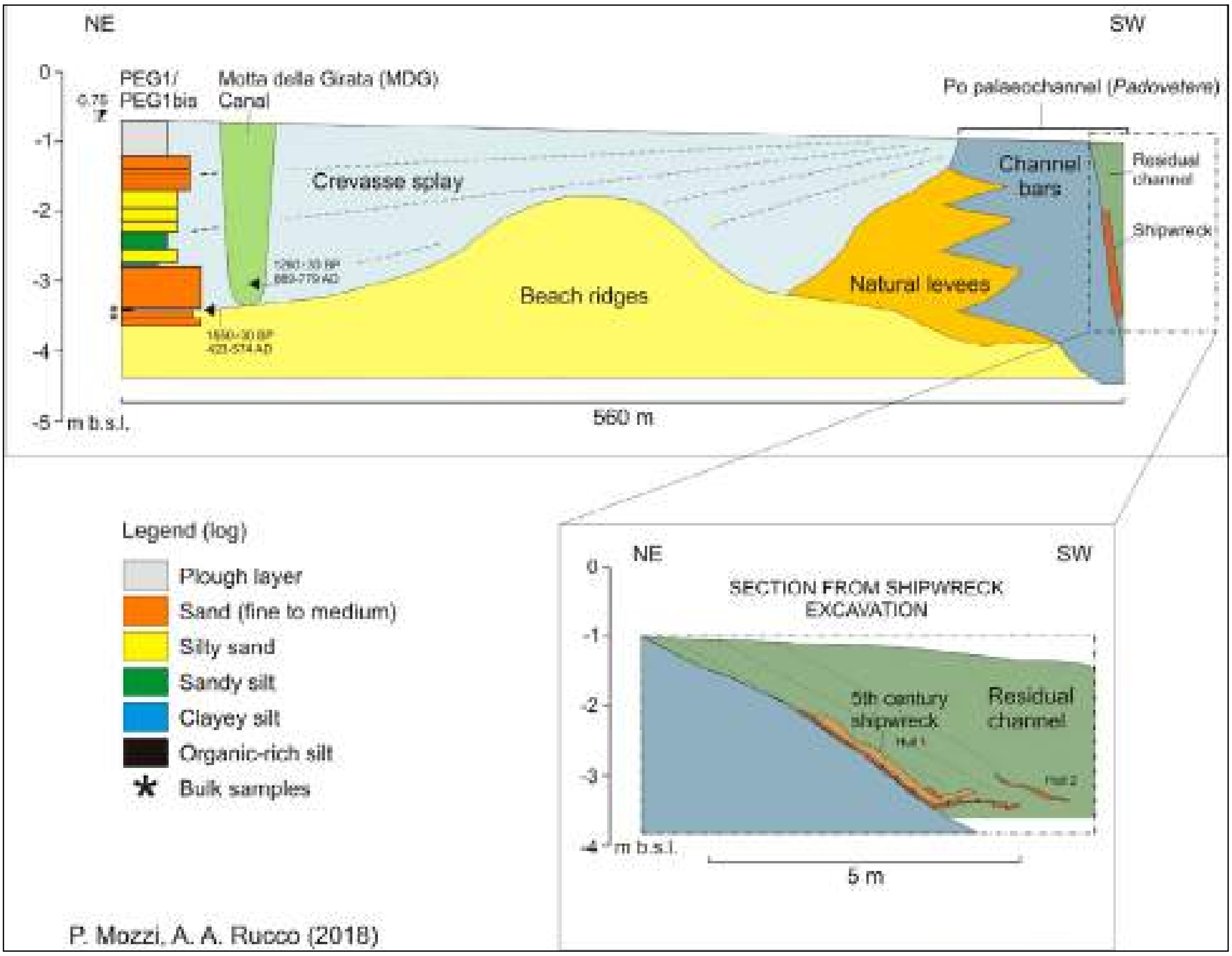


Fig. 7.6. Stratigraphic profile between PEG1/1bis and the wreck site (localization in fig. 7.4).

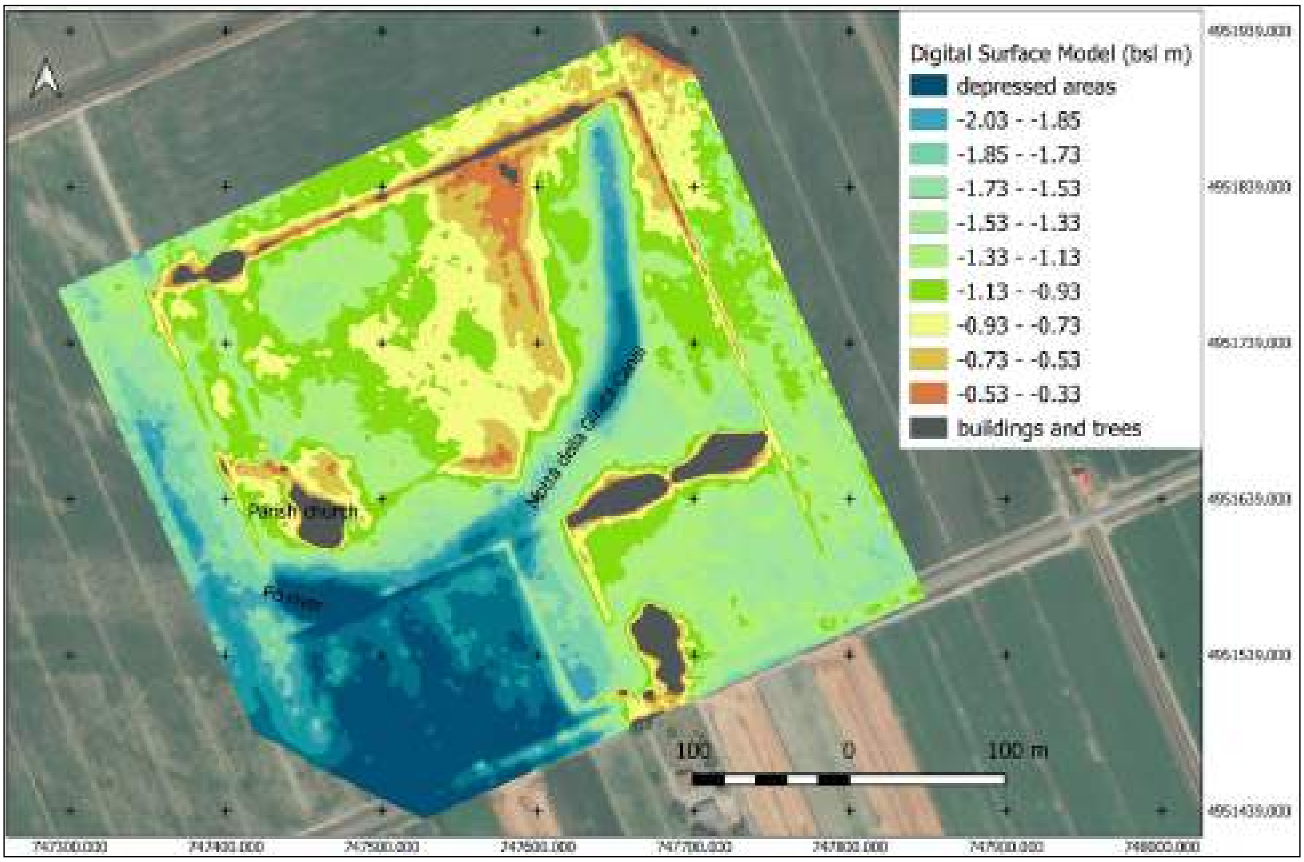


Fig. 7.7. DSM of the study area.

ridge deposits (medium sand, slightly silty, containing many fragments of marine bivalve shells, especially *Cerastoderma glaucum*) were found 2.6 m below the topographic surface. Directly above is the organic-rich silt level dated to 1550 ± 30 BP (423-574 cal AD). The overlying 2.5-metre alluvial succession is dominated by alternating layers of sand, silty sand, and sandy silt up to the present topographic surface. These alluvial deposits are interpreted as crevasse-splay sediments. Lithofacies assemblage and remote sensing indicate faint traces of radial minor channels emanating northward from the Po channel (Fig. 7.8).

This interpretation is consistent with the hypothesis proposed by Balista and Berti (2016-2017) that the first tract of the *Motta della Girata* Canal was realised by taking advantage of a crevasse channel that cut through the natural levee of the Padovetere palaeochannel.

7.4 *Discussion and final remarks*

The alluvial stratigraphy indicates that the crevasse splay at Santa Maria in Padovetere was deposited after 423-574 cal AD. However, given that the foundation of the Santa Maria in Padovetere parish church, which is on top of these alluvial sediments, dates to the first half of the 6th century, the crevasse splay activity is further constrained between 423 AD and approximately the end of the fifth century (Fig. 7.9). This reconstruction is further confirmed by archaeological data coming from the cemetery excavated some 50 m east of the junction between the *Motta della Girata* Canal and the Po river. The excavation carried out in 2022 in this area by Ca' Foscari University of Venice made it possible to understand that the already known graves of this cemetery, characterised by the presence of 5th century pottery and glass assemblages, were realised rightly on top of the crevasse splay deposits described (Fig. 7.8). This indicates that the time interval when a flood (or a cluster of floods) activated the Po river residual channel and fed the crevasse splay at Santa Maria in Padovetere partly overlaps with the end of the barge's life. It is possible that the barge's sinking was related to one of the high-magnitude floods that formed the crevasse splay.

At the regional level, this period of fluvial instability is coeval to a phase of alluvial ridge aggradation of the main course of the Po river, which occurred from the mid-4th century to the end of the 5th century. It is also coeval to the period of enhanced avulsion and aggradation of the channel belts of minor streams that flowed from the Apennines to the Po plain and the Adriatic Sea during the 5th and 6th centuries (Cremonini, Labate, and Curina, 2013).

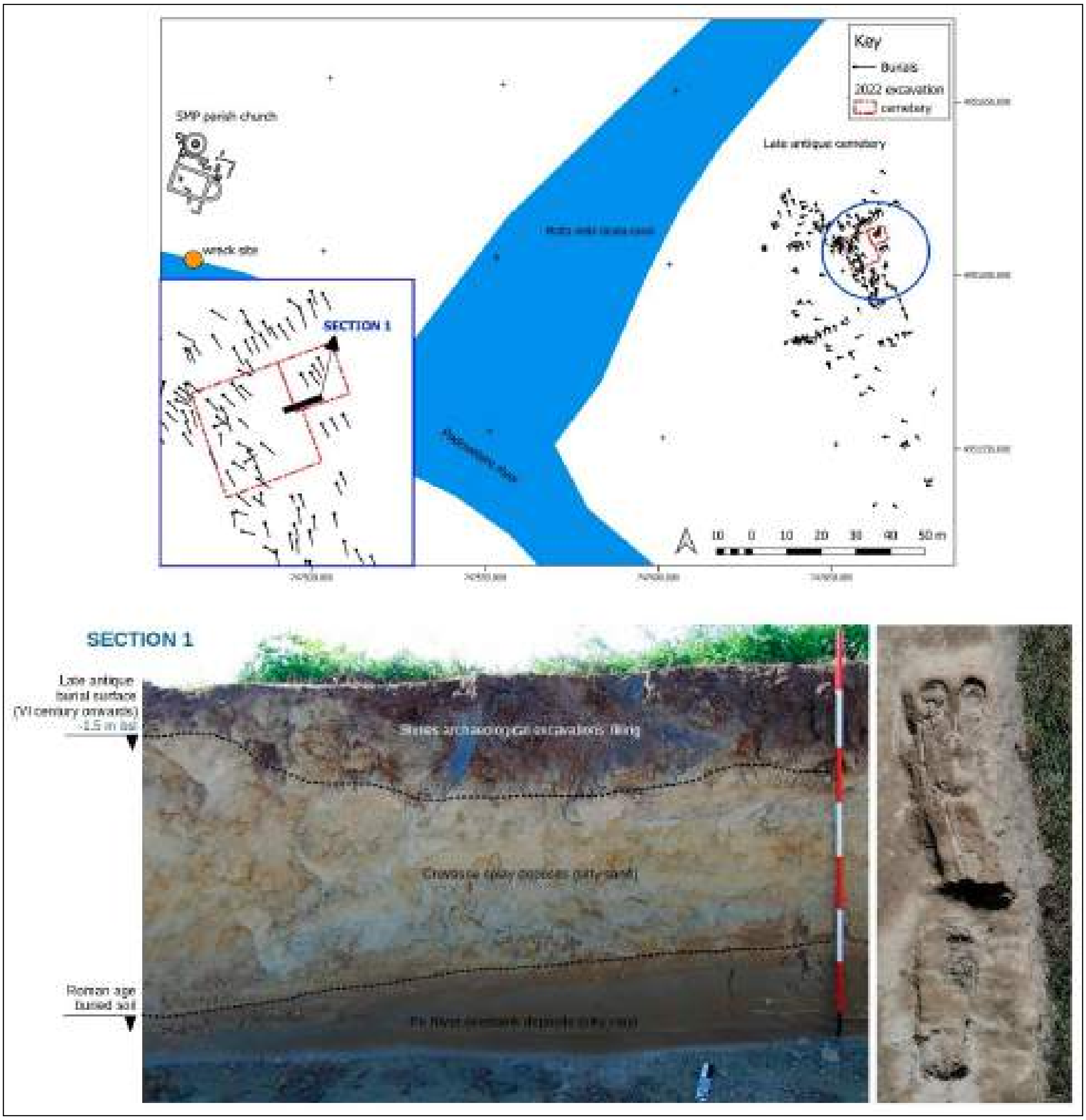


Fig. 7.8. Crevasse splay deposits documented in 2022 excavations (drawing and photos: A.A. Rucco).

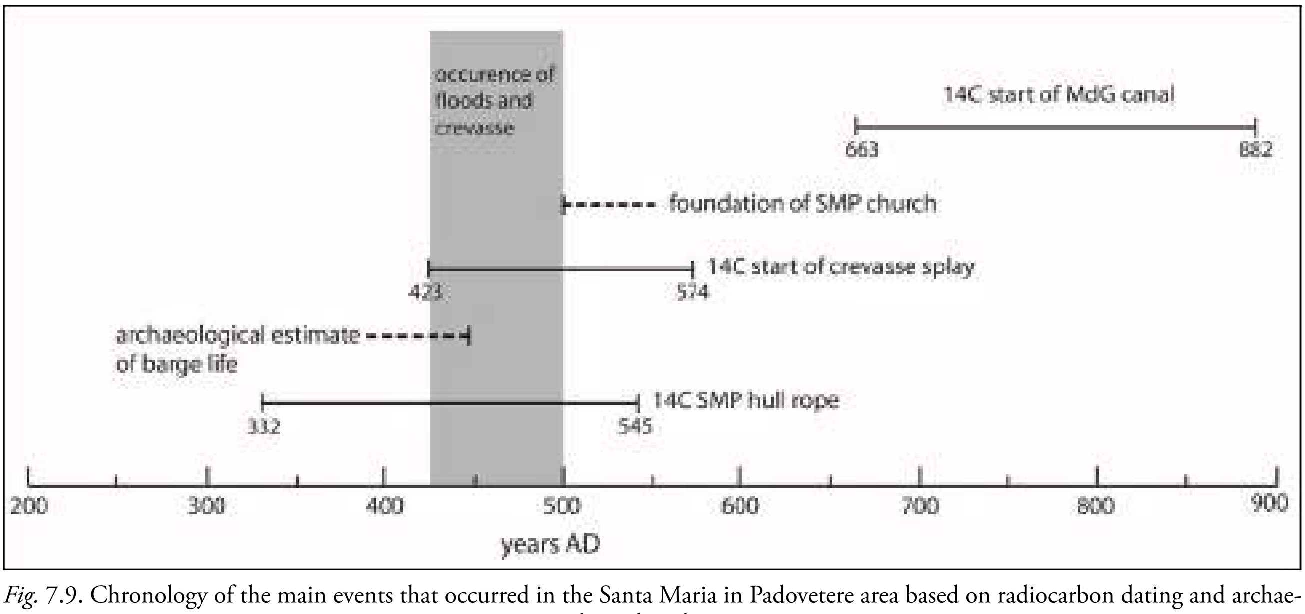


Fig. 7.9. Chronology of the main events that occurred in the Santa Maria in Padovetere area based on radiocarbon dating and archaeological evidence.

Alessandra Forti, Antonella Miola

8. WHICH ENVIRONMENT DID THE BARGE SAIL IN? BIOLOGICAL RECORDS FOR AN ENVIRONMENTAL RECONSTRUCTION AND USE OF THE BARGE

We present here archaeobotanical analysis of the bilge sediments, rope fragments, caulking, wood elements and chemical analysis of the pitch of the shipwreck, thanks to the well-preserved biological remains that have provided information on the environment in which the barge sailed in and on the provenance of the materials used in the barge's construction.

8.1 *Pollen and Non-pollen palynomorph analysis and plant macroremains*

A sediment sample from the bilge of the shipwreck and two sediment samples of an organic layer at the base of the river sequence (core PEG1bis, collected from the same location as core PEG1) were analysed for pollen and non-pollen palynomorphs, assuming that this organic layer could provide biological proxies of a coeval environment near the wreck.

Samples for pollen and NPP analysis were processed following the routine methods (including sieving Ø 0.01 mm) described by Krzywinski *et al.* (2000) and in use at the palynological laboratory of the Department of Biology. Pollen grains and spores were identified (at 1000x) using the pollen references collection and literature for identification (see Tab. 8.1). The relative frequencies of pollen and NPP (in percentages) were calculated for the Comacchio bilge only, as the PEG1bis samples contained almost no pollen (this was determined after reading two pollen slides for each sample). The percentages of each pollen taxon or selected groups of pollen taxa were calculated from the total pollen sum (TPS), which includes all pollen taxa, identified and unidentified. The abundance of other palynomorphs (spores of ferns, mosses and fungi, algal cysts and foraminifera) was calculated using the TPS plus the total sum of each group (TPS + ferns, TPS + mosses, TPS + fungi, TPS + algae, TPS + foraminifers).

To analyse the plant macrofossil content, approximately 100 ml each of PEG1bis 270-275 cm and PEG1 – bis 275-285 cm and 5 ml of Comacchio bilge were treated with 10% NaOH and sieved (Ø 200 µm). Seeds and fruits were collected by hand under STM (40x) and identified using the reference collection and literature such as Körber-Grohne (1964), Mauquoy and Van Geel (2007) and Cappers, Bekker and Jans (2006). Microfragments (less than 500 µm) of plant tissues, leaflets and rootlets, transverse fields, cuticles, and vessels were observed; some of these were mounted on LM slides for identification using Katz, Katz and Kipiani (1965), Katz, Katz and Skobeyeva (1977) and the reference collection.

The shipwreck's bilge sediment preserved pollen and NPP very well. As we can see in Tab. 8.1, tree, and shrub pollen (57%) are much more common than herb pollen (36%). Among the tree pollen, alder is dominant. Pollen of dry land plants and waterlogged or wetland plants is represented almost equally, except for wild Poaceae pollen type (15%), as this type includes both dry land and hygrophilous species, which cannot be identified based on the morphological characteristics of the pollen.

Regarding fungal remains, it can be observed that the most abundant are conidia or chlamydospores of taxa living in the soil (*Trichocladium*, Fig. 8.1j), on dead wood or herbaceous stems, above ground or submerged (*Xylomyces*, Fig. 8.1g), and endomycorrhizal fungi (*Glomus* sp.). Other fungal remains such as the spores of *Gelasinospora* (Fig. 8.1i), *Podospora* (Fig. 8.1k), *Arnium* and *Coniochaeta lignaria*, which normally grow in or on manure, also appear in the pollen slides. *Gelasinospora* can also be carbonicolous or lignicolous, while *Coniochaeta lignaria* is also common on wood (Van Geel and Aptroot, 2006). A number of micro-carbons and micro-fragments of wood are also present in the sample (cross-fields, vessel fragments and perforation plates of hardwood, probably *Alnus*, *Betula* or *Corylus*, cf. Schweingruber, 1990). No plant macro remains were detected.

PEG1bis 275-285 and 270-275 cm contained almost no pollen (Tab. 8.1). Many unidentifiable and uncountable plant macro remain: fragments of moss leaves, Piceoid type cross fields, micro-fragments of cork of *Pinus sylvestris* and exoderm of *Carex* sp. rootlets were identified and counted. Some seeds of plants live and grow along the banks of rivers (*Sambucus nigra*, *Rubus* sp., *Lycopus europaeus*, *Hypericum* cf. *perforatum*, *Verbena officinalis*, *Alisma plantago-aquatica*) and seeds of plants growing in salty soils (*Juncus maritimus* (Fig. 8.1l), *J. gerardii* (Fig. 8.1m), *Aster* cf. *tripolium* and *Beta vulgaris*) (Tab. 8.2).

8.2. *Fibres identification*

To identify the origin of the fibres, three samples of caulking and rope were analysed: a sample of the caulking roll material recovered between the 13th and the 14th planks, a sample of caulking material scattered within the hull, and a segment of sewing rope recovered from a hole in the planking.

The plant fibres were first investigated using the traditional drying-twist test (Marshall, 1992) on bundles of fibres; the bundles were then observed through a stereo-microscope

	PEG 1 bis		"Comacchio sentina				
	270-275	275-285					
	counts	counts	counts	%	group%	Plant environmemnt	References
Tree and shrub pollen types							
Quercus robur-pubescens type			26	5,2	26,4	*Decidous mixed forest*	Beug (2004)
Ulmus			21	4,2			Beug (2004)
Corylus			12	2,4			Beug (2004)
Carpinus betulus			12	2,4			Beug (2004)
Fraxinus ornus			5	1			Beug (2004)
Cornus mas			4	0,8			Beug (2004)
Ostrya type			2	0,4			Beug (2004)
Acer			1	0,2			Beug (2004)
Quercus ilex type			23	4,6		*Mediterrenean temperate and xerophilous forest*	Beug (2004)
Ericaceae-Empetrum group cf *Erica arborea*			3	0,6			Beug (2004)
Juniperus communis type			1	0,2			Beug (2004)
Juglans			4	0,8		*Cultivated area*	Beug (2004)
Olea europea			3	0,6			Beug (2004)
Pinus cf *pinea*			8	1,6			Accorsi, Bandini Mazzanti, and Forlani (1978)
Castanea			1	0,2			Beug (2004)
Fagus			5	1		*Mesophilous forest*	Beug (2004)
Alnus			136	27,4	30,8	*Wet riparial forest*	Beug (2004)
Salix			15	3			Beug (2004)
Sambucus nigra type			1	0,2			Beug (2004)
Populus			1	0,2			Beug (2004)
Herb pollen types							
Sparganium type			2	0,4	4,6	*Riparial and open water*	Beug (2004)
Cyperaceae	3	2	17	3,4			Beug (2004)
Lemna			3	0,6			Moore, Webb, and Collison (1991)
Nymphaea			1	0,2			Beug (2004)
Poaceae wild-group type	1		74	14,9			Beug (2004)
Chenopodiaceae	1	1	18	3,6	16,1	*Upland herbs in the forest, prairie, meadow*	Beug (2004)
Sanguisorba minor type			15	3			Beug (2004)
Urticaceae, Moraceae cf *Urtica* sp.			10	2			Beug (2004)
Senecio type			7	1,4			Beug (2004)
Trifolium repens type			1	0,2			Beug (2004)
Salvia verticillata			1	0,2			Beug (2004)
Artemisia			1	0,2			Beug (2004)
Illecebrum verticillatum			1	0,2			Beug (2004)
Plantago major-media type			1	0,2			Beug (2004)
Brassicaceae			10	2		*Cultivated area*	Beug (2004)
Cannabis sativa			9	1,8			Fleming and Clark (1998)
Broken *Secale*			3	0,6			Andersen (1979)
Secale			2	0,4			Andersen (1979)
Cucumis sativus/C. melo			1	0,2			Beug (2004)
Undeterminated pollen			35	7,1			
Total pollen sum	11	5	496	100%			
Fern spores							
Polypodiaceae			9	1,7			Moore, Webb, and Collison (1991)
Equisetum			5	1			Moore, Webb, and Collison (1991)
Trilete spores			5	1			
Polypodium vulgare type			2	0,4			Moore, Webb, and Collison (1991)
Thelypteris palustris			2	0,4			Moore, Webb, and Collison (1991)
Total pollen sum			23	4,4			
Bryophyte spores			2	0,4			Moore, Webb, and Collison (1991)
Algal cysts						*Open water*	
Dynoflagellates cysts (HdV-230 and HdV_304)			2	0,4			van Geel, Bohncke, and Dee (1981, 1989)
Undeterminated algal cysts			9	1,8			van Geel, Bohncke, and Dee (1981, 1989)
Total			11	2,2			
Foraminifers							
Internal organic linings of foraminifers (HdV700)			5	1			Miola *et al.* (2010)
Total			5	1			
Fungal spores						Soil, dung or decaying wood	
Trichocladium cf *opacum*			43	7,5			Ellis (1971)
Xylomices chlamydosporis /X. aquaticus (HdV 201)			8	1,4			L. Montecchio, pers. com.
Glomus sp. (HdV-207)			7	1,2			van Geel and Aptroot (2006)
Coniochaeta lignaria (HdV-172)			8	1,4			van Geel and Aptroot (2006)
HdV-1010			3	0,5			van Geel and Aptroot (2006)
Diporotheca rhizophila (HdV-143)			2	0,4			van Geel and Aptroot (2006)
Gelasinospora (HdV 1)			1	0,2			van Geel and Aptroot (2006)
Podospora (HdV-368)			1	0,2			van Geel and Aptroot (2006)
Arnium (HdV-262)			1	0,2			van Geel and Aptroot (2006)

Tab. 8.1. Pollen and NPP analysis of PEG1 and of 'Comacchio sentina' (elaboration: A. Forti).

	PEG 1 bis	
Seeds/fruits of trees	270-275 counts	275-285 counts
Sambucus nigra fragments	1	7
Hypericum cf. *perforatum*		1
Rubus sp. fragments	2	4
Aster tripolium	1	
Lactuca cf.	1	
Lycopus europaeus	1	2
Lamium sp.	1	
Alisma plantago-aquatica	1	
Beta vulgaris	3	
Valeriana officinalis		2
Juncus cf. *maritimus*		1
Juncus cf. *gerardi*		
Total	11	18

Tab. 8.2. Seeds and fruits identified in PEG 1 bis (elaboration: A. Forti).

(10-40x) (STM). Then, using standard compound white light transmission microscopy (400x) (LM), the features traditionally used to identify plant fibres were examined, including fibre cross-section diameter and shape and fibre lumen diameter and shape (Catling and Grayson, 1982; Ilvessalo-Pfäffli, 1995). Next, bundles of fibres were enclosed in acrylic resin LR white (polysciences), sectioned with a Reichert-Joung ultracut microtome (2μ) and stained using a solution of 1% toluidine blue and 1% borax. The dislocations (nodes) and cross markings of single fibres were also observed using LM (400x). Since it has been demonstrated that investigation of these traits is not enough to ensure correct identification of plant bast fibres (Haugan and Holst, 2013), single fibres from all the samples were also observed under polarised light using LM (x1000), as recommended by Bergfjord and Holst (2010) and Haugan and Holst (2013).

Caulking samples C1 and C2 were observed at the STM and seem to be composed of long, robust fibre bundles heavily covered with a brown crystallised material, most likely tar (Fig. 8.2a). The rope fragment (sample C3) is not as well preserved as samples C1 and C2, probably due to continuous or prolonged use. It is composed of similar but darker fibres (Fig. 8.2b). Ten separate fibre bundles from samples C1 and C2 react to anticlockwise twisting in a drying twist test, which is typical of hemp fibres (*Cannabis sativa* L.), jute (*Corchorus olitorius* L. and *C. capsularis* L.) and sisal (*Agave sisalana* Perr.) (Marshall, 1992). Only two of the ten fibre bundles in sample C3 twist anticlockwise; the others remain inert, probably due to damage to the fibre wall.

Some of the bundles under the transmitted light microscope show parenchyma cells all around the fibre bundle (Fig. 8.2c-d). The cells are fairly regular and rectangular and show openings very similar to the phloem ray cells seen in hemp stem samples (Catling and Grayson, 1982). Some clusters of crystals (probably calcium oxalate) were observed within the parenchymal cells and on the surface of the fibres (Fig. 8.2d); such clusters are frequently found in hemp stems in the pericycle, secondary phloem and parenchymal rays (Catling and Grayson, 1982; Bergfjord and Holst, 2010). Observed under LM, the ultimate fibres of the coloured cross-sections of the bundles have thick, angular walls with three, four or five sides and rounded edges, or are oval or round (Fig. 8.2e-f). The largest diameter ranges from 7 to 24 μm (mean 15.5 μm; n = 100). The lumina are round or flat and have a width between 1/3 and 2/3 of the cell diameter. The thickness of the cell wall and the size of the lumen are useful characteristics for species identification although these conditions vary until the cell has reached its final shape and depending on the growth conditions of the plant (Catling and Grayson, 1982; Ilvessalo-Pfäffli, 1995). The average fibre width in this study is narrower than those reported for hemp by Ilvessalo-Pfäffli (1995, av. 25, 10-51 μm) or by Garcia-Jaldon, Dupeyre and Vignon (1998, 20-40 μm), but our data fit well with the width of fibres macerated in our laboratory from cultivated hemp stems (Fig. 8.2g).

The single fibres under LM appear flat and ribbon-like with tapered ends. Many have nodes or dislocations, and no remnants of epidermis, hairs or stomata were observed. Although most of the fibres are fragmented, they are several centimetres long, in all samples. All fibres separated from the samples and observed under LM with polarised light exhibit 'Z'-oriented microfibrils on the upper outer wall surface when passing through the polariser plates (Fig. 8.2h-j). This observation and the results of the modified Herzog test, which was yellow, confirmed the identification of the bast fibres as hemp fibres. Therefore, based on traditional observations and the use of polarisation microscopy, we can conclude that all the fibres in the analysed samples are derived from hemp.

8.3 *Wood anatomy*

A total of 73 samples were collected from each element of the barge and the study on wood anatomy showed 4 types of wood used for the timber elements of the boat: *Quercus* spp. (deciduous oak), *Quercus ilex* L., *Ulmus* spp. and *Buxus sempervirens* L. (Tab. 8.3, Fig. 13.2). Once collected, the samples were stored in fresh water and then analysed under low-power STM (10x, 20x, 50x) to identify wood using specific literature (Schweingruber, 1990; Nardi Berti, 2006). According to wood identification, oak and elm are the most used woods for wooden floors in this wreck. In particular, *Quercus* spp. (49 specimens) was also used for most of the side planking (both sewn and clinker), for the shelf-clamp, for the stern-post, for the long peg inserted in the stern-post and for the treenails that join the frame to the planking; *Ulmus* spp. (22 specimens) was used for the lower planking, for the L-shaped element joined to the upper planking near the post and for a clinker plankon the southern side; *Buxus sempervirens* and *Q. ilex* are represented by only one specimen respectively and were used one, *Buxus*, for a peg that fastened the seam in the holes and the other, *Q. ilex*, for a treenail joining the frames to the hull.

Taxa	N.
Buxus sempervirens	1
Quercus ilex	1
Quercus spp.	49
Ulmus spp.	22
Total	73

Tab. 8.3. Wood identified (elaboration: A. Forti).

8.4 *Discussion*

The origin of the sediment

To evaluate the biological data examined so far, it is first necessary to understand the origin of the sediment. If we assume that it was deposited during the use of the barge, we might assume that it contained pollen and other plant remains of the vegetation of the environment in which the boat sailed, as well as some remains of the transported cargo. In this case, the biological record gives a possible reconstruction of the environment in which the boat sailed and information about the boat's use. To test this hypothesis, it is necessary to compare the pollen association recorded in the bilge sediment with stratigraphically related environmental samples. On the contrary, if the sediment was deposited after the boat was abandoned, it is probably similar to alluvial sediment deposited directly on the wreck and therefore not useful in providing information on the environment in which the boat sailed. It was therefore decided to compare the bilge sediment with that of the PEG1bis samples, which are approximately of the same age as the rope fragment and the amphora fragments found above the hull. These sediments contain plant remains which are very different from those collected in the bilge of the wreck. In both PEG1bis samples, pollen grains are very rare and cannot be compared with the pollen association of the samples collected inside the barge. There are quite a few identifiable fragments of taxa living in the lowlands along the river (probably *Phragmites australis* and *Carex* sp.) and of taxa living in the mountains (probably *Picea* sp. and *Pinus sylvestris*). Very fast sedimentation could be the reason why a low pollen grain content is observed in PEG1; an occurrence that fits well with a crevasse splay formed during an alluvial event – and the high fragmentation of the remains for long-distance transport. In the deepest sample, the presence of a few seeds of salt-tolerant plants, such as *Juncus maritimus* and *J. gerardii*, suggests that, prior to the deposition of alluvial sediments, the site was characterised by wet coastal vegetation growing on salty soils. In addition, the excellent preservation of pollen and spores in the bilge sediment and the low number of plant taxa that do not live in the lowland or coastal plain (only beech and chestnut) suggest that the bilge sediment and its fossil content were not reworked or transported over long distances by high-energy waters and were probably deposited under calm conditions. Therefore, the sediment collected from the bilge did not mix with the sediment transported during the mid-5th century AD flood event, which was probably the origin of the PEG 1bis samples examined.

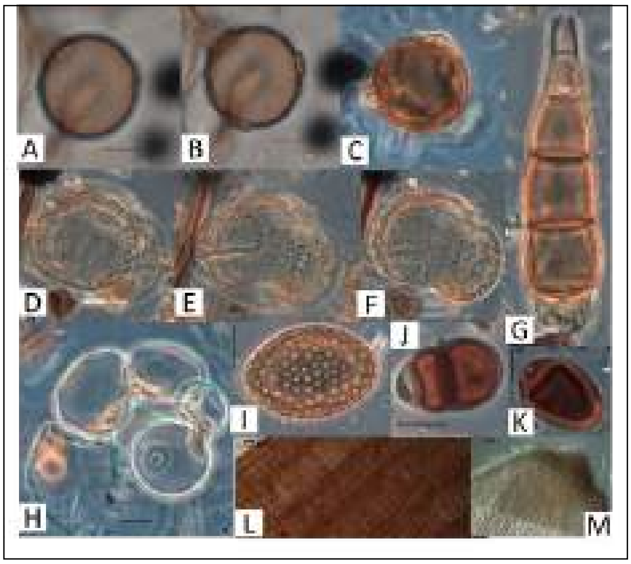


Fig. 8.1. Pollen and NPPs from the bilge clayey sediment (A-K) and seeds from PEG1bis 275-285 cm organic-rich silt layer (L-M). A-B: *Cannabis sativa*. C: *Sanguisorba minor* type. D-E-F: *Pinus* cf *pinea*. G: HdV-201 *Xylomyces chlamidosporis/X. aquaticus*, bar = 20 µm. H: HdV-700 IOL of foraminifers. I: Ascospore of *Gelasinospora* sp. J: Conidium of *Trichocladium* cf *opacum*. K: Ascospore of *Podospora* type. L: Testa cells of a *J. maritimus* seed. M: Exagonal outer cells of the endosperm and endosperm inner cells of a *Juncus gerardii* seed (Bar = 10 µm if not differently indicated) (photo: A. Miola and M. Maritan).

When was the bilge sediment deposited?

Regarding the problem of understanding when the bilge sediment was deposited, the bilge pollen record was compared with 26 pollen records collected in Emilia Romagna and dated to the Subatlantic climatic period (2700 BP to recent) (Accorsi *et al.,* 1999), which obviously includes barge dating. Forest pollen spectra in Emilia Romagna in the period from 2700 BP to recent are consistent with the bilge sediment pollen association. The percentage of tree and shrub pollen varies from 60% to 41%, indicating 'semi-open areas', which led Accorsi *et al.* (1999) to interpret the lowland landscape as a mosaic of open areas, deciduous mesophilous mixed woods (mainly composed of *Quercus*, *Ulmus*, *Carpinus*, *Corylus*, *Fraxinus* and *Acer*) and some stands of Mediterranean evergreen oak wood.

Several cultivated plant taxa such as *Juglans*, *Olea* and *Castanea*, *Secale*, *Cannabis sativa* (Fig. 8.1a-b) and *Cucumis sativus/C. melo* appear in our pollen record. This evidence suggests a more precise time frame because we know that pollen grains of walnut and olive were common in Roman times in the North Adriatic coastal plain and in the pollen records of the central Po Valley (Accorsi *et al.,* 1999; Miola and Valentini, 2004; Mercuri *et al.,* 2013; Bosi *et al.,* 2015), and that the low percentage of chestnut pollen (0.2%) fits well with the average pollen percentage of 2%, in the Emilian pollen records of Subatlantic and Roman lowland sites (Bosi *et al.,* 2015). Higher percentages of chestnut only occur in Medieval pollen records from the 7th to 9th century AD (Mercuri *et al.,* 2013; Bosi *et al.,* 2015). Furthermore, the relatively high percentages of Brassicaceae, rye, hemp *and Cucumis sativus/C. melo* could also be connected to the cultivation of these plants in open areas near the banks. During the Roman period, in fact, the cultivation of Brassicaceae, rye and hemp (the pollen grains of which occur in our record) is well documented in the coastal plain and central Po Valley (Accorsi *et al.,* 1999; Mercuri, Accorsi and

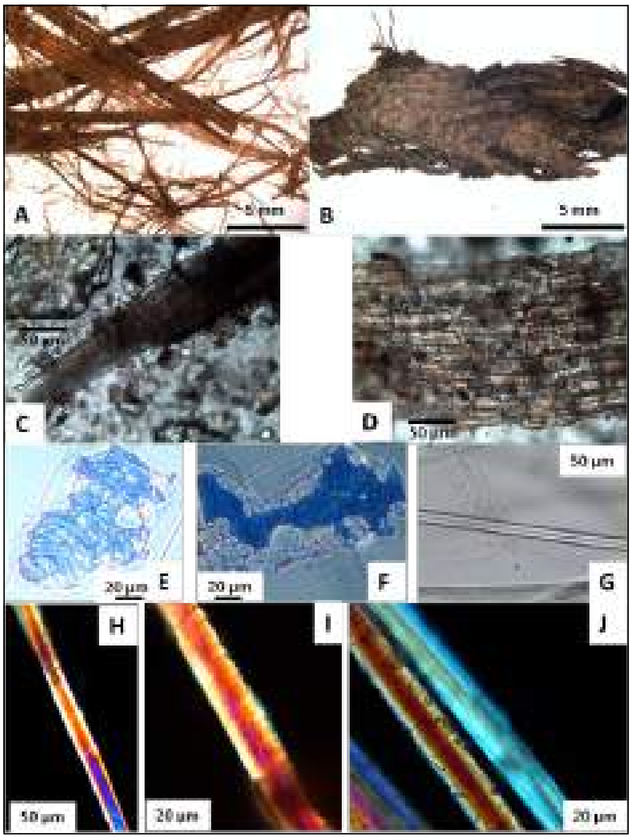


Fig. 8.2. Fibres from caulking mat and a rope fragment of Santa Maria in Padovetere wreck. A: Caulking material from between 13th and 14th plank of the ship's hull (sample C1); B: Segment of a tarred rope (sample C3); C: Bundle of fibres with parenchyma cells all around; D: Parenchyma cells around the bundle of fibres; E: Cross section of the ultimate fibres of the bundles' stained cross sections (sample C1), intense blue colouring of the fibres due to high content of lignin on the thick secondary wall of fibres, lumen extremely reduced; F: Cross section of the ultimate fibres of the bundles' stained cross sections observed under light microscope (sample C2), intense blue colouring of the fibres due to high content of lignin on the thick secondary wall of fibres, lumen extremely reduced; G: Ultimate fibre of *C. sativa*; H: Ultimate fibre (sample C1) observed under polarised light, Intense birefringence, presence of dislocations (nodes), lumen extremely reduced; I: Ultimate fibre (sample C2) observed under polarised light, focus and zoom on the upper surface of fibres wall, fibrillary orientation arranged in Z twist sense; J: Ultimate fibres (sample C3), observed under polarised light, focus and zoom on the upper surface of fibres wall, fibrillary orientation arranged in Z twist sense (photo: M. Maritan).

Bandini Mazzanti, 2002; Miola and Valentini, 2004; Bosi *et al.,* 2015; Mercuri *et al.,* 2015). As for the presence of *Cucumis melo,* its appearance is documented in the region by the recovery of seeds only after the 1st and 2nd centuries AD in Mutina (Bosi *et al.,* 2015). The rare presence of *Fagus* in this analysis fits well with the hypothesis proposed by Accorsi *et al.* (1999) and Bosi *et al.* (2015) that, during the Roman and early Medieval period, *Fagus* grew at lower altitudes than today, so only a few grains would have reached the plains. The absence of *Tilia* pollen is also in agreement with Roman and early Medieval pollen data from the Emilia plain (e.g. Bosi *et al.,* 2015). In addition, the absence of this pollen is connected to the use of green branches as food for livestock, preventing them from flowering and producing pollen (Accorsi *et al.,* 1999). We conclude that the comparison of the bilge pollen record with the regional pollen record suggests that the sediment was deposited at least after the 1st or 2nd century AD (depending on the appearance of *Cucumis melo* cultivation) and does not exclude the possibility that the sediment was deposited during the life of the barge, at the end of the Roman Age or the beginning of the Middle Ages.

Palaeoenvironment

Concerning the reconstruction of the palaeoenvironment, we can observe that most of the dry components of the bilge pollen record are now present in the wild plant communities growing on the Adriatic coast, mixed with the historical pine forests of San Vitale-Ravenna, Cervia and Classe (Lazzari, Merloni and Saiani, 2010). More interesting is the presence in our pollen record of pollen grains (Fig. 8.2d-f) similar to *Pinus pinea* pollens, in size, leptome wall sculpture (psilate) and the presence of an evident marginal frill (Accorsi, Bandini Mazzanti and Forlani, 1978). In these historical pine forests, the pine stone is the main species, although it is not an autochthonous component but successfully introduced by the Etruscans, Greeks, Romans, and Arabs throughout the Mediterranean, where it now grows mostly in pure stands in acidic or neutral sandy soils (Fady, Fineschi and Vendramin, 2004). As far as we know, Roman cultivation of pine in Emilia Romagna has only been hypothesised by archaeobotanists to explain the very frequent reports of its edible seeds (e.g. Bosi *et al.,* 2015) and of wooden artefacts, particularly those used for shipbuilding, in Roman archaeological contests (e.g. Beltrame and Gaddi, 2007, 145; Boetto, 2008, 48-49; Allevato *et al.,* 2010; Sadori *et al.*, 2015; Giachi *et al.,* 2017; Essert *et al.,* 2018; Moser, Nelle and Di Pasquale, 2018). Therefore, the presence of well-preserved pollen of *Pinus* cf. *pinea* in our record is very intriguing despite its rarity (1.6%), because it could document the presence of cultivated plants in the coastal area of the north-western Adriatic, where the aeolian dunes provide a favourable habitat for this species. Pollen analysis of a well-dated sedimentary sequence from the area could verify this hypothesis.

Hygrophilous and marshy trees, shrubs and grasses are well represented by the pollen grains and provide information on the wetland communities along the watercourses and thus on the environment in which the barge was navigating. The prevalence of riparian wildwood pollen taxa (*Alnus*, *Populus*, *Salix* and *Sambucus nigra*) suggests a freshwater environment, since among these, only *Alnus glutinosa* can tolerate saltwater. The taxa of freshwater hygrophilous herbs are represented by the *Cyperaceae* and the *Sparganium* type (including the species of bur reeds and narrow-leaved cattails), which typically grow on riverbanks. Hygrophilous Poaceae (such as the common reed, *P. australis*) could also be a peculiar component of these riverbanks, even in slightly brackish water conditions. Horsetails (*Equisetum*) and marsh ferns (*Thelypteris palustris*) indicate wetland plant communities of open areas; *Lemna* (including *L. minor*) and *Nymphaea* (5%) represent open water plant communities. None of these species tolerate salt or brackish water. Fragments of dinoflagellates and foraminifera are present in our record, Fig. 8.1h). They are usually common in marine and coastal waters (Meier and Willems, 2003), but their scarce presence cannot be taken as an indicator of salty or brackish water conditions and, especially, they are not associated with pollen from halophilous or salt-tolerant grasses such as Chenopodiaceae, Asteraceae (e.g. *Aster tripolium*) or Plumbaginaceae (*Limonium narbonense*, *L. bellidifolium*), as normally occurs in pollen records from the North Adriatic coast (Miola *et al.,* 2010). The relatively high percentages of pollen of Brassicaceae, rye, hemp and *Cucumis sativus/C. melo* could be related to barge loading or the cultivation of these plants in the centuriated soils near the riverbanks (see the map of south-western Comacchio in Zangheri, 1936). The relatively high percentage of pollen (3%) of the dry meadow plant *Sanguisorba minor* (Pignatti, 1982) (Fig. 8.1c) and the co-occurrence of some other meadow species such as *Trifolium repens-type*, *Salvia verticillata* and *Plantago major-media*-type may indicate that the barge was used to transport animals and their fodder. It should be noted that a Mediterranean subspecies (*Sanguisorba minor* subsp. *muricata*) is known to be a very nutritious forage for sheep (Viano, Masotti and Gaydou, 1999). The presence of fungal spores growing in or on the dung supports this hypothesis.

8.5 *Materials and technology used in the construction of the boat*

Analysis of the wood and its selection, pitch and plant fibres collected in the hull provides information on barge construction technique.

An examination of the wood used in the barge suggests that the timber was collected at a local level. In fact, the two most represented species, oak and elm, were components of the mesophilous mixed deciduous forest that is supposed to have been in the area. These woods offer important advantages in boat construction due to their mechanical and technological properties. Oak and elm woods are particularly useful because they are very crash-resistant and do not decompose easily in a permanently damp environment, thus ensuring stability and long life for a wooden boat (Rival, 1991; Sadori *et al.,* 2015). Boxwood, which is used to make a barge peg, is used for this employment only in shipbuilding. It is in fact a type of wood that does not float because it is very hard and very compact, with a high specific weight, and in addition, it is not impact-resistant and therefore completely unsuitable for shipbuilding (Rival, 1991; Walker, 2019). Elm and deciduous oak are respectively used for planking and frames. The common use of these two hardwoods in ancient shipbuilding is well established, as can also be verified in several wrecks, such as those found in the Roman ports of Pisa, Portus and Neapolis (Sadori *et al.,* 2015). The use of oak and elm may indeed be considered a standard practice in the construction of sewn ships during the Roman period in northern Italy (Beltrame, 2002a; Beltrame and Gaddi, 2013a). As already mentioned, their use is due to their specific properties that make them excellent materials for shipbuilding. Their presence also provides environmental data on the catchment area of the timber, which was, according to pollen data, characterised by mixed mesophilous forests in which some evergreen taxa were present.

Caulking and ropes: which vegetable fibres?

In Italy, research on the origin of seam wadding, caulking and rope from archaeological sites is still very rare (cf. Mercuri *et al.,* 2015). In particular, very few studies have been conducted on this topic in the Mediterranean area (Black, 1999; Shimony and Werker, 2003; Boetto and Rousse, 2012; Boetto *et al.*, 2012), and even fewer concern shipwrecks on Italian coasts (Castelletti *et al.,* 1990; Arobba *et al.*, 2014). From the literature, we know that in a study of the hull of the Roman ship Albenga, found in the northern Tyrrhenian Sea (Savona, Italy), Arobba *et al.* (2014) documented the use of hemp fibres, while Willis (2017) reports that bast fibres, 'probably from *Tilia* sp.', were used for stuffing seams, and that esparto grass (*Stipa tenacissima*, native to Spain) was used as cordage in three sewn boats in the north-western Adriatic tradition. Plant and animal materials in north-western Europe were used for shipbuilding, and mosses were also reported to be common in the construction and repair of wooden ships from the Bronze Age to the 20th century, because they were easy to find and be adapted to this use. Hemp as a caulking material has never been reported in the construction of ships in north-western Europe (Deforce *et al.,* 2014), while the use of straw in combination with reed is mentioned by de Weerd and Haalebos (1973) regarding a Roman riverboat in the Netherlands, and Beltrame (2002a) has hypothesised the use of these materials in Roman ships on the Adriatic coast. The use of hemp fibres for caulking and ropes can be explained by the very well-documented expansion of hemp cultivation in the Italian peninsula during the Roman era (Mercuri, Accorsi and Bandini Mazzanti, 2002) and by the fact that reed leaves degrade very quickly (Dinka, Ágoston-Szabó and Tóth, 2004) and are probably less durable than hemp fibres. *S. tenacissima* fibres would have to be imported from Spain.

Organic residues of pitch samples taken from the barge

Archaeological information can also be obtained by analysing the biomolecular components of the pitch organic residues and the natural products that contributed to its formation (Evershed, 2008). Therefore, samples from different parts of the barge were analysed by Andrea Vavasori from the Department of Molecular Sciences and Nanosystems of the Ca' Foscari University of Venice using FTIR (Ribechini, 2009). Vavasori (Beltrame *et al.*, 2021) reports that the signals at 1722-1695 cm-1 indicate the presence of esters and carboxylic acids, while the signals at 2928 and 2867 cm-1 are characteristic of aliphatic hydrocarbons. As referred by the scientist, analyses of these spectra, together with their comparison with previously reported FTIR spectra (Robinson *et al.*, 1987), suggest that the pitch from this barge was probably produced from Pinaceae resins (Beltrame *et al.*, 2021).

The same samples were treated with acetone and the extracted liquids were analysed by GC-MS. The fact that diterpenoid compounds, oleic acid, long-chain alcohols and hydrocarbons, silicates, phthalates and adipates were detected in all samples proved that the pitch was derived from a resin of the Pinaceae family. Markers were also detected, such as, retene, tetrahydroretene, dehydroabietic acid, 7-oxo-dehydroabietic acid, methyl-dehydroabietate and abietic acid. In addition, the presence of tetradecene and unsaturated fatty acid derivatives, which are believed to indicate vegetable oils, agrees with the apyrolytic treatment of resinous pine wood. Furthermore, Vavasori points out, the detection of long-chain alcohols and hydrocarbons derived from palmitic and stearic acids indicates that Pinaceae resin was probably mixed with wax (Beltrame *et al.*, 2021).

TECHNICAL STUDIES

Carlo Beltrame, Elisa Costa

9. DESCRIPTION AND ANALYSIS OF THE HULL OF SANTA MARIA IN PADOVETERE

The preserved remains of the hull of Santa Maria in Padovetere are 20 m in length and 4 m in width. The hull is orientated east-west and is aligned with the ancient bank of the paleo-river *Padus*; it lies at a steep angle sloping from a depth on the sea level of -1.26 m to -2.35 m in a thick layer of sand and from -2.35 m to -3.60 m in a thick layer of clay. The hull lies on the right side with the bottom, listing transversally at around 40° to the vertical and longitudinally at around 10°. The deeper portion of the hull, the stern, part of the bottom and part of the right side, lies below the aquifer, permitting the wood to be maintained in excellent condition. On the contrary, the higher portion in the sand is almost completely decomposed and has probably been impacted by post depositional factors (Figs. 9.1, 9.2).

9.1 *The bottom and the sides*

The barge belongs to a type of flat-bottomed boats with a 'box-shape'; the bottom of the hull measures 17×2.9 m and it is composed of nine single-plank strakes, flush-laid and joined by running stitching. The width of the planks ranges from 24 cm to 36 cm and the thickness is about 50-60 mm. The bottom is complete in the stern, while it is incomplete in the bow, as some planks on the portside have deteriorated, leaving the complete shape of the bottom in this part only slightly legible. The longest central strake is complete and is made by a unique plank measuring 17 m long, cut to form a pointed end at both ends. Towards the stern of the barge, between frames F17 and F19, at 2.60 m from the end of the third plank strake (P3), there is a sewn repair, probably made after construction, to stitch a longitudinal fracture of a crack in the wood 1.12 m long (Fig. 9.3).

The planking is assembled with the sewn technique. The diagonal channels of the sewing, with an inclination of 70° and a diameter around 2 cm, was realised at 2 cm from the inner edge of the planks, with intervals from 5 cm to 8 cm; they are plugged with conical wooden pegs from the interior face of the plank to the external edge (Fig. 9.4a). A vegetable seam wadding, or caulking roll, runs inside the boat and is held by the stitching. The ropes used to join the planks are three-stranded braided 8 mm wide, like those of the Valle Ponti ship (see further) (Castelletti *et al.*, 1990, 155); this kind of rope is softer and more homogeneous in the fold and at the same time it is flatter than a multi-stranded round rope and was better adapted for its purpose because it was more yielding and it could be better compressed in the channel (Fig. 9.4b). The sewing pattern consists of an X alternating with double parallel stitches (XIIXIIXIIXII) and is similar to that of the Valle Ponti hull, although there are four transverse ropes (Berti, 2017, 30, 4) (Fig. 9.5a-d).

The portside near the stern of the barge has collapsed, allowing the little portion of the side and the stern-post to be in the lower strata of clay and under the water table. This allowed, as already mentioned, the perfect conserva-

Fig. 9.1. The hull at the end of the excavation (photo: C. Beltrame).

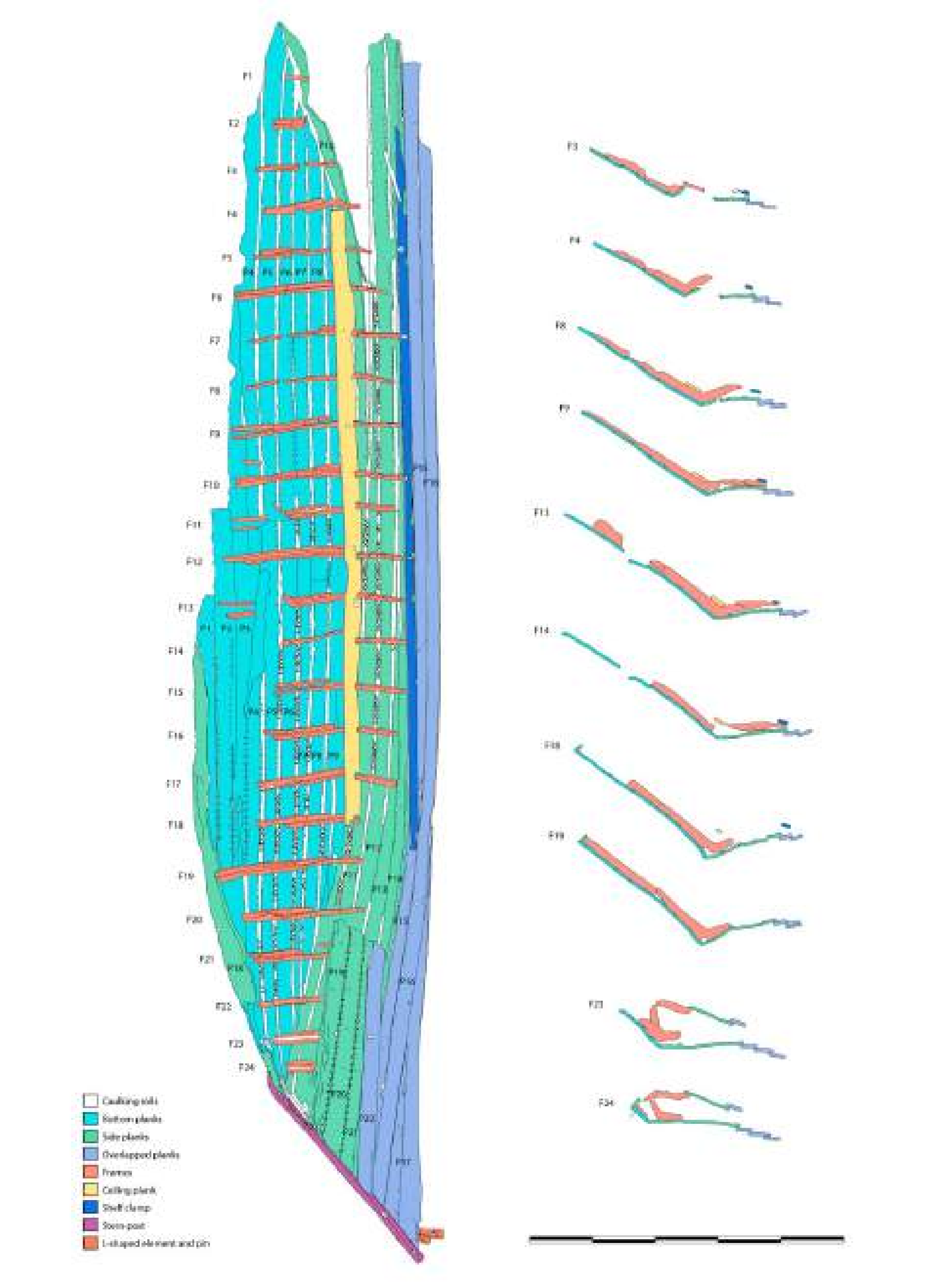


Fig. 9.2. Perspective drawings of the barge: plan and section in navigation position (drawing: E. Costa).

Fig. 9.3. Longitudinal fracture on plank P3 repaired with the sewing technique (photo: E. Costa).

Fig. 9.4. a. Conical wooden peg. b. Sample of the braided rope recovered from the sewing (photos: E. Costa).

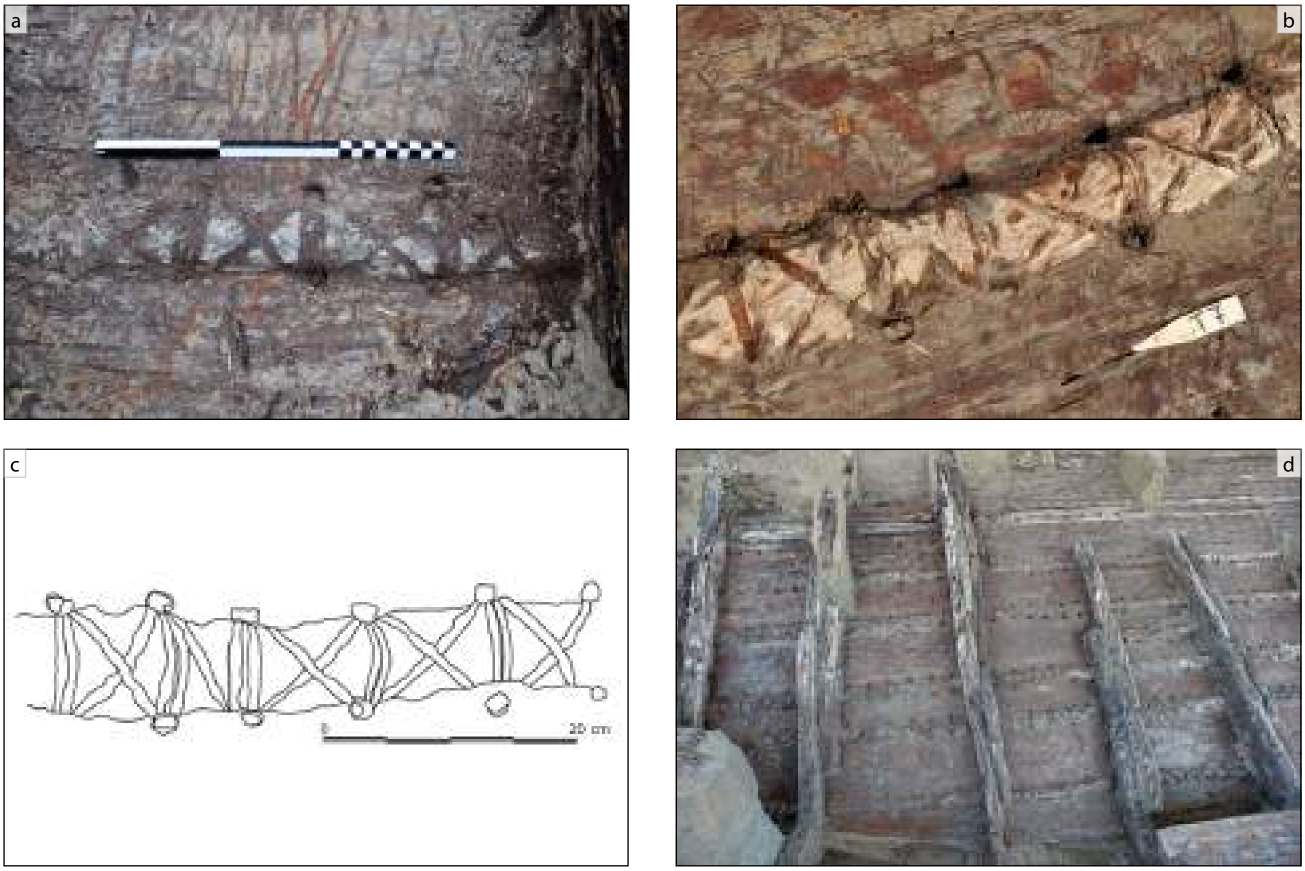


Fig. 9.5. a-b. A detail of the sewing. c. Drawing of the sewing pattern. d. Bottom of the hull with the sewing technique (photo and drawing: E. Costa).

Fig. 9.6. The part of the portside collapsed inside the hull (photo: E. Costa).

Fig. 9.7. A detail of the external hull with the holes of the sewing technique (photo: C. Beltrame).

tion of the entire area of the stern (Fig. 9.6). The portion of the collapsed side has allowed the documentation and study of the external surface of the hull's planking and the sewing. The diagonal channel of the sewing, in contrast with the inner face, ends at the edge of the plank with a squared recess that protects the sewing rope from damage from abrasion and, furthermore, reduces friction with the water (Fig. 9.7).

The section of the barge presents a flat bottom without a keel and the sides are joined to the bottom strakes with an inclination of 130° at the midships. The side planking is both sewn and nailed to the bottom planking. Indeed, it is possible to count four iron nails (spaced by an average of 1 m) on the only visible part of the first plank of the portside, near the stern. In this portion of the boat, it has been possible to control the sections of the planks in connection between the bottom and the side, which are bevelled at 45°, permitting a more stable connection and avoiding a different deformation of the two planks leading to a fracture (Fig. 9.8).

The completely preserved starboard side is 1.45 m in height at the midships and 2.15 m at the stern. This side is made up of 8 strakes: the first five strakes are assembled by stitching and flush-laid, while the three upper strakes are overlapped and nailed along the edge; one of these does not cover the entire length but starts from about two thirds of the hull. The five sewn planks (P10-P14) have an average width of 28 cm and a thickness of 4.5 cm; the last plank P14 has a thicker lip, interpreted as a reinforcement to accommodate the nails joining it to the first lapstrake plank or 'clinker strake'. The P11 and P13 planks do not reach the bow but they end tapered about respectively at a third and at half of the hull, to follow the water lines (Fig. 9.9).

The first two lapstrake planks, P15 and P16, are 24 cm wide and about 6 cm thick; in the stern portion, the P16 plank is broadened through mortise-and-tenon technique with a triangular stealer reaching a width of 70 cm, to raise the terminal area of the stern. The six tenons have no pegs and are arranged along the edge at irregular intervals. Measuring from the stern we have 12 cm between the 1st and the 2nd mortise, 38 cm between the 2nd and the 3rd, 42 cm between the 3rd and the 4th, 42 cm between the 4th and the 5th, 65 cm between the 5th and 6th (Fig. 9.10a-c).

Fig. 9.8. A detail of the connection at 45° between the first plank of the side and the plank on the bottom (photo: E. Costa).

For a further rise of the stern area, a third lapstrake plank of elongated triangular shape is added at 6 m from the stern (P17). These three overlapped strakes are nailed with sparse iron nails; the use of this technique for assembling the planks suggests that they did not have a structural function and that they never went below the water level, but that they were probably used as side protection during moorings and often needed to be replaced (see further).

The thickness of the side planking decreases on a regular basis towards the stern, until reaching the batten with a thickness of 1.2 cm. In the last two metres towards the stern, the overlap of the strake gradually decreases until it disappears in the connection with the stern-post, where the planks become carvel jointed; to carry out this expedient, the underlying plank actually has a degrading moulding along the contact surface between the planks (Fig. 9.11a-b).

At the stern end, the first lapstrake plank P15 has two rectangular notches on the top edge of 4 cm and 7 cm

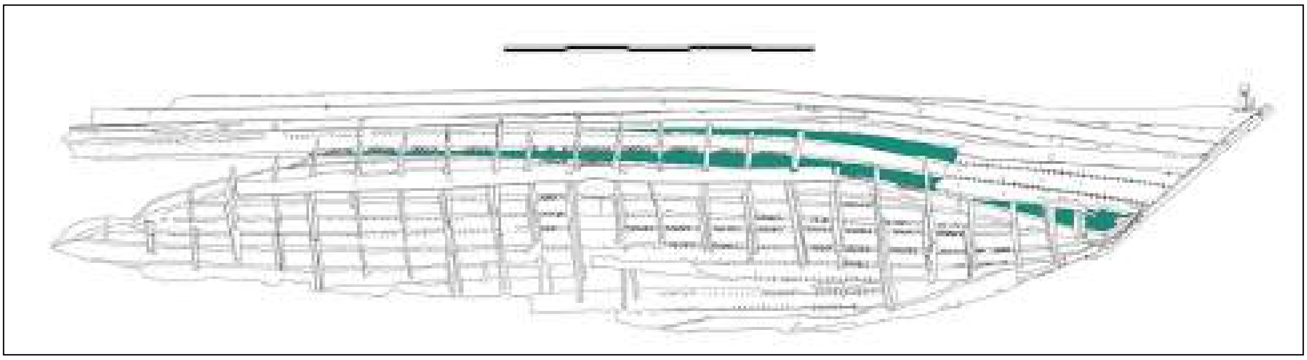


Fig. 9.9. Plank P11 and P13 that end tapered (drawing: E. Costa).

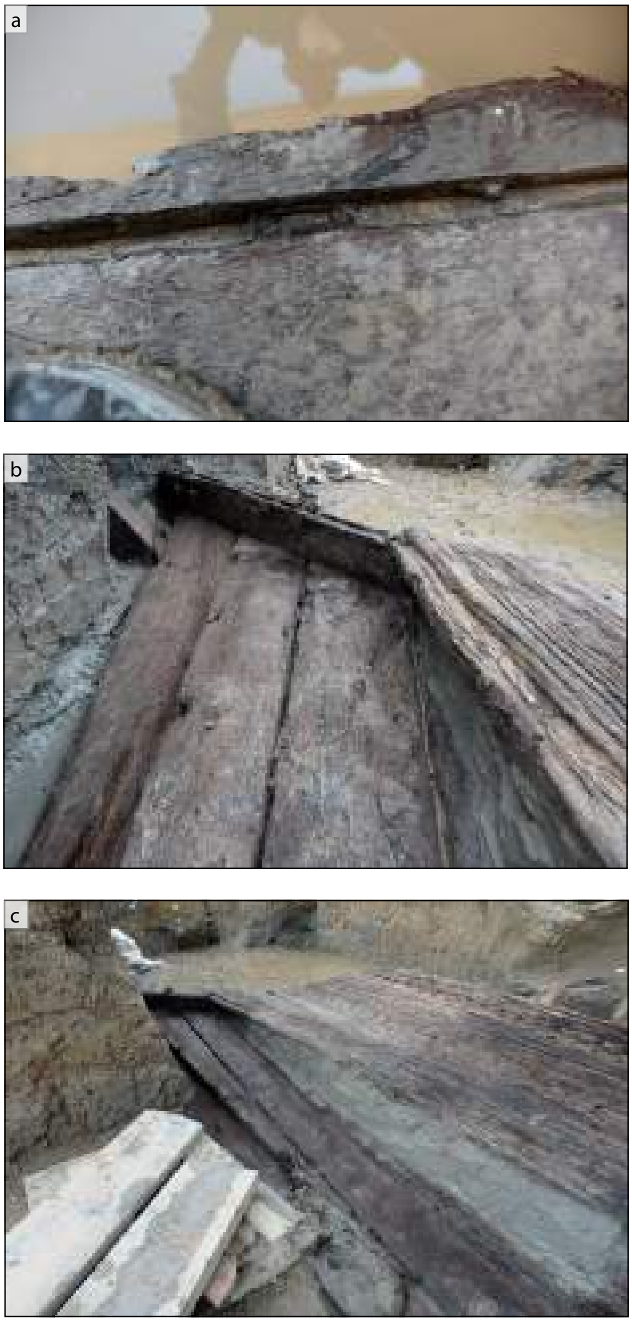


Fig. 9.10a-c. The mortise-and-tenon joint (photo: E. Costa).

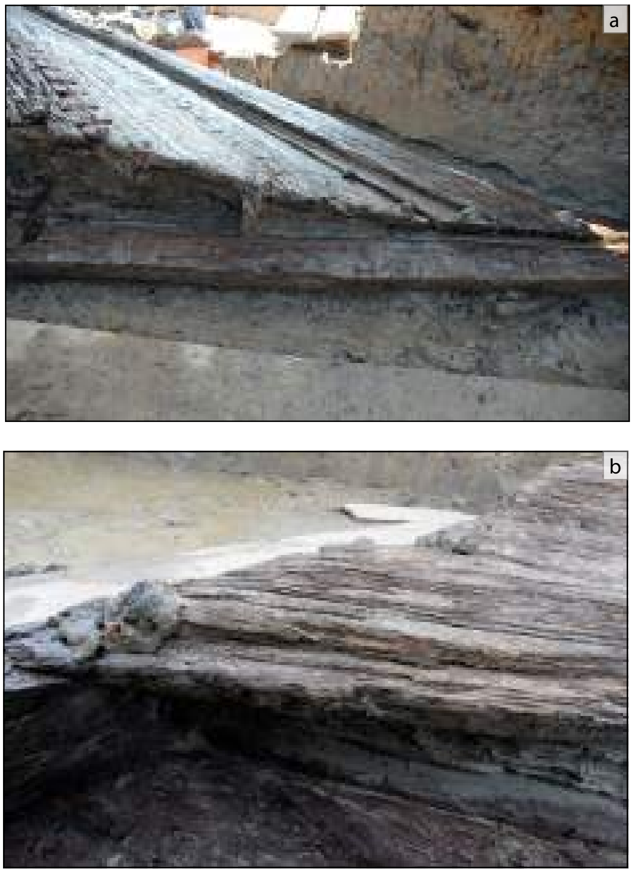


Fig. 9.11a-b. Degrading moulding along the contact surface between the planks to reach the batten of stern with a minimum thickness (photo: E. Costa).

in length and 3 cm in depth and one trapezoidal of 10×3 cm; these most likely serve the purpose of supporting the transverse beams of the little stern deck.

The incomplete portside of the hull is composed of four planks, the first one (P18) is still in the original position connected to the bottom and the second strake is no longer visible; the collapsed portion, still connected with the frame and the stern-post but disjointed and rotated, is composed by other three sewn planks (P19-P21) and one lapstrake (P22) (Figs. 9.12, 9.2).

Fig. 9.12. The four planks of the collapsed portside (photo: E. Costa).

Fig. 9.13. A detail of the holes of the sewing as a reinforcement of the connection between the planks and the hull in the lower part (photo: E. Costa).

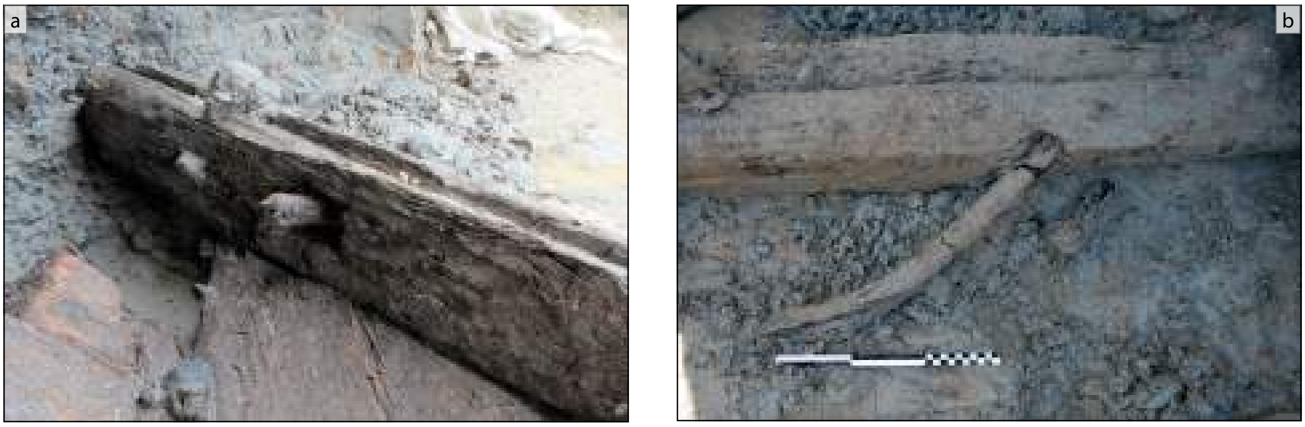


Fig. 9.14a-b. The vertical squared through-hole with the broken wooden peg (photo: E. Costa).

Fig. 9.15. The L-shaped timber at the stern (photo: E. Costa).

9.2 *The stern*

The long stern-post is 3.60 m long and forms a longitudinal angle of 140° with the bottom. The thickness of the stern-post is 14 cm and the width tapers from 17 cm at the bottom to 15 cm at the top. It curves and continues for about 40 cm along the bottom of the hull, joined from the outside to the central plank with three iron nails without any visible more elaborate scarf. The extremities of the planks are fixed with nails seated in a rabbet, 2-3 cm wide, which runs the entire length of the stern-post. In addition, at the lower end of the post, the first three strakes are also joined with a sewing, of which we can appreciate only the channel in as much as the ropes are not preserved. The sewing holes are spaced at about 10 cm intervals (Fig. 9.13).

In the upper part of the post, at 46.5 cm from the top external edge, there is a perfect vertically squared through-hole, 8×6 cm, in which a broken wooden peg is inserted; it is 60 cm long with a diameter of 3 cm but was originally longer (Fig. 9.14a-b). In the same area, an L-shaped wooden element is still nailed, with an iron nail, to the topmost strake on the portside, at 15 cm from

Fig. 9.16. a. The vertical treenail connecting the frames to the hull. b. The horizontal treenail connecting the frames between them (photo: E. Costa).

Fig. 9.17. The L-shaped floor-timbers obtained from naturally curved branches.

Fig. 9.18. Rounded notches in correspondance with the caulking rolls and squared limber holes (photo: E. Costa).

Fig. 9.19. One of the futtocks connected to the frame with iron nails (photo: E. Costa).

the post, in vertical position; the trapezoidal shape, the presence in the lower face of a diagonal cut parallel to the side and a concretion of an iron nail indicated that this was not its correct orientation but that it had to be rotated in a horizontal position and had to be nailed both in the portside and in the starboard side to hold and strengthen the sides of this area. The peg and L-shaped timber may have supported a steering device, suggesting the west end as the stern (Fig. 9.15).

9.3 *The framing*

The framing consists of alternating and symmetrical pairs of L-shaped floor-timbers obtained from naturally curved branches. They are connected to the hull with at least three treenails with a diameter of 2 cm, and to each other through two or three horizontal treenails with the same diameter of the vertical ones (Fig. 9.16a-b). The frames have a rectangular section of about 12 cm sided (6 cm for each

Fig. 9.20. The shelf-clamp running from F4 to F18 (photo: E. Costa).

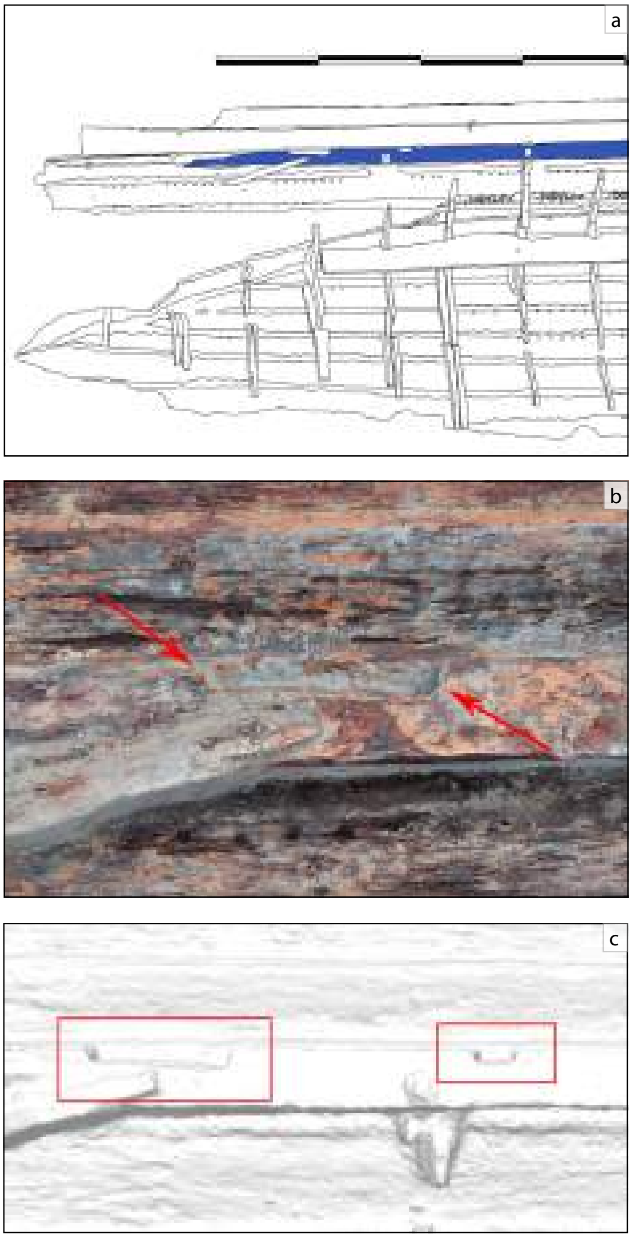


Fig. 9.21. a. The first big notch and two of the small six rectangular notches. b-c. Detail of the first notch at the bow (image and 3d model) (photo and drawing: E. Costa)

element), 16-22 cm moulded and have a centre distance of approx. 60-80 cm (Fig. 9.17). On the face in contact with the planking, in correspondence with the caulking rolls, there are rounded notches, 10 cm wide and 3-4 cm high; along the face in contact with the bottom, there are also rectangular limber holes, 7 cm wide and 2 cm high, located in the centre of each strake in order to avoid stagnation of water in inaccessible points and to facilitate its flowing, making it easier to empty the boat at the lowest point of the hull (Fig. 9.18).

In some cases (F6-7-9-10-11), the frames do not cover the entire height of the side and require an additional in-line element, a futtock, which is fixed by means of an iron nail

Fig. 9.22a-b. The L-shape recess with two holes near the stern (photo: E. Costa).

Fig. 9.24a-b. A detail of the rectangular recesses along the external edge (photo: E. Costa).

Fig. 9.23a-b. The ceiling plank connected to frame F9 with an iron nail (photo: E. Costa).

along the diagonal scarves between the two elements. The futtocks measure, on average, 15 cm in height, they have the same thickness as the frames and the length is variable depending on the position on the hull and the length of the related frame (Fig. 9.19).

9.4 *The longitudinal inner timbers*

Along the starboard side a shelf clamp, or notched stringer, 14 cm wide, 6 cm thick and 11.50 long, was nailed

Fig. 9.25. The quadrangular recesses and the curvature of the ceiling plank in the central area, between the frames F12 and F13 (photo: E. Costa).

with at least five iron nails to the ends of the frames, running from F4 to F18, very similar to the one found in the Valle Ponti ship (Berti, 2017, 31) (Fig. 9.20a-c). On its upper side, seven small rectangular notches were created, probably suitable for housing the beams supporting the deck, which unfortunately have not been preserved. Six of them measure about 10 cm in length and 4 cm in height, whereas the first at the bow measures 40 cm in length (Fig. 9.21a-c); the extremity at the stern ends with an L-shaped recess, with two holes of 2 cm in diameter, positioned at 5 cm and 40 cm from the head of the stringer and it probably has the same employment and the same functioning of the rectangular notches, but the holes could be connected with others functions (Fig. 9.22a-b).

Only one ceiling plank is still *in situ* and lies over the floor-timbers from F4 to F18, but it seems to be broken at the stern end and presumably it continued for several metres; it is nailed to frame F9 with a big iron nail (Fig. 9.23a-b) and it measures 9.80 m in length, 30 cm in width, 4.5 cm in thickness. It presents rectangular recesses along the edge to adapt, fit and reinforce the vertical parts of the frames (Fig. 9.24a-b). Its visible surface presents many axe marks, a hole with 3 cm of diameter at the bow extremity and three quadrangular recesses in the central area, between the frames F12 and F13. One of them is littler and measures 4 cm; the other two measure approximately 7 cm and delimit a portion of the ceiling which presents a curved shape along the internal edge, apparently for a bilge pump (Fig. 9.25).

9.5 *A bilge-pump area?*

A curious aspect of this hull is the absence of the caulking rolls and of the holes or signs of sewing in the area of the curved shape of the ceiling between frames F12 and F 13; it was not possible to identify how the planks are joined as it would have been necessary to disassemble the hull and highlight the side of the planks, but the use

Fig. 9.26. The area of planking between frames F12 and F13 without the holes and the sewing and the curvature of the ceiling planking (photo: E. Costa).

of unpegged mortise-and-tenons is a possibility. Between planks P8 and P9, on the other hand, the pegs of the stitching holes are still visible and the caulking rolls are cut in correspondence with the frames, determining that the two planks were originally sewn (Fig. 9.26).

A very similar situation was found in the ship of Valle Ponti, where the stitching in the central bilge is missing and the ceiling is worked with the same curvature (Berti, 2017, 31). In that case, Bonino (Berti, 2017, 38) made the hypothesis that in this area there was a mast; this is not a very plausible proposal since it does not justify the absence of stitching between the planking which would create a critical area of water infiltration in the most stressed part of the hull due to the force of the mast and the sail.

This area, in correlation with the squared holes located on the lateral position of the curvature of the ceiling, could be interpreted as the location of the structure for a bilge-pump that is not preserved, since the absence of caulking rolls would have allowed the free flow of water in this central part of the hull. An example of this typical curved shape for the hosting of a bilge-pump can be seen on the ceiling of the Port-Vendrés A shipwreck and on many other ships of the Imperial period (Chevalier and Santamaria, 1972, 27). The digital reconstruction of the barge (see further) confirms that the central area between frames F12 and F13 is the lowest part in lightship condition. In medium and full cargo conditions, the lowest part of the boat is between frames F16 and F17, but in this area, the absence of the deck, a necessary condition for the upper structure of the pump, implicates the setting-up of the bilge pump between F12 and F13. Most likely, the barge were emptied without the cargo onboard.

Carlo Beltrame

10. METHOD OF CONSTRUCTION AND TYPOLOGICAL STUDY OF THE SANTA MARIA IN PADOVETERE SHIPWRECK AND COMPARISONS WITH SIMILAR BARGES

The construction method of this boat cannot be indexed in the 'classical' skeleton-first or shell-first methods. Since this is a riverine watercraft with a completely flat bottom, the identification of the construction method must be found outside the marine environment. The sequence of construction which we can see on this barge can be compared to one used in many watercrafts discovered in Central Europe, in the lakes and in the rivers (especially along the Rhine) and dated to the Roman or Late Roman period. Arnold (1998) has coined the definition 'construction sur sole', which can be translated as 'bottom-based' to define the method used in this macro-region to build boats with flat bottoms and hard chine, without a keel, and made of planks not jointed together and caulked with nailed moss. In these boats, the sides form an almost 90° degrees angle with the bottom producing a sort of 'box shape' transversal section; sides and bottom are jointed thanks to the use of L-shape frames.

According to Arnold (1998), bottom planks had to be placed over a work-platform, presumably made with temporary transverse timbers, where they were pulled together with high precision. Flat frames joined to the bottom could also join together with the bottom planks. Moss was used to close the spaces between the planks (Fig. 10.1).

It is probable that the barge of Santa Maria in Padovetere was assembled according to, more or less, the same sequence. The planks could be fixed over temporary transversal timbers, but they were joined together with the sewing technique where the caulking (that has to be considered the water-proofing) was guaranteed by the contact between the planks and the caulking roll of pitched vegetable fibres. The joining of the sides to the bottom was made using the sewing technique and the help of the L-shape frames. Since the stem was not preserved and the stern was not completely excavated, we can only hypothesise as to their sequence of construction. Indeed, we can assume that the post was joined to the bottom at a second stage, before the construction of the sides, followed by the frames, and that the clamps and ceiling were fitted last. In sequence it is probable this was the sequence of construction (Fig. 10.2):

A. Bottom planking;
B. Stem and stern;
C. Side-planking;
D. L-shape frames;
E. Clamps and ceiling.

This is one of the very few inland watercrafts of the Roman period known in southern Europe. Of the known Roman river boats, the Santa Maria in Padovetere barge most resembles the 1st century AD Stella 1 boat (Castro and Capulli, 2016), found about 150 km from Comacchio. Stella 1 is much smaller and less well preserved than the Santa Maria in Padovetere barge (Figs. 10.3, 10.4). Similarities can be seen in the pointed ends, the flat bottom, the hard chine connecting the bottom and the sides, and in the use of the sewing technique to join the planks. One difference is found in the arrangement of the frames: while the frames of the Santa Maria in Padovetere barge are composed of pairs of L-shaped floor-timbers, those of the Stella 1 are single floor-timbers with L-shape 'futtocks'.

A very different barge to the Santa Maria in Padovetere one was found in 1890 at Lipe (Slovenja), in the Ljubljanica river and tentatively dated to the 1st century AD (Gaspari, 2009 and references) (Figs. 10.5, 10.6). Here, the ends are truncated, and the futtocks are not joined to the ends of the single floor-timbers. Furthermore, the sewing technique was different, having a pattern of only diagonal and no parallel lines. This barge was defined by Gaspari (2009) *pontonium* a term used by Isidorus (*Etymologiae*, XIX, 1, 24) to describe a slow riverine boat, that is the same type of boat found in Santa Maria in Padovetere: *Pontonium navigium fluminale tardum et grave, quod nonnisi remigio progredi potest. Hic et traiectus, id est extentus: est enim latus; unde et transenna dicitur extentus funis*.

The two boats found in the Roman rural settlement of Corte Cavanella, close to the modern city of Rovigo and the ancient Adria, were built with a similar sewing technique and flat bottoms but were much smaller and had a different shape (Beltrame, 2002a). There is insufficient evidence of their sides and frames to enable a thorough comparison.

Wrecks of river barges of Roman and later periods are relatively widespread in central Europe (Boetto, Pomey and Tchernia, 2011). Although their construction techniques are very different from those of the Adriatic Sea, we can observe a general similarity in shape and in some technical features. Their ends, as opposed to watercrafts of the Northern Italy, are often truncated, as seen on the boat found in the Ljubljanica river, which, as noted, presents other differences to the Santa Maria in Padoverete barge. A similarity can be seen, however, in the sides of riverine boats of Central Europe. The use of two nailed lapstrake planks, as a sort of 'pseudo-clinker', that protrude from each side can be seen

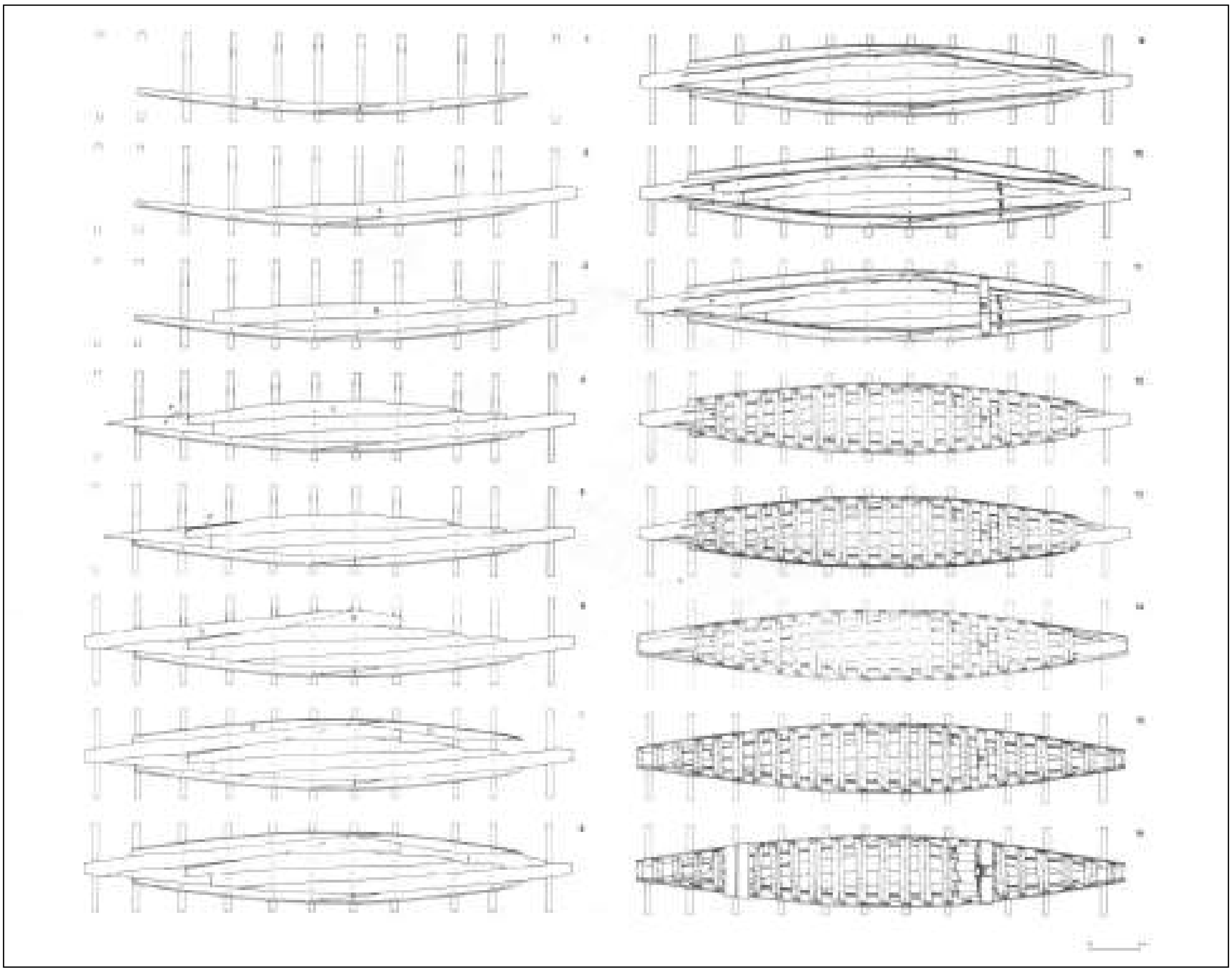


Fig. 10.1. Sequence of construction of the barge of Bavaix, 1970/CH (Arnold, 1998, Fig. 1).

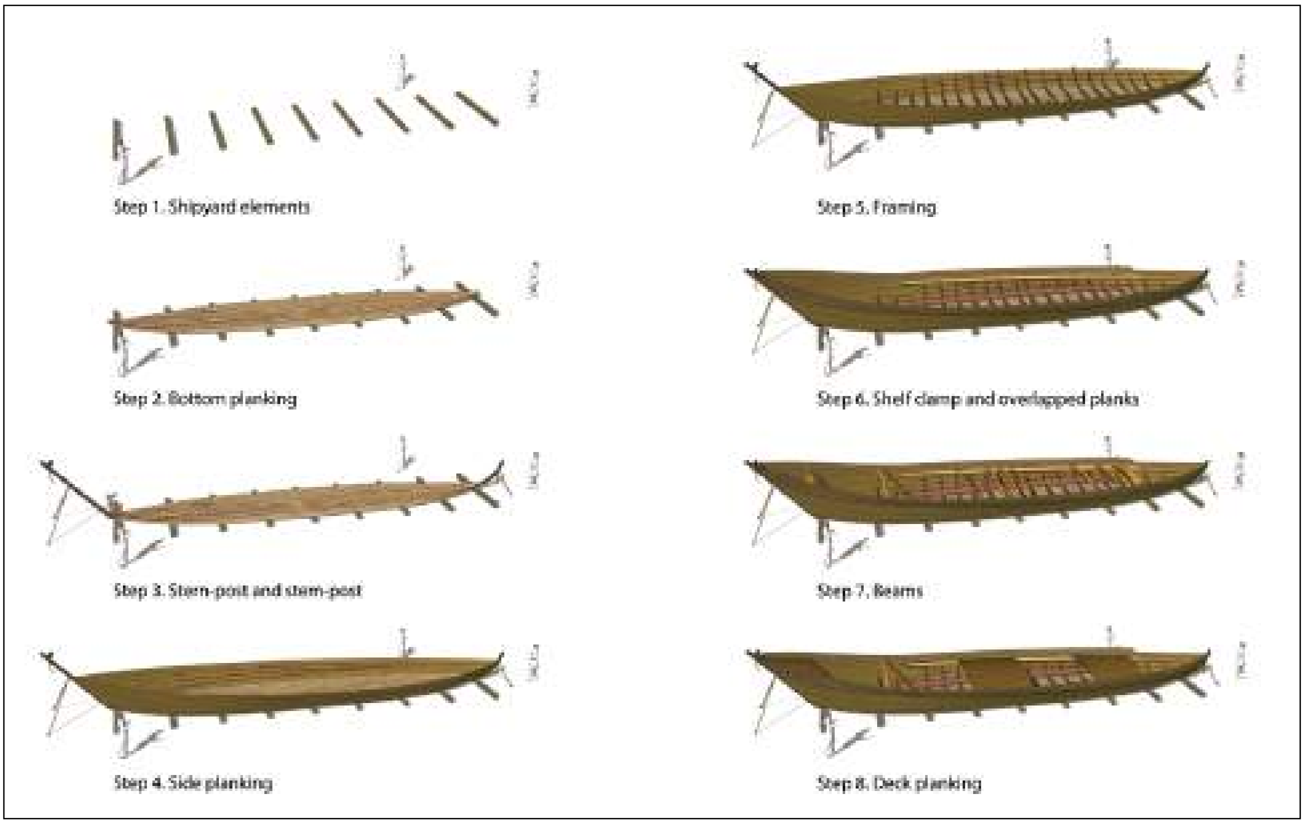


Fig. 10.2. Presumed sequence of construction of the barge of Santa Maria in Padovetere (Drawing: E. Costa).

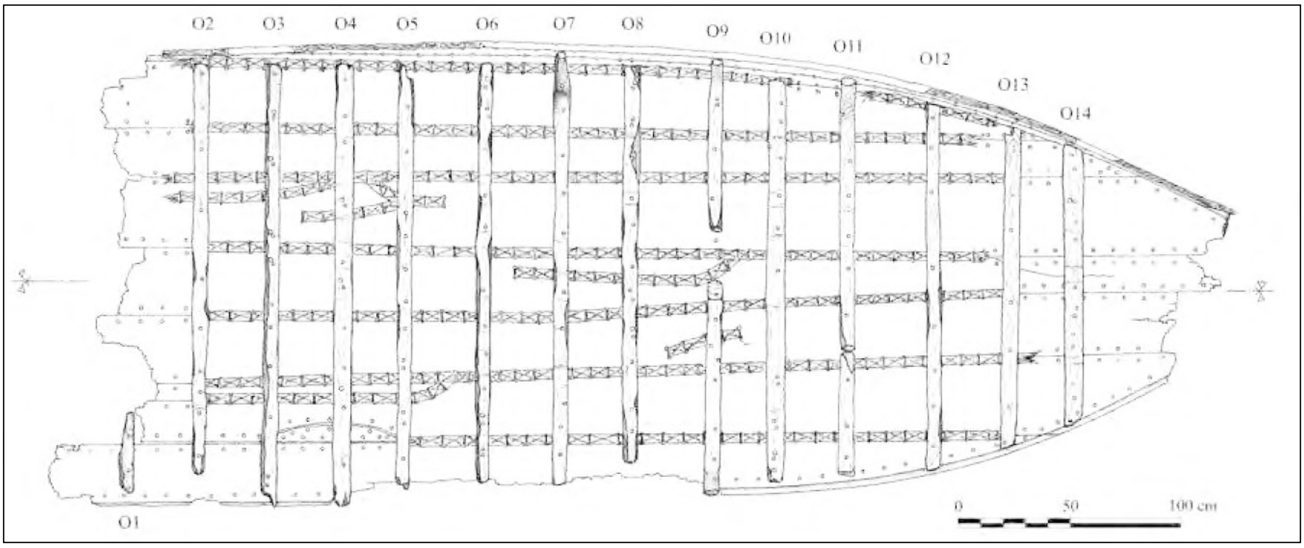


Fig. 10.3. Plan of the wreck of a small Roman barge from the Stella river (Udine) (Castro and Capulli, 2016, Fig. 3).

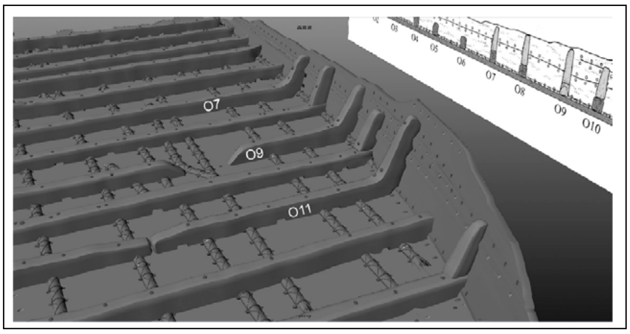


Fig. 10.4. 3D reconstruction of the Roman barge from the Stella river (Castro and Capulli, 2016, Fig. 7).

also in the Zwammerdam 2, 4 and 6 (de Weerd, 1977), Woerden 1 (Haalebos, 1987, 27) (Fig. 10.7) and Woerden 7 (Blom and Vos, 2008), Xantem-Wardt (Böcking, 1996), De Meern 1 and 4 (de Groot and Morel, eds., 2007, 33, 38) and Mainz 6 (Pferdehirt, 2002, 101-102) barges. This feature might be explained as creating a sort of fender to protect the sides during contacts with riverbanks and docks. It, perhaps, also allowed not only greater ease of construction but also easier replacement of broken planks, as it is easier to remove a few nails than to re-sew strakes.

Ancient sculpture offers a suggestive comparison to interpret this 'pseudo-clinker' planking of the right stern side of the barge of Santa Maria in Padovetere. The boats carrying barrels and sailing along the Danube river, which have been sculpted on the Colonna Traiana (Coarelli, 1999) (Fig. 10.8), show a deck built with lapstrakes. Indeed, the planks have superimposed edges and are fixed to an inner structure by nails with a big head. This document indicates that this technique could also be used in the upper parts of riverine boats where there was absolutely no necessity to obtain waterproof planking.

Since this use of lapstrakes has no comparison to other boats of the Mediterranean, it would be interesting to understand if this solution has been influenced by the Central Mediterranean ship-building tradition, where the clinker technique was familiar. This would be the second aspect of the construction of this barge, together with the high stern-post to be discussed shortly, which strongly recalls barges built beyond the Alps.

Of less interest is the use of some tenons, without pegs, along the upper planking of the same side of the Santa Maria in Padovetere barge. The use of tenons in some parts of the hull of boats built with the sewing technique, especially at an upper level or at the extremities, is relatively frequent both in the Greek and the Roman periods (see further). The best example is the sewn ship of Valle Ponti (Berti, 1990, Figs. 7, 8). The use, in the same shipyard, of the two techniques is not strange since both were well known and were probably used according to practical necessities.

Considering the very good level of conservation of the barge, at least on the right side, of Santa Maria in Padovetere, comparisons with riverine boats found in Italy and in Central Europe, just mentioned, do not add anything more for the reconstruction of the entire barge. Inner parts and propulsion and manoeuvring systems can be hypothesised only by looking at the iconography of the Roman period, reading the Latin authors, describing the inland navigation, and comparing this watercraft to ethnographical documentation about similar barges.

The long (stern) post of the Santa Maria in Padovetere barge seems to be a very characteristic feature.

The design of this tall post can be compared to reliefs of the Imperial period found in *Germania*. The stele of the *Nauta Blussus* of the Landesmuseum of *Moguntiacum* (Mainz) (Boppert, 1992/93) (Fig. 10.9) and the stele of the Roemisch Germanisches Museum of Cologne (Arnold, 1999, 153) (Fig. 10.10), both dated to the 1st century AD, depict flat-bottomed riverboats, with hard chine, in which the helmsman stands on a small, raised deck allowing him both to see his way, and to manipulate a long single rudder. Other, less precise, images, such as the relief of the Tiber

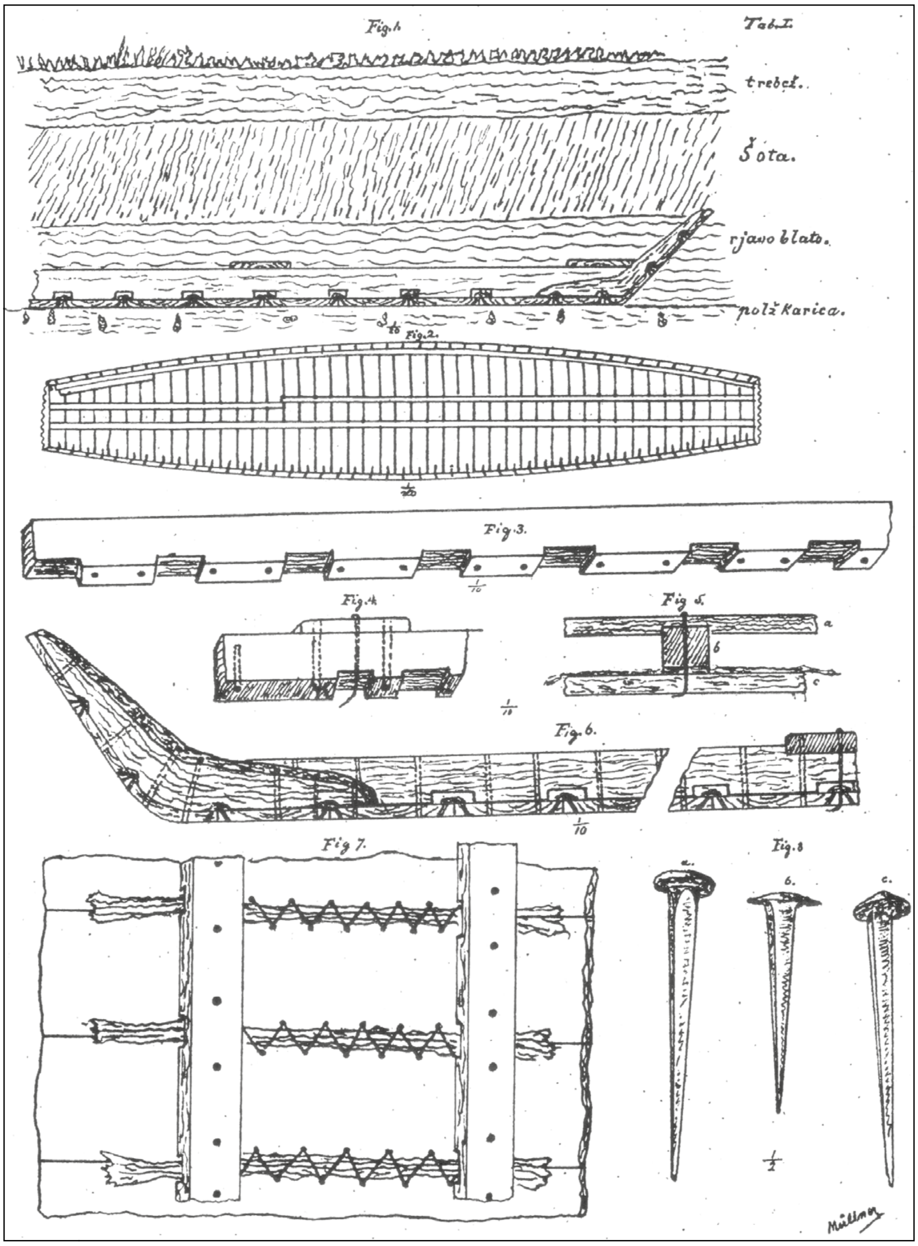


Fig. 10.5. Original documentation of the Roman barge of Lipe found in the 1890 in the Ljubljanica River (Muellner, 1892, Tab. 1).

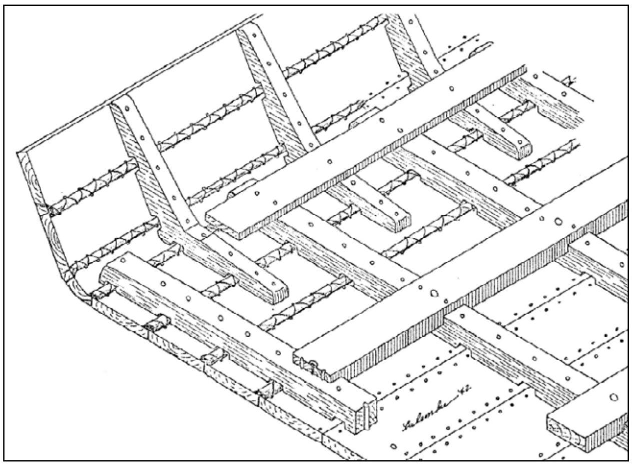


Fig. 10.6. Axonometry of the Roman barge of Lipe (Salemke, 1973, 23).

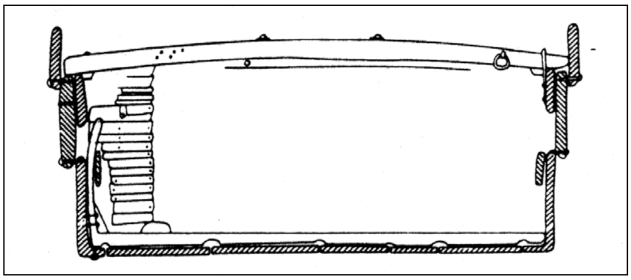


Fig. 10.7. Transversal section of the Roman barge *Woerden 1* (Utrech) (Haalebos, 1987, fig. 4.2).

at the Louvre (Le Gall, 1944) (Fig. 10.11), dated at the beginning of the 2nd century AD, and the relief from the temple of Nehalennia of the Rijksmuseum voor Oudheden in Leiden (Stuart and Bogaers, 2001, 58) (Fig. 10.12), dated between the 2nd and the 3rd century AD, show the same type of very long single rudder used on riverine boats both in Lugdunensis and along the Tiber.

It seems that the riverine Boat F found in the river harbour of Pisa S. Rossore also had a single rudder mounted on the side of the hull (Bonino, 2015, 71). A central long steering oar was also found on the Arles-Rhone 3 shipwreck (Marlier and Poveda, 2014, 214-215), a well-preserved Roman barge with some similarities with the Santa Maria in Padovetere boat but without a high stern-post (Fig. 10.13).

Fig. 10.8. A cast of the sculpture of the Colonna Traiana which shows the stern, with a possible 'pseudo-clinker' planking, of a boat, belonging to the fleet of Traiano, sailing in the Danube with a cargo of barrels (photo: C. Beltrame).

Fig. 10.10. Stele of the Roemisch Germanisches Museum of Cologne (1st century AD) (Arnold, 1999, 153).

Fig. 10.9. The Roman stele of the *Nauta Blussus* from Mogontiacum (Mainz) (1st century AD) (Roemisch-Germanisches Zentralmusuem, Mainz).

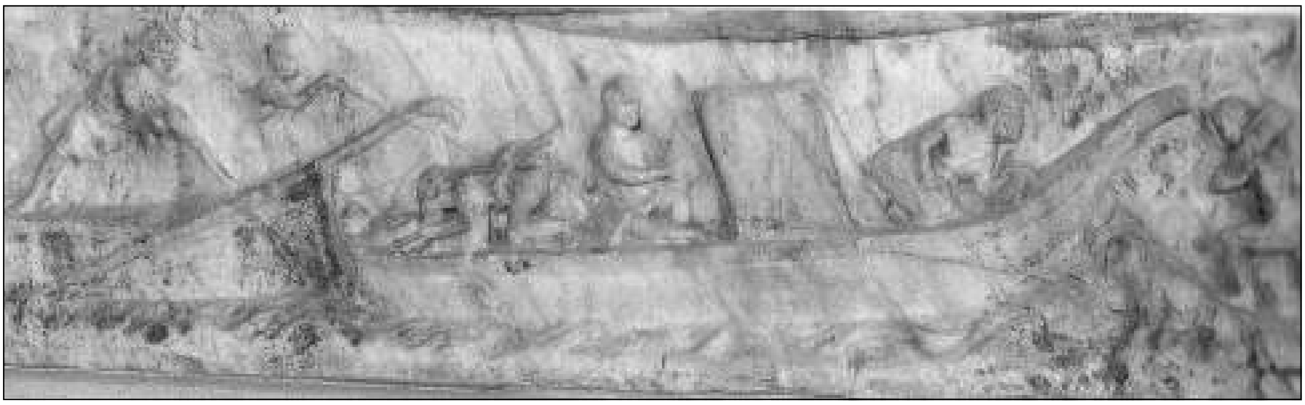


Fig. 10.11. Relief of the Tiber at the Louvre (beginning of the 2nd century AD) (Le Gall, 1944).

Fig. 10.12. Relief from the temple of Nehalennia of the Rijksmuseum voor Oudheden in Leiden (between the 2nd and the 3rd century AD) (Stuart and Bogaers, 2001, 58).

Fig. 10.13. Central rudder of the barge *Arles-Rhone 3* in the Musée de L'Arles antique (photo: E. Costa).

The junction system of the rudder on the stern-post and the technique of its manoeuvring can be suggested by the observation of the, already mentioned, stele of the Roemisch Germanisches Museum of Cologne (Fig. 10.10) where we can see a long rudder fixed, or simply placed, in some way, on the top of the post. A rope fastens the blade of the rudder to this point, while another rope fastens the top of the rudder to the inner side of the sternpost. The rudder is manoeuvred by the *gubernator* (see further) through a thin rod jointed to its top.

All these comparisons suggest that both the large peg, passing through the sternpost, and the wooden L-shaped element nailed to the upper most strake close to the post, found in the wreck of Santa Maria in Padovetere, are elements for the fastening of a steering device of this type. Unfortunately, the interruption of the excavation in the stern area did not allow to collect sufficient data to make a convincing reconstruction hypothesis for this device.

Carlo Beltrame

11. ASPECTS OF THE RIVERINE NAVIGATION IN ANTIQUITY AND THE PROPULSION OF THE BARGE OF SANTA MARIA IN PADOVETERE

The archaeological study of riverine navigation should be considered complementary to maritime navigation, especially in a river like Po, but also a type of navigation with deep differences from sailing by sea. This is evident not only due to the influences of the season and of the environment but also due to the frequent necessity of moving in shallow water, with many possible submerged and not submerged obstacles, in very tight spaces, with possible sudden gusts of wind and fogs. This implies the opportunity of moving, possibly with particular boats, with a reduced tonnage due to the necessity of limiting the draught and the size, and with mariners who were very familiar with that river. It is almost certain that the use of local crew, or at least local pilots, had to be necessary if not obligatory. Ulpiano (Dig. 19.2.13.2 = *Ulpianus* (libro 32 *ad edictum*)) (pers. inf. P. Arnaud) mentions the use of riverine pilots (*gubernator*) as a legal obligation.

Since we have evidence that the draught of Roman or Early Middle Age maritime ships very rarely reached 3 metres, and we have evidence of maritime ships sunk in rivers (such as in the Auser, close to Pisa), we can think that the entry in the main rivers, such as the Po, with a maritime ship of medium size, cannot have been a big problem. We could also mention Felici's (2016, 86-87) tale about navigation along the Tiber with cargoes carrying marble in the Roman period. These considerations do not exclude special riverine barges as being much safer and sometimes faster. Riverine barges, then, probably had to be necessary to reach cities far from the coast, for shallow rivers and in order to move past the bridges crossing the rivers. Arnaud (2016, 149-150) thinks that, in the Roman period, the load break had to be more the rule than the exception, that is that the use of the riverine barges must have been necessary quite often. In the *Digesto*, the river connecting Minturno with the sea was the witness to the break both of part of the cargo (Dig. 14, 2, 4 = *Callistratus libro secundo quaestionum*) and of the entire cargo (Dig. 19, 2, 13, 1 = *Ulpianus*, libro 32 *ad edictum*) of two ships.

This inner navigation required ships that were able to move not only by sail but also by other techniques of propulsion. Indeed, both the navigation following the current and the navigation against the current required solutions other than the sail. If the current could help to move the boat quickly toward the mouth of the river, its force had to be controlled with oars – as told by Sidonio Apollinare when he mentions a change of rowers at Brescello, during the famous navigation route from Pavia to Ravenna, along the Po, in 467 AD (I, V, 3-5) – poles or anchors.

Riverine navigation was relatively regular, as compared with maritime navigation, but unexpected situations could also delay the journey by many days. The stories of navigation in the 20th century along the waterways of the Veneto, as told by sailors (Jory, 2009), are very instructive and testify situations which could stop the trip for days or weeks compromising the delivery of the goods.

We have no archaeological information concerning the mode of propulsion of the barge of Santa Maria in Padovetere but might turn instead to the words of the Latin authors who, describing the navigation along the waterways of this area such as the *Padusa*, the *Fossa Augusta* and the *Vaternus*, mention the use of both towing (*Gaius Valgius Rufus*, fr. 4) and oars (*Martial*, *Epigrammaton libri*, III, 67, 1-4). As we know from Procopius (V, 26, 11-12), towing was the normal mode of propulsion for barges along the Tiber river in the middle of the 6th century AD. This type of propulsion was eternalized also in the 'sculpture of the Tiber at the Louvre (Le Gall, 1944) and was used also in Gallia, as the relief from Carbrières-d'Aigues documents (Fig. 11.1). The technique was also the obvious mode of propulsion against the current in many rivers of the Po Valley and in any period till the end of the Second World War when riverine boats without engines disappeared (Fig. 11.2). Against current the sail was used more seldom, in very good conditions and without strong current (Turato *et al.*, 1981, 33-35). Towing was not possible in windy rivers and in presence of natural or artificial obstacles along the bank as happened along the Rhone in the modern age (Rigaud, 2004, 272), but, along the Tiber, towing could be alternated by the sail and by rowing in case the animals were tired (Procopius, II, 7, 4-9).

The boats had to be equipped with a mast on the prow where a long rope was tied on the top. The very advanced position of the mast at prow allowed better control of the towing from the bank. The rope or the ropes (called *remulcum* or *remulco*: Isid. Orig., XIX, 4, 8; Festus, word *remulco*; Ausonio, *Mosella*, 39-42) could be towed from one bank by men (probably called *helciarii*: Marziale, Ep., IV, 64, 22; Sidonio Apollinare, II, 10, 4), oxen, mules (or horses at least in the modern era) according to the size of the boat, the tonnage of the cargo and the availability of the animals or of the slaves. Iconographic evidence and storytellings of this navigation, both with human propulsion (Ausonio, *Mosella*, 39-42) and animal propulsion (Horatius, *Satirae*, I, 5, 3; Strabo, V, 3, 6), both in the Po Valley (Lucian, Amber or the swans, 1-3) and elsewhere, are numerous in the Roman period, but evidence from writers of the Early Middle Age is not lacking (Calzolari,

Fig. 11.1. Relief (possibly of the 2nd century AD) from Carbrières-d'Aigues showing a boat towed perhaps along the Durance in Gallia (from: www.marine-antique.net/http://latogeetleglaive.blogspot.com).

Fig. 11.3. *Caudicaria* towed ship, *Isis Geminiana*, painted at Ostia (Museum of the Vatican Library) (end of the 2nd-beginning of the 3r century AD) (Pomey, eds, 1991, 117).

Fig. 11.2. Boat towed by men along the Bacchiglione river at Padova (from www.flaviomarchi.altervista.org/i-burci-nella-storia-veneta/).

1989, 30). The most precise description of this practice (which was called *élko*: Lucian, Amber or the swans, 1-3), in this last period, comes from Procopio (I, 26) and concerns the navigation along the Tiber, but we could also recall the description by Cassiodoro of the towing during the navigation in the canals of the lagoons of the *Venetia* (*Variae*, XII, 24, 2).

Nautical evidence of ships being equipped for towing is represented perhaps only by the two *caudicariae naves* found in the harbour of Claudius and dated in the 4th-5th century AD (Boetto, 2008). Both their particular ship-shape and the presence of a small, very advanced, mast-step in one of them, which could have hosted a small mast for towing, allow a comparison of these ships with the image of a towed ship from the *Isis Geminiana* at Ostia (Fig. 11.3). However, the use of the towing technique could have also left evidence in the, already mentioned, Zwammerdam and Woerden ships where the reconstructed advanced masts could be used both for a sail and for a towing-rope. The finding of a silted ship at Mandirac, close to Narbonne, dated between the 4th and the 5th century AD, because of the shape of the hull, has been interpreted as a riverine towed ship too (Jézégou *et al.*, 2020). A horse and a presumed yoke found close to the 5th-6th century AD boat D of Pisa San Rossore have been interpreted as evidence of the towing of this small ship by animals (Peruzzi, 2014).

Elisa Costa

12. THE DIGITAL 3D RECONSTRUCTION OF THE BARGE OF SANTA MARIA IN PADOVETERE AND ITS HULL SHAPE

The reconstructive study is important in order to study the shapes of a ship in depth, both through the creation of a wooden model and through a digital model with 3D graphics (Crumlin-Pedersen, and Olsen, 2002, 55; Lemée, 2006, 102-105; Trakadas, 2011, 44-45; Martorelli, Pensa and Speranza, 2014, 81-93). Until the advent of digital survey techniques that allow a 3D *datum* to be obtained at the time of acquisition, bi-dimensional documentation was used to create the scaled wooden models that would have allowed the analysis of the shape of the hull and the reconstruction of its original hull lines through mechanical and practical operations. In this project, we have also realised a plywood scale model of the boat (Fig. 12.1a-c), based on the 2D drawings of the frames and the developed bottom and the side planks. The digital development technique has been used to obtain the correct drawings to print and cut the planks for the realisation of the plywood model in order to be able to fold them again in the phase of reconstruction of the shape (Ravn, 2012, 316). The model still proves to be an indispensable tool for analysing the hull lines and interpreting the construction shapes and learning the techniques of assembling wooden elements, although digital techniques are beginning to overtake this (Jones, Nayling and Tanner, 2013).

During the reconstruction of the boat of Santa Maria in Padovetere, we wondered about the purpose of realising a model for simplified surfaces when we also had a textured digital model perfectly corresponding to the real thing. To a non-expert eye, the need to modify a digital model to obtain another one, albeit of two different types, was not understandable and evident. The answers to this question are different: first of all, the polygonal modelling of the boat does not replace the mesh of the digital model obtained through photogrammetric technologies. The models represent two different types of visualisation (Fig. 12.2): the photogrammetric model is a twin copy of the subject, metrically and radiometrically correct, which allows taking measurements and displaying the exact shape and chromaticity of the subject, while the reconstructed model by surfaces is intentionally schematic in order to facilitate the study of ship construction and the interpretation of the hull. On the other hand, the best way to know the shapes and study the construction technique of a ship consists in breaking it down into the elements that compose it, which can be identified and separately interpreted. The modelling and graphic rendering are not as objective as the representation of the digital model, but they are necessary to draw and highlight some hidden elements or to complete and improve a survey and to eliminate irrelevant details such as cracks or deterioration of the wood, in order to make accessible the different parts that compose the boat. The modelling technique is often criticised due to the subjectivity in the interpretation of the elements while, in fact, it is essential, so as not to invalidate the scientific nature of the laser scanning or photogrammetric survey, that the researcher who deals with the documentation and modelling is a shipbuilding expert (Poveda, 2015; Beltrame, 2017; Tanner, 2020).

3D modelling software is widely used to process point clouds and textured meshes of a digital survey in order to recreate the reality of a site or an artefact (Remondino and Rizzi, 2010). In the case of the boat of Santa Maria in Padovetere, with half of the hull almost perfectly intact but deformed, the complete reconstruction of the hull lines is only possible through the correction of the distortion of the shapes with a digital modelling (Gonizzi, Remondino and Visintini, 2013; Jones, Nayling and Tanner, 2013, 123-124).

The survey techniques used on the Santa Maria in Padovetere boat are well developed and consolidated as a method of documentation, but the digital reconstruction has partly followed an experimental method, combining known techniques with new approaches and exploiting the developments of digital technologies (Costa and Beltrame, 2021). The digital photogrammetric model represents the barge *in situ*, and it is composed of both the wooden construction elements and the clay left as a support element for some parts to prevent their collapse. Only with manual modelling it was possible to digitally delete these parts and design each wooden element in its real shape, allowing the study of the construction techniques. Moreover, given there is a complete side, digital modelling has allowed the reconstruction of the original complete shape of the barge.

The reconstruction could be subdivided in two main steps:

- the vectorization of the existing elements;
- the reconstruction of the original shape of the barge, which could be subdivided into three other different steps:
    - the modelling of the existing elements based on analysis and correction of the distortion and the deformation of the digital survey model (Castro and Capulli, 2016, Pulak, Ingram and Jones, 2015, Koncani, Boetto and Uhac, 2019);

- the modelling of the missing elements, but based on clear signs of their original existence in the hull (Tanner, 2013; Poveda, 2015);
- the modelling of totally hypothetical elements, based on archaeological and ethnographic comparisons (Poveda, 2015; Tanner, 2020).

12.1 *The vectorization of the existing wooden elements*

By comparing the point clouds created with the different survey techniques, it was decided to use the digital model obtained through photogrammetry, as, compared to the laser scanning, the metric accuracy was high, and it has a higher number of points and a better texturing thanks to the use of photographic images taken with a professional reflex camera.

The first step of the complex procedure is subdividing the wooden elements into different layers, one for each construction element, identified by a different colour to facilitate the recognition of the lines and to facilitate the restitution operations by working only on the layer concerned.

The vectorization of the wooden elements follows two different procedures: first, the lines were drawn manually following the edges and curves of each visible portion of the digital model of the hull (Dostal, 2017, 87) (Fig. 12.3a), and second, the lines of a 2D plan created by digitising the orthophoto were projected onto the mesh (Jones, Nayling and Tanner, 2013, 124) (Fig. 12.3b).

Since the barge is a 'bottom-based' construction, and the bottom is one of the main elements of the hull and the first from which construction begins, it was decided to start vectorization from the caulking rolls between the planks. In the beginning, the restitution was carried out in correspondence with the bilge since the caulking rolls themselves remain hidden by the frames. The construction elements relating to the stitching of the planks, the braided cords and the pegs used to wedge the ligatures, were also represented. Then, having determined the rolls and the stitching, it was possible to hypothesise the course of the bottom planks by extending the line where the caulking was absent due to deterioration or due to lack of construction as in the central part of the bottom (Fig. 12.4).

Following the longitudinal elements, we vectorized the planks of the side, the last three overlapped planks, the ceiling, and the shelf-clamp. We continued with the restitution of the transversal elements such as the frames, of which the original shapes have been preserved, maintaining every important detail of the construction techniques, such as the vertical wooden pins that connect the frames to the bottom and the horizontal ones that connect the frames between them.

Once the totality of the lines of the wooden elements was obtained, in a visualisation defined *wireframe* (obtained through the survey with the Faro Arm measuring arm, a technique usually employed in the laboratory documentation of boats; Crumlin-Pedersen, 2003, 31, 35; Tanner, 2013, 17), it was possible to obtain the volume of the elements through a model for surfaces (Figs. 12.2-12.3).

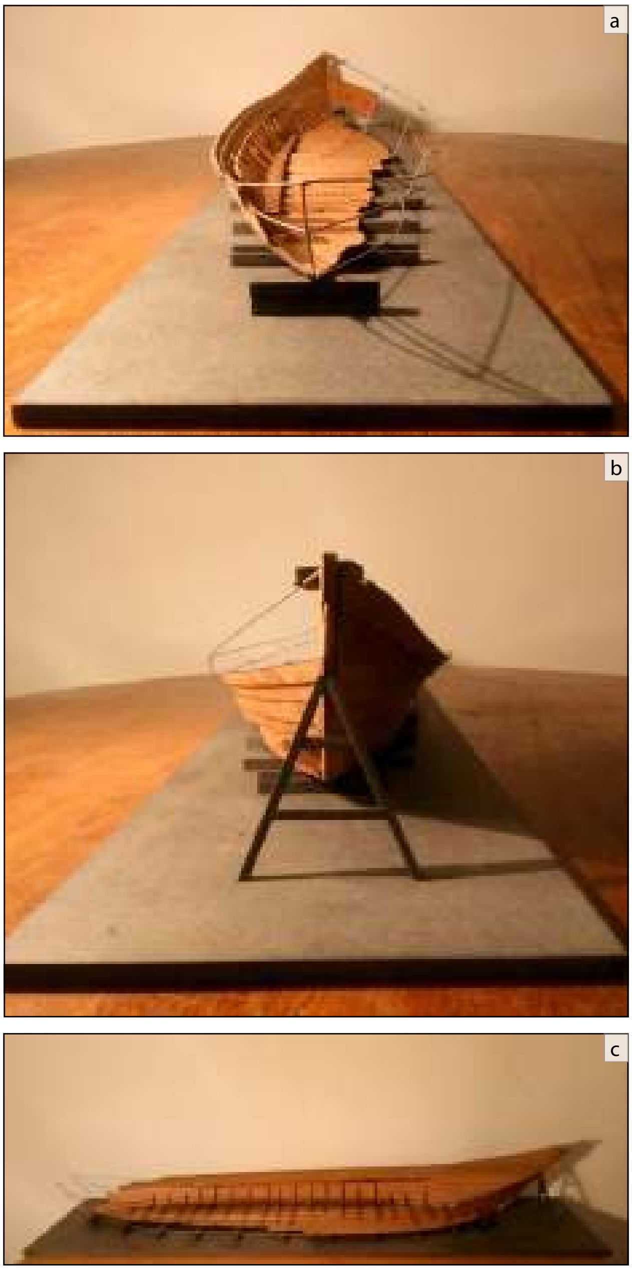


Fig. 12.1. Plywood scale model. a. view from the stem; b. view from the stern; c. view from the portside (model and photo: E. Costa).

12.2 *The modelling and the reconstruction of the existing wooden elements*

From the analyses of the survey and the vectorization, the deformations of the wood are evident and impressive. The inclined position of the barge caused, as in the Arles-Rhone 3 shipwreck (Marlier, ed., 2014, 76), the falling of the left side and the stern inside the boat and the partial distortion of the right side, consequently creating a slight opening of the planks of the starboard side with respect to the frames that remained almost intact (Fig. 12.2).

The first operation to correct these deformations and reconstruct the original hull shapes is the rotation of the

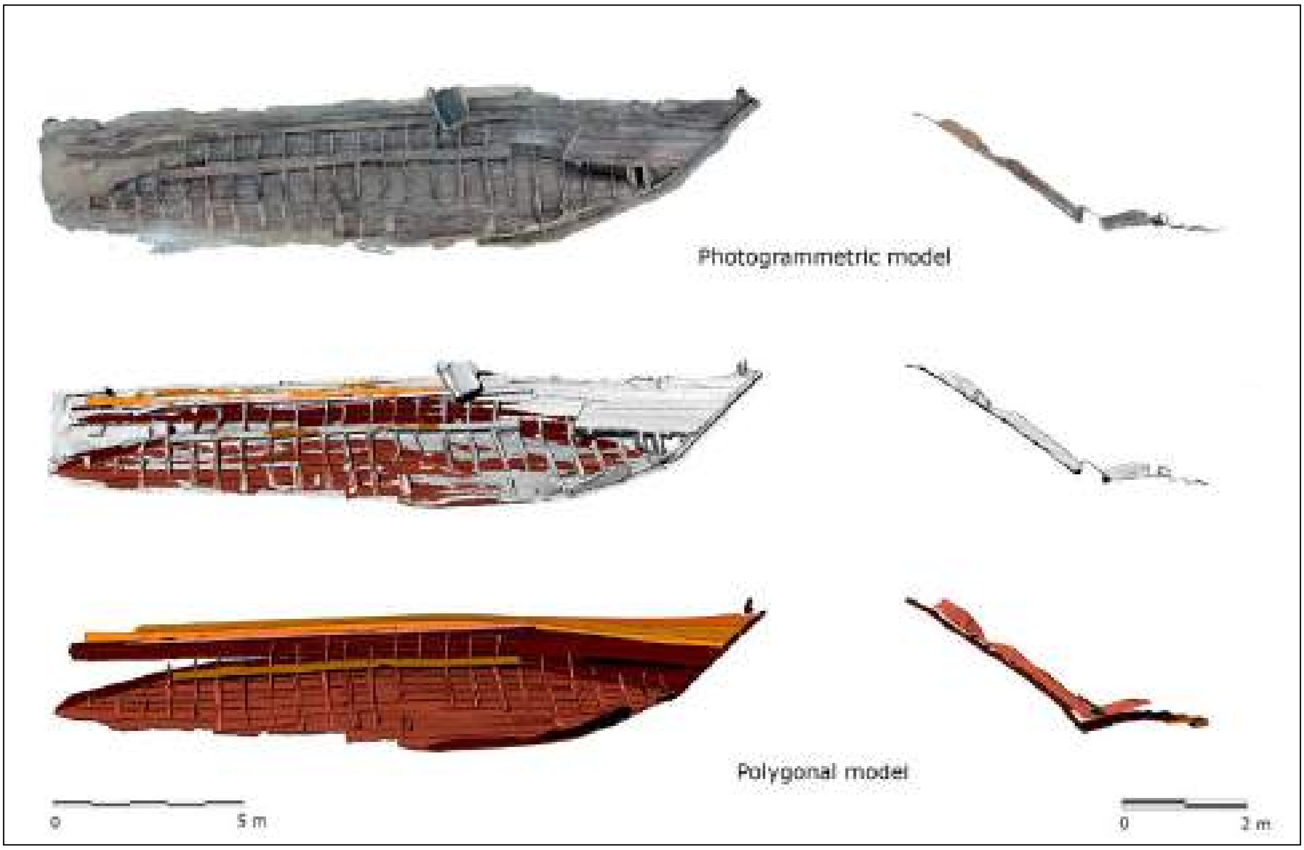


Fig. 12.2. The development from photogrammetry to polygonal model; on the left, the plan; on the right, the section at frame 11 (elaboration: E. Costa).

hull in the navigation position (Jones, Nayling and Tanner, 2013, 124) (Fig. 12.5). The rigid rotation of the entire hull was carried out taking as reference the central frame F14 for longitudinal rotation and the central plank P5 for transversal rotation.

Once the previous operation had been completed, the longitudinal deformation suffered by the bottom planks was evident, showing how they lost their original structure while laying on the ancient riverbank. It was necessary to model the planks to bring the bottom to its correct shape; during this procedure, the planks are aligned along the horizontal axis without a dimensional change since they are not projected onto a plane, but they are developed maintaining the same length (Fig. 12.6).

Through this development, it was possible to identify the correct shape of the bottom. Plank P5 was considered the central axis of the hull since it ends at the stern-post; on this basis, the preserved right side of the hull has been mirrored, but in this way, the left side is in correspondence with the blue line of Fig. 12.7 and does not correspond to the existing portion of the side. If, on the other hand, we create a central axis based on the existing bottom lines, this corresponds to the green line and not to plank P5. Consequently, it was assumed that the barge of Santa Maria in Padovetere was not symmetrical; this feature could be considered plausible on the basis of comparisons with other barges, such as the Arles-Rhone 3 shipwreck (Marlier, ed., 2014, 223-226), which is asymmetrical. Likewise, in all probability, the shipwreck of the Stella river (Castro and Capulli, 2016, 33) would also result asymmetrical if the same analysis were carried out on that hull. The asymmetrical situation also remains, albeit less evidently, if we consider a possible crooking of the planks, the warp along the length of the edge, and we model and adjust the planks from the central one in a way that perfectly fits the central axis (Fig. 12.7).

Observing the survey model and the vectorization, the barge has also undergone an evident deformation in a transverse direction. The orientation of the frames was normalised by taking as a rotation centre the point on the central planks P5 (Figs. 12.8). Furthermore, the frames, following the deformation of the bottom planks in a longitudinal direction, cannot simply be translated vertically, but must be repositioned while respecting the original distances (Fig. 12.9). The arrangement of the frames along the correct central position has been obtained reporting the frames on the central line of the developed bottom and checking the correspondence between the caulking rolls and the arches on the bottom side of the frames. In this way, a development error of 1.7 cm was obtained, over a total length of 17 m, equivalent to 1%.

The stern-post, inclined 45° to the bottom, was individually rotated and vertically positioned using the point of contact with the P5 planks of the bottom to which it is nailed with three iron nails. The stern-post was modelled

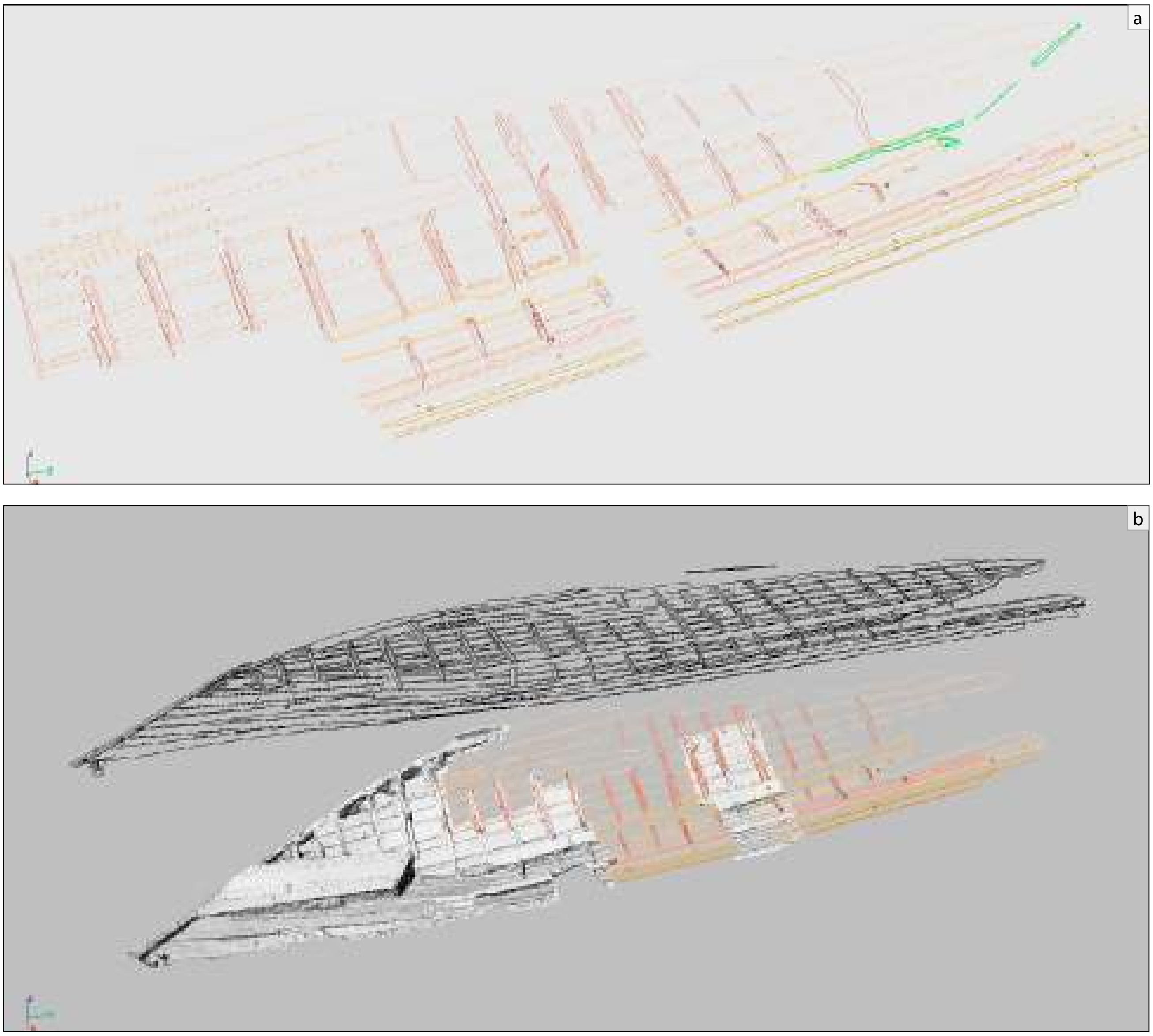


Fig. 12.3. a. Wireframe of the wooden elements, 2014. b. Projected lines plan on the digital mesh, 2015 (elaboration: E. Costa).

Fig. 12.4. Detail of the stern with the caulking rolls, the sewing elements and the planks of the bottom (elaboration: E. Costa).

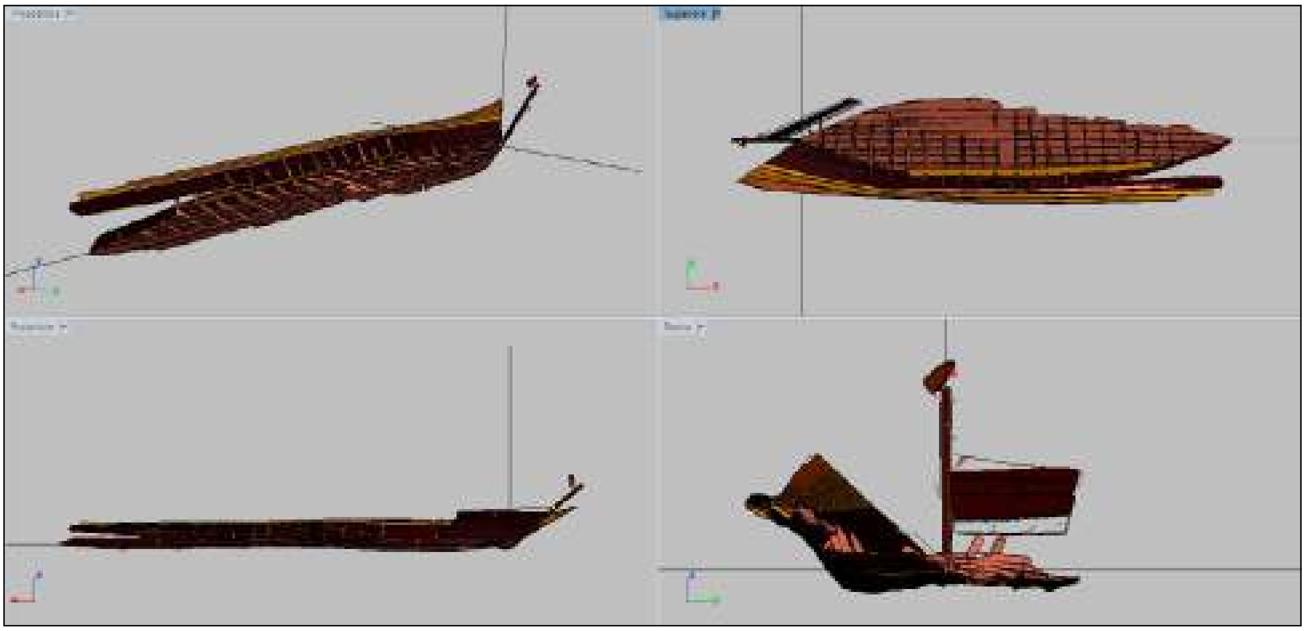


Fig. 12.5. Rotation of the boat in navigation position, where is impressive the deformation of the starboard side of the hull (elaboration: E. Costa).

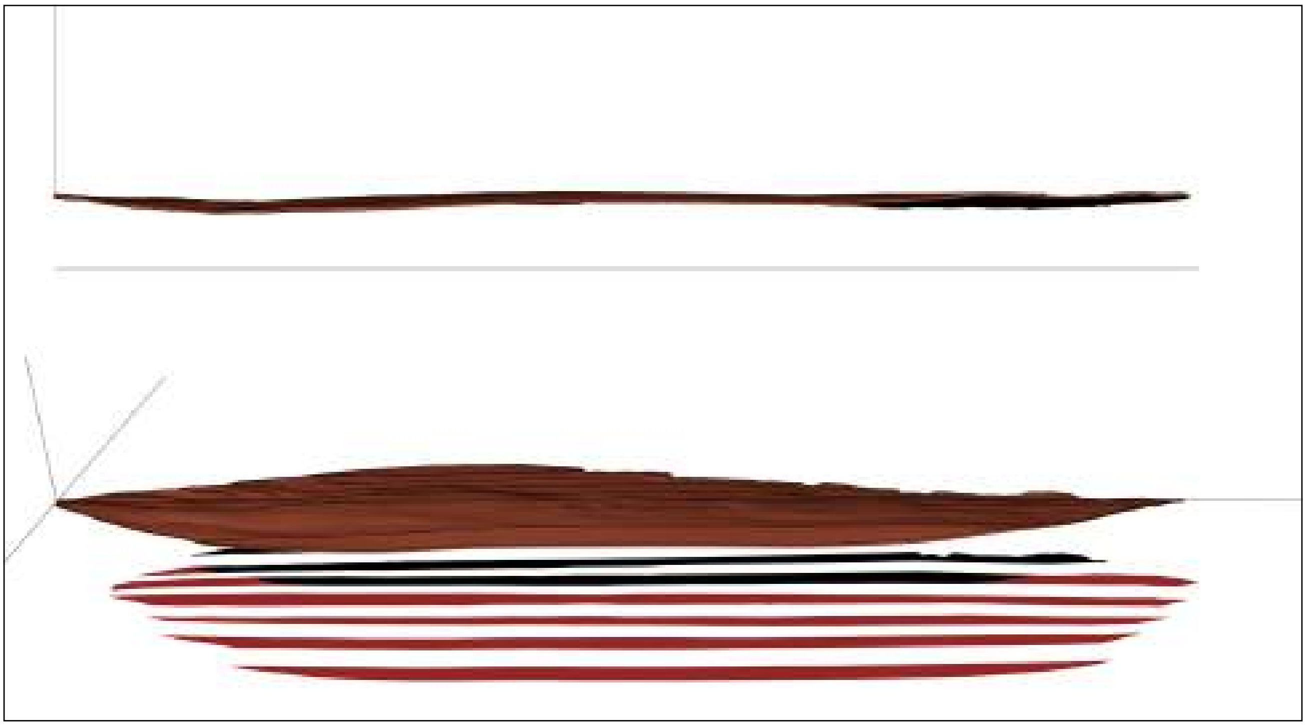


Fig. 12.6. Distortion of the bottom planks on the riverbank and development of the bottom planks on a horizontal plane (elaboration: E. Costa).

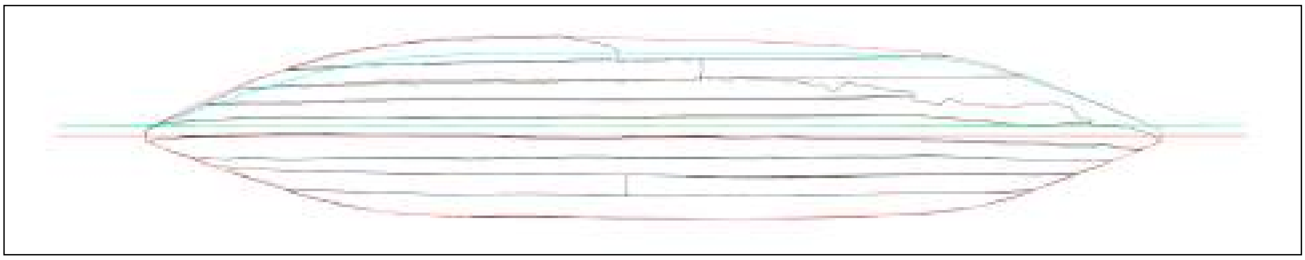


Fig. 12.7. Lines analysis of the bottom symmetry (elaboration: E. Costa).

because during the collapse on the right side it underwent a slight twist, in addition to the transverse rotation; this deformation is evident from the comparison between the mesh of the original survey and the reconstructed volume presented in Fig. 12.10.

For the side planks, on the other hand, a rotation is not sufficient, but twisting and bending must be carried out. A commonly used technique in this context could be represented by the *Bend* command in *Rhinoceros* software (Jones, Nayling and Tanner, 2013, 127), but the excessively complex shapes of the detected planks did not allow their use with perfect control of the length of the planks. Moreover, we noticed how this command would have resulted in a forced and unnatural bending for a wooden plank.

It was therefore decided to create a network of triangles on the planks that could be bent and rotated in order to twist the side without changing its actual measurements given that the triangle is a non-deformable figure (Fig. 12.11).

The first operation was carried out on the side plank sewn to the bottom, starting from the central part still connected, where the torsion is easy and minimal, through the ends, where the joining between the side and the bottom was not possible unless the bottom itself was subject to bending to connect it to the side in a raised position. This operation led to a raising of the bottom lines at the ends, with a lifting of 22 cm at the bow and 12 cm at the stern. In this way, the bottom has acquired a plausible curvature for correct hydrodynamism, finding comparisons with flat bottom boats in ancient and modern times (Rieth and Guyon, 2010, 35-104; Marlier, ed., 2014).

The bending operation through the division into triangles was carried out on all the planks of the starboard side individually, taking the previous plank as a reference in order to maintain homogeneity of the side, as with the plywood study model (Ben-Zeev *et al.*, 2009; Beltrame and Gaddi, 2013b, 14). In this way, it was possible to fold and rotate the side of the boat in the correct position, checking the correspondence between the reconstructed planks, the frames, and the arches on the frames for the caulking rolls.

Completing the shape of the side, the stern-post was rotated in the longitudinal axis by a few degrees in order to correctly match the end of the bent planks with the connection point on the post, also accurately measured directly during excavation (Fig. 12.12a).

Then, the internal longitudinal elements, such as the ceiling and the shelf-clamp, were straightened following the same triangulation procedure used for the side planking. The shelf-clamp was also modified in the bow part to follow the course of the last plank of the side to recreate the necessary correspondence of these two constructive elements which represent the support of the deck.

Once the hull was completed, the reconstruction of the frames continued; the right frames are completely intact in the vertical portion on the side and degraded in the left end on the bottom, while the left frames are completely missing in the vertical portion on the side, but the right end on the bottom remains. First, the existing portions of the frames were reconstructed, eliminating the deformations and re-

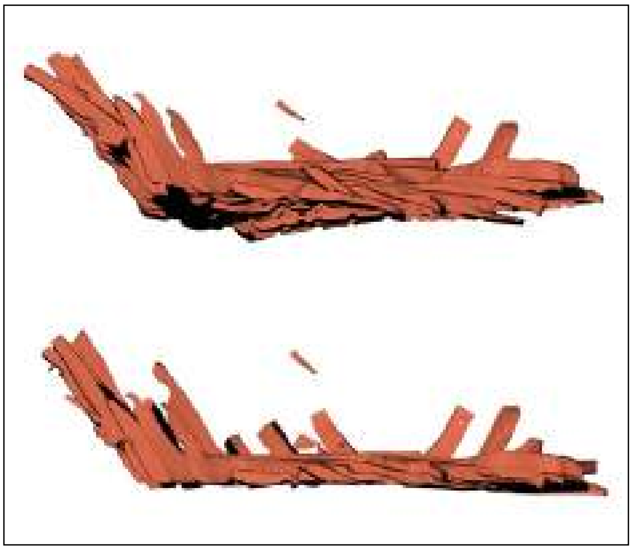


Fig. 12.8. Transversal view of the frames before and after the rotation in the correct position (elaboration: E. Costa).

building where necessary, integrating the terminal part of the plane on the basis of the symmetrical twin frame. The reconstruction of other parts of the frame will be described in the next paragraph since they are part of the elements of the barge reconstructed on the clear signs of their original existence in the hull or mirroring the existing ones.

12.3 *The modelling of the missing elements*

An important modelling phase concerns those missing elements whose shapes and dimensions can be supposed and modelled since their lines can be traced as evident constructive signs of their existence on the hull or by mirroring the existing side and elements, such as the beams, the portion of left frames and the portside.

Proceeding with the modelling of the inner elements to complete the transverse framework of the hull and integrate the missing left part, the reconstructed frames were mirrored. Since there is not a perfect symmetry between the left side of the bottom and the right one, the frames were translated to be correctly positioned in contact with the portside and the recesses of the arches of the caulking rolls and limber holes of the frames were modified and correctly moved.

It is evident that, once the frames were reconstructed, they underwent a slight transverse rotation in a homogeneous manner, which occurred simultaneously with a deformation of the bottom as is evident from the absence of breakage in the vertical connection pins. The final model was corrected by normalising the horizontal and vertical axis of the frames with respect to the bottom and the sides.

To determine the correct line of the hull, the angle of the frames was analysed and used together with the curvature of the planks, following the correct practices in the reconstruction of the shapes of the wrecks (Beltrame and Gaddi, 2013b, 14; Jones, Nayling and Tanner, 2013, 124).

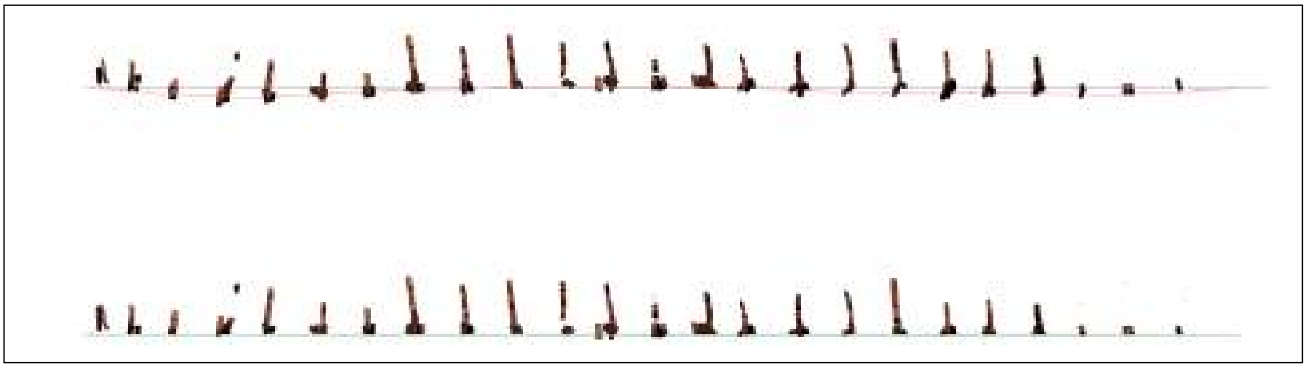


Fig. 12.9. Longitudinal view of the frames before and after the arrangement in the correct position (elaboration: E. Costa).

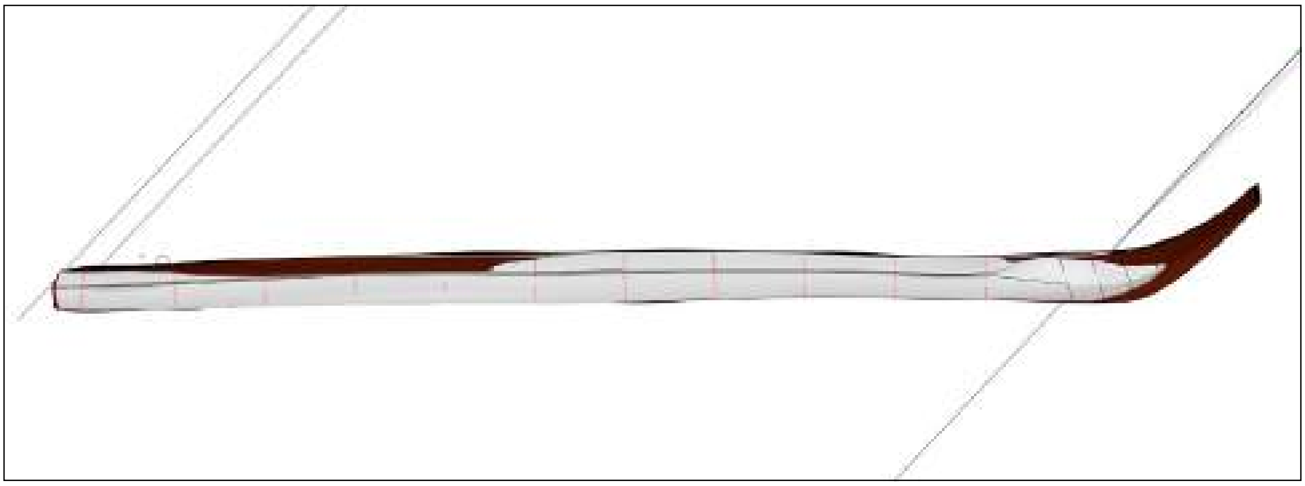


Fig. 12.10. Original stern-post from the survey (brown colour) and modelled stern-post (grey colour) (elaboration: E. Costa).

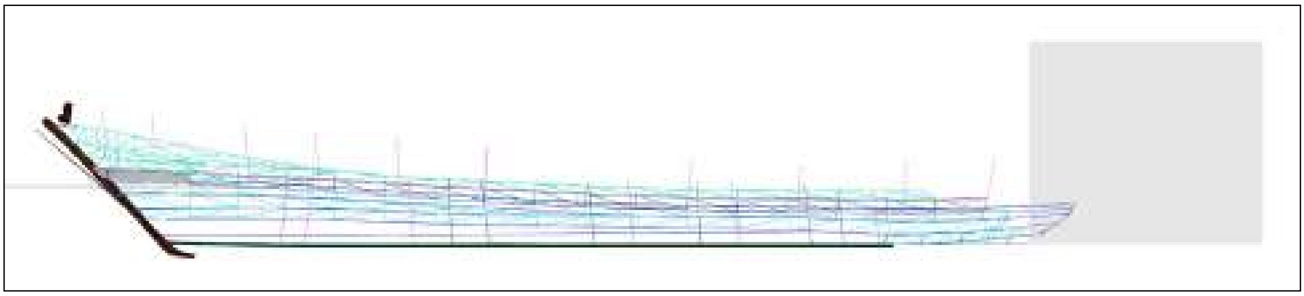


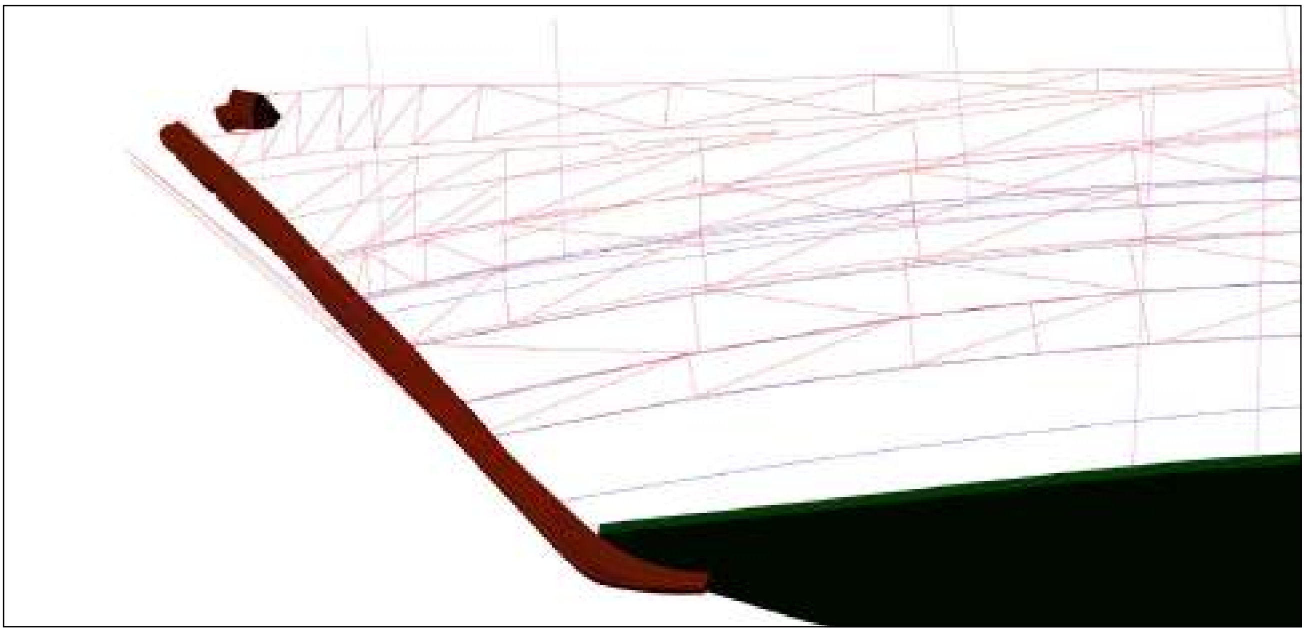
Fig. 12.11. Triangle shapes created on the planks to rotate and bend the planks not to lose the correct length of the planks (elaboration: E. Costa).

Differently from other shipwrecks, of which there remains only the lower hull and for which the hull lines must be hypothesised (Gassend, Liou and Ximénés*,* 1984, 75-106; Castro, 2005; Castro *et al.,* 2010; Batchvarov, 2012, 175-181; Poveda, 2012, 331-336; Radic *et al.,* 2014; Castro and Capulli*,* 2016; Capulli, 2017), our work consisted of a reconstruction of existing but deformed shapes.

The existence of a series of transverse beams (Fig. 12.13) was hypothesised on rectangular notches placed at regular distances on the upper side of the shelf-clamp; the curvature of the beams was calculated on the shape of the notches, which are not orthogonal but are slight.

12.4 *The modelling of totally hypothetical elements*

Several constructive elements, such as the stempost, the deck planking, the rudder, and the bow mast, must be hypothetically reconstructed. It was impossible to obtain the virtual model of some wooden parts, hidden by the clay supporting the elements or by the construction elements themselves. For complete documentation, the hull would have to be dismantled, but this is not possible unless the recovery and restoration of the barge are planned, therefore, an integration is required through manual drawing and a digital reconstruction of the non-visible parts.



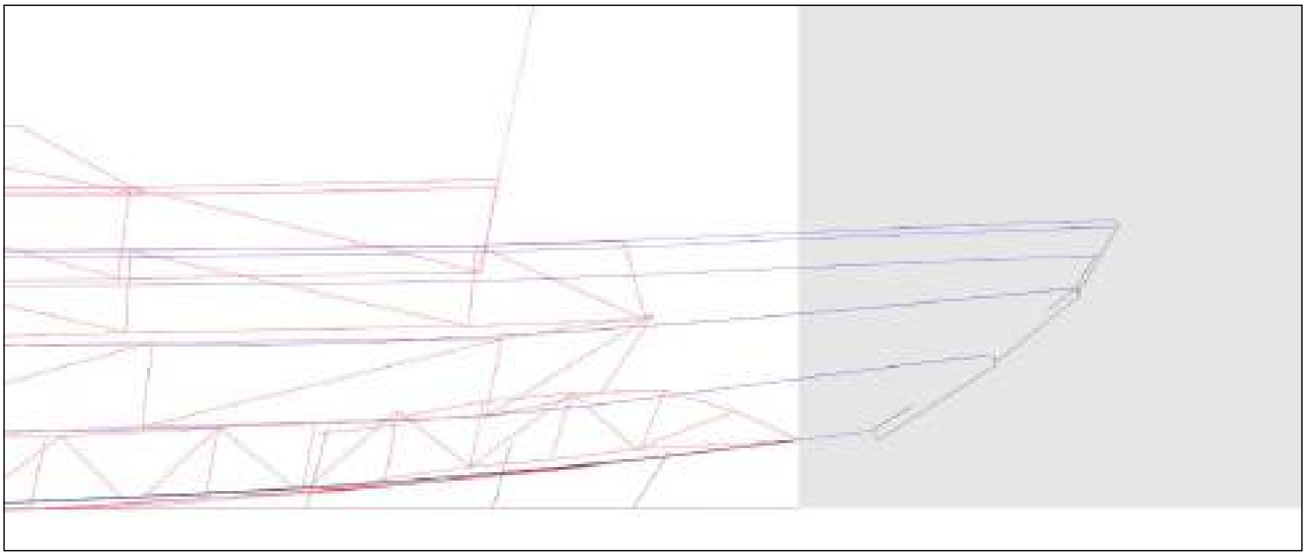


Fig. 12.12. Triangle shapes created on the planks to rotate and bend the planks not to lose the correct length of the planks. a. Portside. b. Detail of the reconstruction of the bow lines (elaboration: E. Costa).

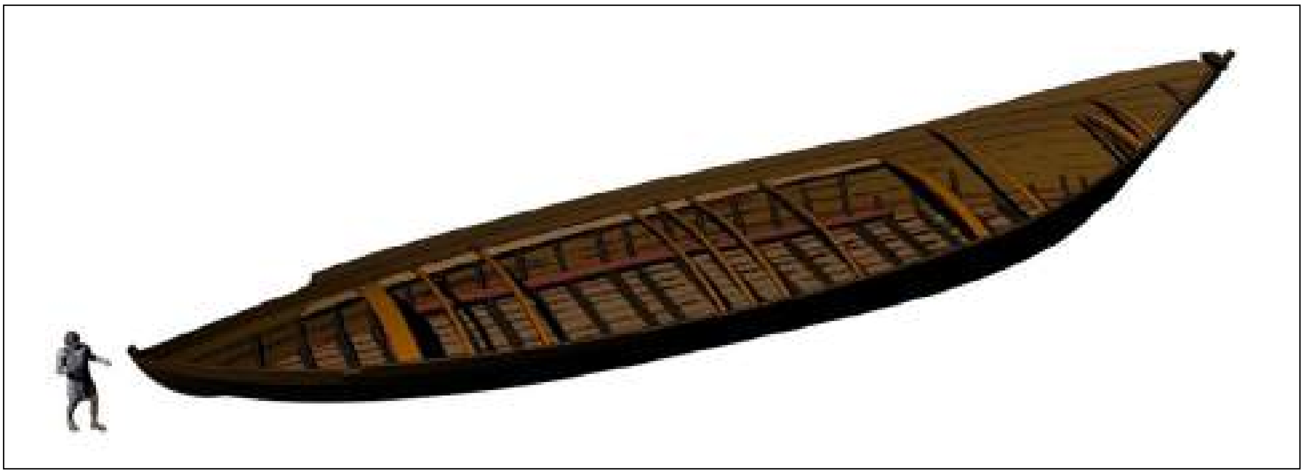


Fig. 12.13. Reconstruction of the beams on the square notches on the upper side of the shelf-clamp (elaboration: E. Costa).

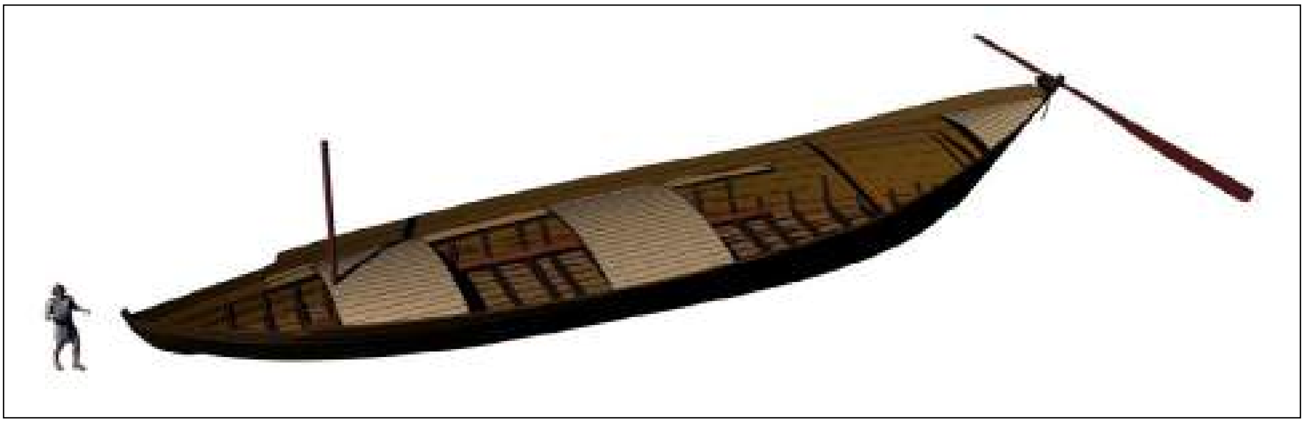


Fig. 12.14. Reconstruction of the deck planking over the beams (elaboration: E. Costa).

The position and shape of the stempost were created on the closure of the side planks that join in a specific position along the central axis of the hull, even if these are deteriorated and do not reach the central axis in the bow. To be able to determine the bow end, the lines of the planks were automatically lengthened following the curvature of the board up to the vertical plane passing through the central axis of the hull, reproducing the operations that would result in operating on a cardboard model (Ben Zeev *et al.*, 2009, 38-39). The generated lines are the most probable since they are created on a very small missing portion (1-2 m) compared to the length of the whole length (18-20 m) of which we know the correct curvature (Fig. 12.12b).

On the other hand, the shape of the section of the stempost is not known, which is in fact created in a completely hypothetical way, with a simple rectangular section and the rabbet for the side planking, taking as reference the section of the sternpost and comparing this with other shipwrecks albeit with different constructive characteristics and different dating (Charlin, Gassend and Lequément*,* 1978, 64-65; Beltrame and Gaddi, 2007, 139).

The beams realised on the notches of the shelf-clamp were used as support for the deck planking and the presence of three distinct decks was hypothesised in correspondence with those transversal elements positioned at a proper distance to allow the positioning of the planking without breaking, leaving a free area in the middle to permit an easy loading of the cargo (Fig. 12.14). A little deck up to the stem, in continuity or not with the first one on the beams, is plausible, reinforcing the area near the bow and protecting the inside from incoming water.

The deck on the stern was reconstructed on some rectangular recesses of the last plank of the side which are higher than the notches on the shelf-clamp. This high deck and the two extra planks at the end suggest the need to protect an element located high up in this area, inviting comparisons with iconographic images from Central Europe, dated to the Roman Period (see above). This end and the rise of the sides at this part provide a clear view and good control of a long central steering oar, suggesting the presence of a helmsman in this area.

The reconstruction of the rudder as a long single oar-rudder has been realised based on the reliefs of the Roman Period (see above), the Arles-Rhone 3 shipwreck (Marlier and Poveda, 2014, 214-215) and ethnographic comparisons, such as some types of flat-bottomed river boats. Indeed, the *Courpets*, which navigated the Dordogne river until the beginning of the 20th century (Beaudouin, 1985, 73), the *Rabelos*, which moved along the Douro in Portugal till the 1960s (Filgueiras, 1989) and the *Zilia*, which navigated the Vtlava (Ossowski, 2010, 138), had similar single rudders. These comparisons help to suggest that both the squared hole in the sternpost with its large pin and the wooden L-shaped element nailed to the upper plank could be elements of a steering device, but they do not give us a certain attribution and reconstruction.

The width of the last beam toward the stem, which measures 40 cm instead 10 cm as the other beams do, and some archaeological (Boetto, 2008, 46-47; Marlier and Poveda, 2014, 209) and ethnographic comparisons (the *Zilia* of the Vtlava river (Ossowski, 2010, 138)), let us suppose the presence of a small mast to tow the boat from the riverbank. The mast-beam can be solid enough to fit a 14 cm diameter mast, and it is positioned at about 1/5 of the length, further forward compared to other wrecks, such as Mainz 6 and Zwammerdam 2 and 4, where the mast-beam is positioned at 1/4 of the length or Woerden 1, where it is at 1 / 3.4. In recent times, ropes positioned in the bow are used to open or close the angle of the tow rope so as to move the traction towards the bow; in this way all the different positions of the masts found in the shipwrecks are correct.

The reconstruction has improved observations of construction aspects of the boat, with a total length of around 23 m, a maximum width of 5 m, and a height of 1 m in the middle section and 2.20 m at the stern. The tapered shape with a 1/6 ratio, the flat bottom and the absence of evidence of a closed deck and a sail mast, confirm the use of this barge as a river transport watercraft; this is one of the few barges used only for inland navigation during the Late Roman Period in southern Europe for which the almost complete shape is known (Rieth and Guyon, 2010; Marlier, ed., 2014) (Figs. 12.15, 12.16).

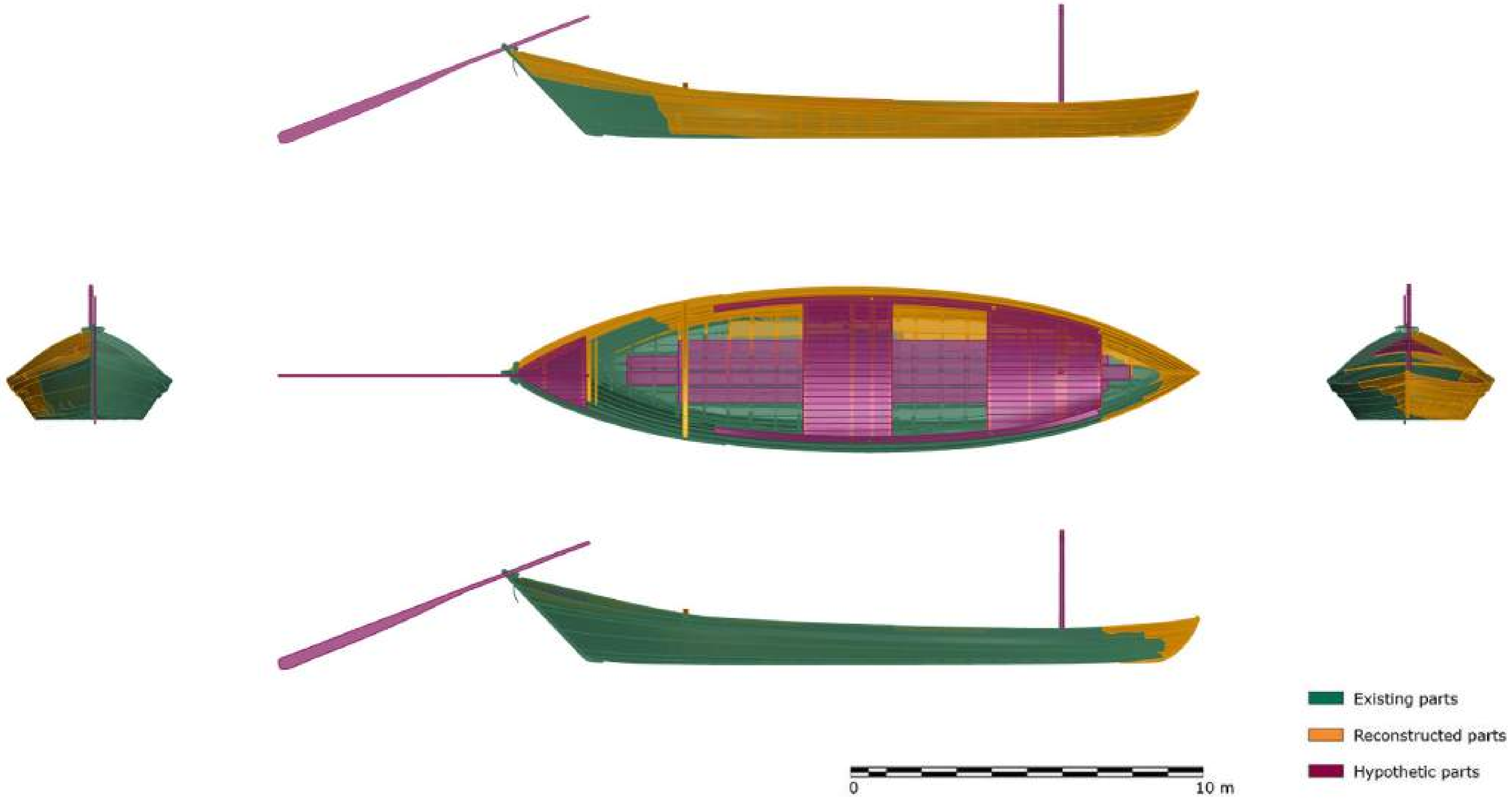


Fig. 12.15. Model of the existing parts (green), reconstructed parts (yellow), and hypothetical parts (violet) (elaboration: E. Costa).

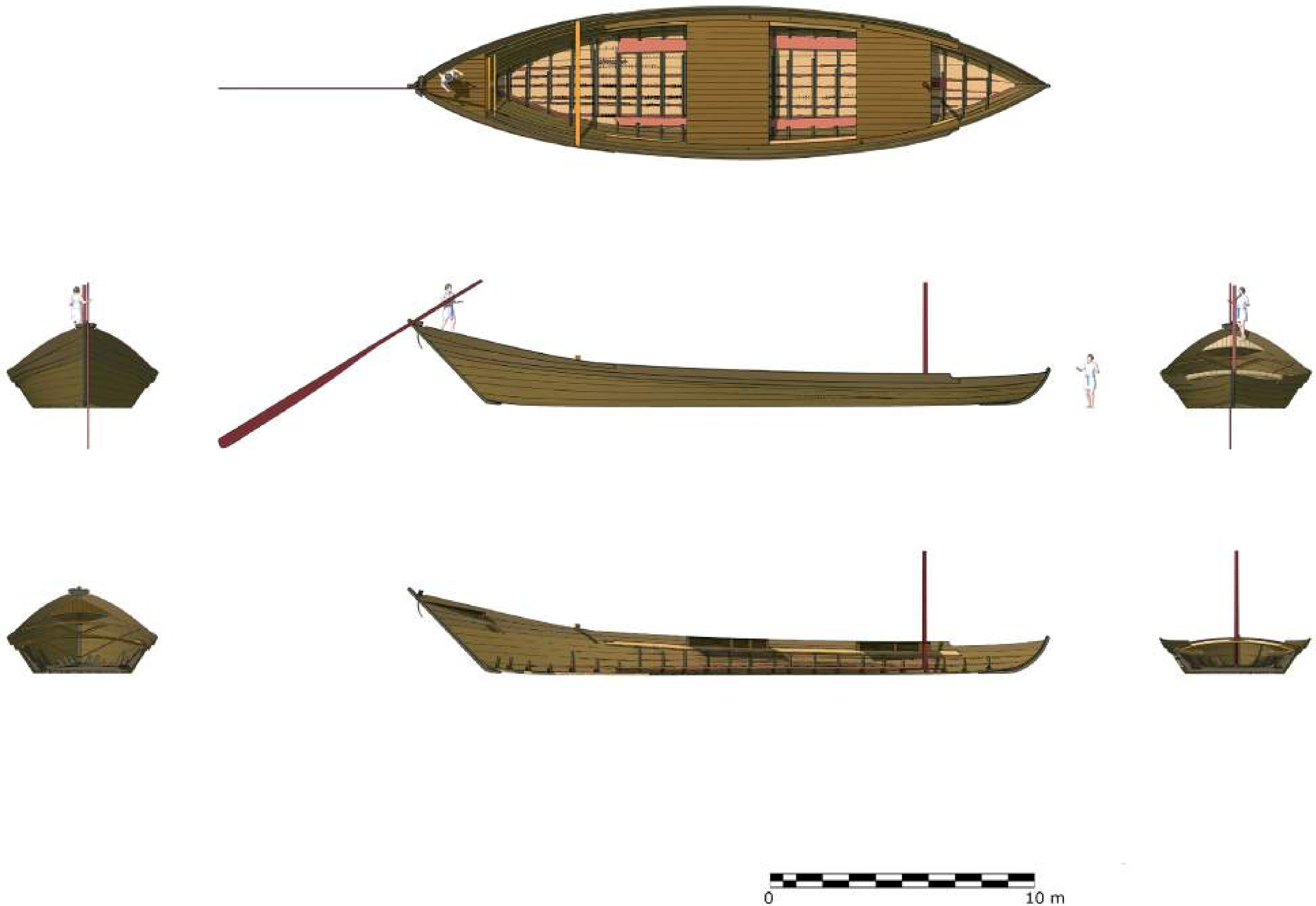


Fig. 12.16. Final construction plan of Santa Maria in Padovetere barge (elaboration: E. Costa).

Elisa Costa, Germano Degan

13. HYDROSTATIC AND HYDRODYNAMIC ANALYSES ON THE HULL SHAPE OF THE BARGE OF SANTA MARIA IN PADOVETERE

Considering the above quoted sources, despite the exiguous archaeological information related to the propulsion of the 5th century AD barge of Santa Maria in Padovetere, the towing technique can be proposed; this technique represents the most specific way of propulsion for sailing upriver, against the current. Indeed, the absence of oarlocks or notches on the edge of the side hull implies that this boat was not moved with the use of oars; the use of paddles is not plausible either due to the excessive height of the side, while the use of one or more oars as a pole for moving the hull is possible (see above). The presence, in the bow area, of the wide beam and the archaeological and ethnographic comparisons, have clearly supported the reconstruction of a small towing mast. From a physical point of view, if the boat was towed by a rope placed on the stem it would have hit the shore unless the helmsman made an excessive effort to keep the boat parallel to the shore; while, if the boat were towed by a central rope, it would have tended to rotate around this point, making it impossible to advance. If the mast were positioned between the stem and the centre of resistance of the hull, the boat would have acquired a slightly diagonal course with respect to the current; in this way, the result of the resistance of the water would have been applied to the front of the boat and would have tended to move it away from the shore to counteract the traction from the shore and make the boat advance parallel to it, limiting the effort exerted on the rudder (Rieth, 1998, 106). Unlike the side rudder used on Roman maritime ships that operated only by rotation and was fixed, the oar-rudder of the river boats was mobile, both laterally and, in particular, along the longitudinal vertical axis. In this way, the helmsman could steer the boat even in shallow water by advancing on the deck and changing the angle of the rudder, leaving the blade immersed and maintaining the efficiency of the rudder (Fig. 13.1). The draft and the trim of the hull depend on the loading conditions, according to the weight of the material transported and its position onboard; the mobility of this oar-rudder allowed its propulsion and directional effect to be maintained in every condition (Rieth, 1998, 109-111).

In recent times, modelling and digital technologies are used to reconstruct boats, to analyse and study the internal spaces of a hull, and to hypothesise possible stowage and weight of the cargo, confirming the importance of a multidisciplinary study conducted by naval engineers, archaeologists and historians of navigation. A 3D model specifies and facilitates the number of hydrostatic calculations, allowing the determination in a quick and easy manner of the different conditions of loading, drafting and seaworthiness (Castro *et al.*, 2010, 2; Poveda and Boetto, 2018; Tanner and Belasus, 2021).

The first hydrostatic analyses were performed with the empty hull. The first step is to estimate the complete weight of the barge, considering the essence of the woods and their distribution. Based on the restitution model, it was possible to carry out a precise volume of all the elements of wood and to measure for each of them the location of their centre of gravity. The specific weight of the wood essence is attributed to the volume of each wooden element, also considering the specific weight of the hemp for the caulking rolls, the stitching and the towing ropes.

Wood analysis carried out indicates the wide use of *Quercus sp.* for most of the side planking, the shelf clamp, the post, the long peg piercing the post, the frame, and the treenails, and *Ulmus* for the bottom planking, the L-shaped element joined to the top strake near the post, and one clinker plank on the southern side. *Buxus* was used for at least one peg used to secure the sewing in the holes, and *Quercus ilex* for at least one treenail joining the frames with the hull (Fig. 13.2).

Considering the volumes and the essences, the lightship weight is 6.9 t, and the draft of the boat is only 18.5 cm; the position of the centre of gravity (C.o.G.), the conformation of the flat bottom and straight sides allow a very wide maximum inclination with a freeboard of around 90 cm in normal conditions, reaching 7 cm of freeboard at a maximum inclination of 25° (Fig. 13.3).

Subsequently, the cargo was hypothesised based on the study of the organic materials found during the excavation phase in contact with the hull. The relatively high and unusual pollen percentage of the dry meadow plant *Sanguisorba minor* and the co-occurrence of some other meadow species could be related to the use of the barge for the transportation of animals and their forage. The presence of spores produced by fungi associated exclusively with animal excrement, in particular with that of sheep and goats, supports the same hypothesis (Marlier, 2014, 277; Beltrame *et al.,* 2021, 3, 14-15). The discovery of a high percentage of pollen of *Brassicaceae*, rye, hemp, *Cucumis sativus* and *Cucumis melo* could be related to free cargo scattered on the boat or inside bags (see above). The large space and the absence of a closed deck facilitate the positioning of animals and free cargo, confirming the hypothesis of this kind of cargo.

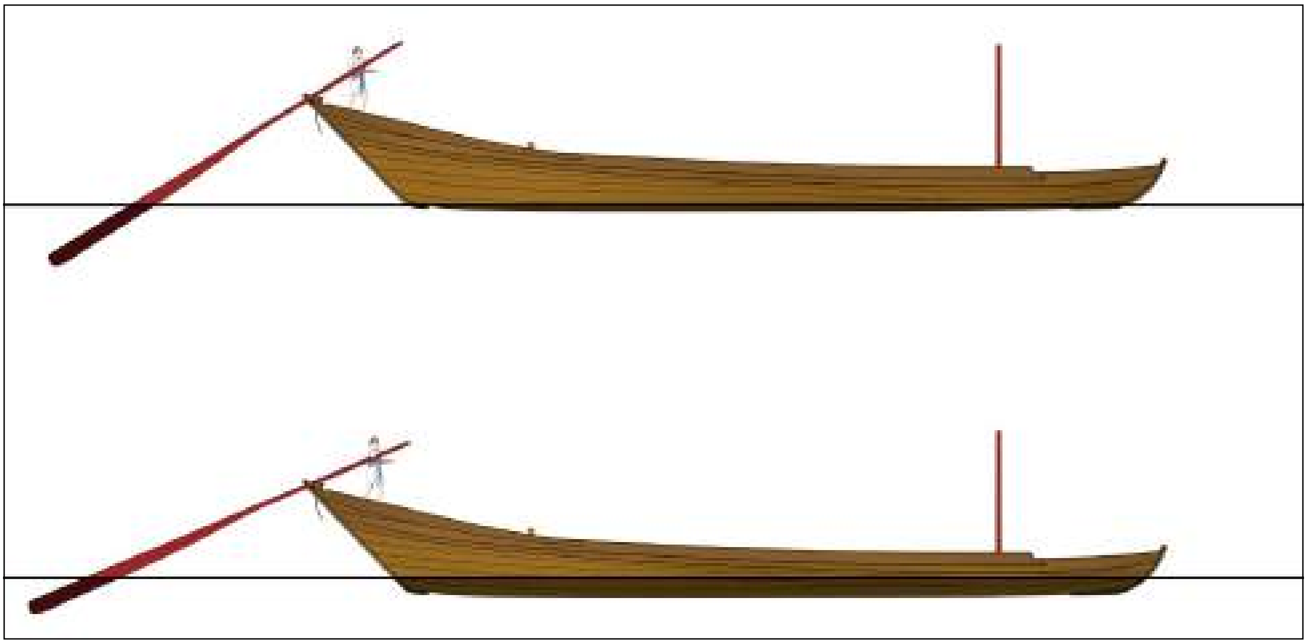


Fig. 13.1. Two different positions of the rudder depending on loading conditions of the barge (elaboration: E. Costa).

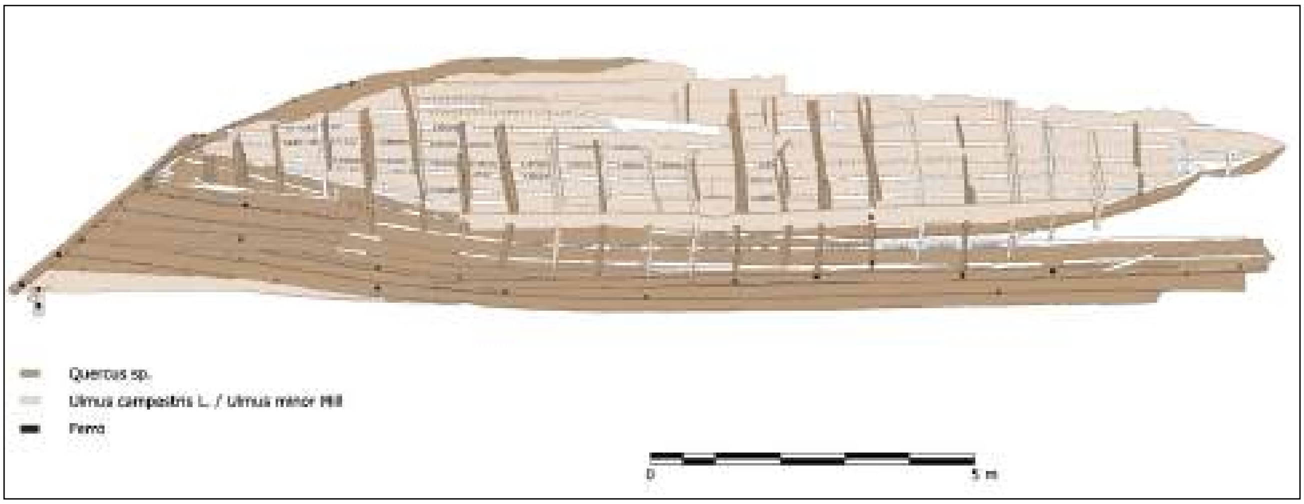


Fig. 13.2. Plan of the boat with the wood essences (elaboration: E. Costa).

Another type of cargo was hypothesised based on the study of archaeological findings as an amphora Keay LII for the transportation of wine (Fig. 13.4).

Once the carried materials were identified, their arrangement inside the boat were evaluated to analyse different loading conditions as case studies based on the sizes of the cargo. A low/medium and a medium cargo were obtained considering the amount of space needed to contain the volume of the objects.

Real calculations of the actual dimension of every single element of the cargo were completed to obtain the effective volume of each type of material. For the modelling of the sheep and the goats, the real dimensions of these animals in ancient times were considered, which were smaller than today, and the number of items that is possible to store in the empty known space of the barge was considered. Based on this and considering 50 items, the total weight of the caprines results in 2.5 t. It was decided to maintain the caprines as part of the cargo both for the low/medium and the medium loading condition in the open space of the barge and to modify the rest of the cargo to obtain two different displacements for the hydrostatic and hydrodynamic analyses.

For low/medium cargo, scattered forage or *brassicaceae* was arranged in the central barge's hold, for a total weight of about 5.65 t. The amphoras Keay LII were positioned at the stem and stern, respectively 450 on two levels and 400 on three levels, reaching a total weight of about 7.25 t (Fig. 13.5). In this condition, the total displacement is 22.3 t and the payload of about 15.4 t; the draft is 52.5 cm, with a freeboard of around 63 cm in normal conditions, reaching 4 cm of freeboard at a maximum inclination of 15° (Fig. 13.3).

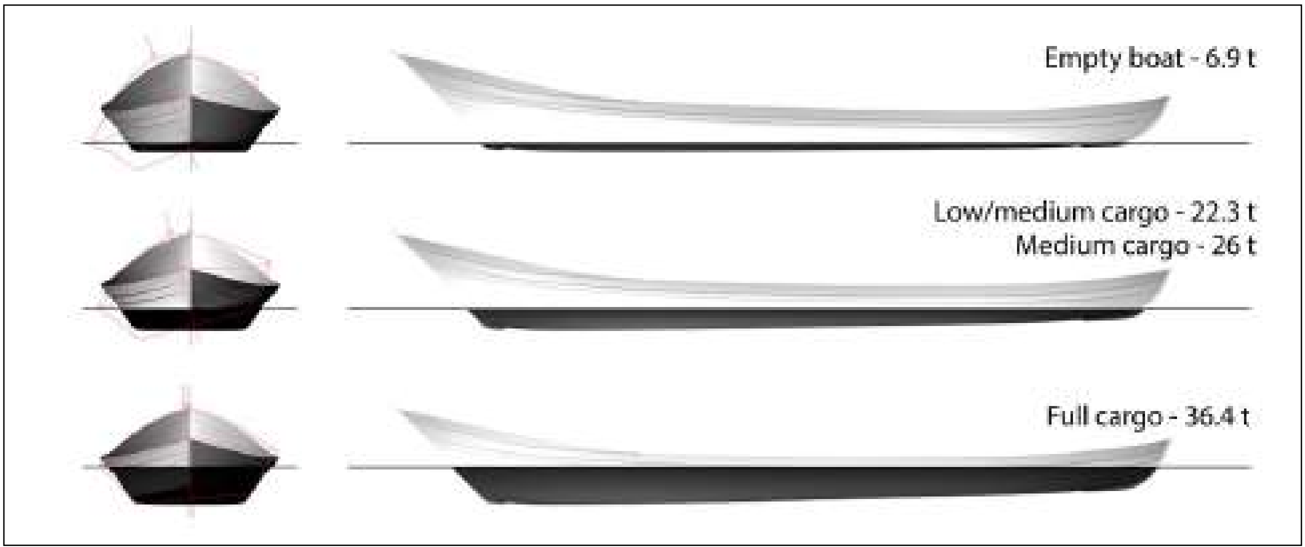


Fig. 13.3. Comparison of water level and stability with three different cargo conditions. a. Empty boat. b. Low/medium and medium cargo. c. Full cargo (elaboration: E. Costa).

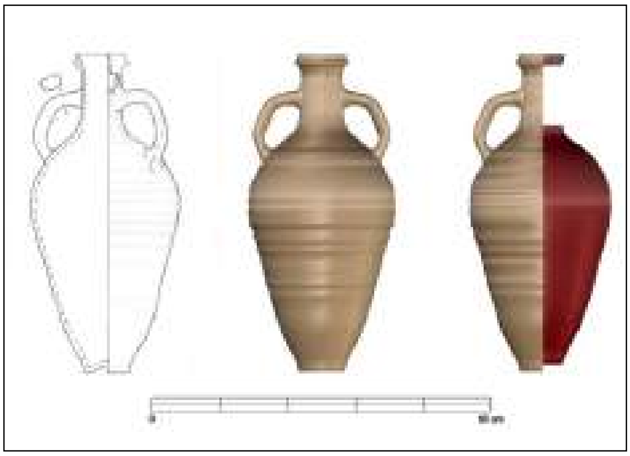


Fig. 13.4. Reconstruction of the Keay LII to calculate the perfect weight of the amphora (elaboration: E. Costa).

For medium cargo, bags of forage or *Brassicaceae* were arranged in the empty space apart from the sheep and goats, with a weight of about 16.6 t (Fig. 13.6). In this condition, the total displacement is 26 t and the payload of about 19.1 t; the draft is 59 cm, but the freeboard both in normal conditions and at a maximum inclination of 15° is the same as the low/medium cargo (Fig. 13.3).

Furthermore, the maximum payload and the condition at maximum displacement were calculated. To obtain the displacement for the full cargo, we did not start from the effective weight of a hypothetical cargo, but from the opposite calculation, considering the maximum weight that this kind of hull shape could support, maintaining a sufficient and safe freeboard.

For full cargo, the total displacement is 36.4 t and the payload of about 29.5 t; the draft is 78 cm, with a freeboard of around 26 cm in normal conditions, reaching 5.6 cm at a maximum inclination of 5° (Fig. 13.3).

To establish the full-loading condition, some considerations are necessary. A minimum freeboard in still water conditions must be fixed, which corresponds to the full-load displacement. The weight of the cargo (payload) is then obtained by subtracting the lightship displacement from the full load displacement. Once known the payload, its volume is found considering its mass density, consequently the C.o.G. In this condition, the transport of a large volume of cargo is allowed, but stability margins are scant. As in a typical river waterborne area, there is no risk of waves, but the full load condition must be considered as an extremely hazardous situation due to the reduction of stability margin in terms of C.o.G. vertical position, a small heel would cause flooding. An exceptional transport could be carried out only for short distances and in those sections where the river itself does not provide dangerous conditions, strong currents or difficult meanders offer the risk of a possible sinking.

To improve the hydrodynamic analysis, the 3D model was imported into naval-architecture design software. Following the cargo conditions as a result of the finds found during the excavation and considering lightship (structure, equipment), crew, provisions and various payload weights, a detailed table was prepared (Tab. 13.1) with the different loading conditions, the calculation of the maximum draft and determination of hull coefficients.

The maximum draft was determined based on stability criteria related to still water (inland), considering the effect of a longitudinal trim variation with reference to the lightship condition.

Intermediate drafts were calculated, related to the corresponding displacement, for different loading conditions, as reported by archaeological investigations. The full load condition corresponds to a displacement with sufficient stability margin. For each draft, hull coefficients were determined to perform resistance and propulsion calculations.

Beyond the evaluation of the cargo capacity of the boat in different conditions, the analyses continue to the evaluation

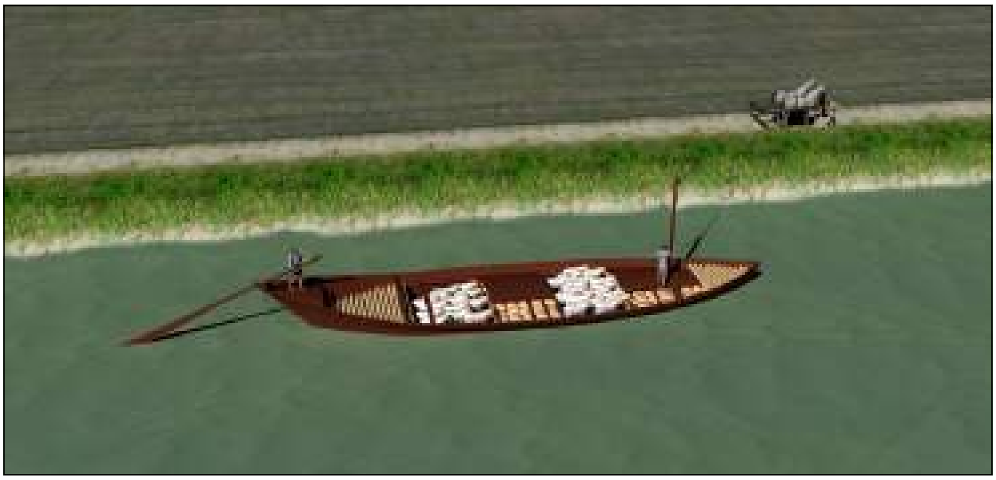


Fig. 13.5. Hypothesis of the disposition of the low/medium cargo with caprines, forage or Brassicaceae and amphoras (elaboration: E. Costa).

Fig. 13.6. Hypothesis of the disposition of the medium cargo with caprines and forage or *Brassicaceae* (elaboration: E. Costa).

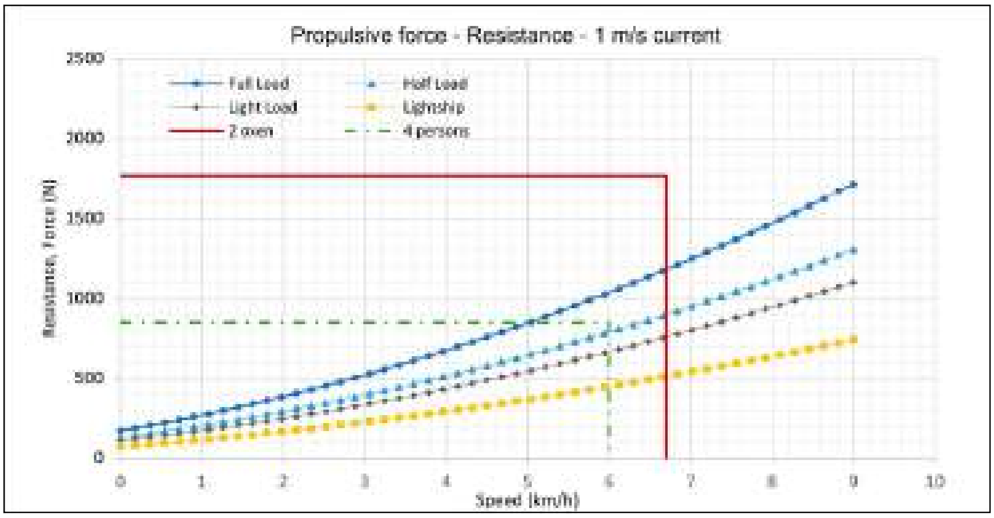


Fig. 13.7. Table with the curve representing the power needed (y-axis) for every speed (x-axis) at the displacement considered (elaboration: G. Degan).

of the seaworthiness of the boat, its stability and speed, combining and studying all the factors to better understand the relation between nautical qualities, efficiency, and economic productivity, estimating the advantages and disadvantages from both marine and commercial points of view (Poveda and Boetto, 2018, 48-49).

For each displacement, the stability curve was calculated to understand how much the boat could load and consequently analyse the problems and dangers of each cargo and transport condition. The flat-bottomed hull certainly allows a large load capacity and good stability at low/medium and medium cargo, especially in a river area, in absence of waves and without reaching high speeds.

Based on the previous analyses, calculations on the resistance and powering of the barge were performed. The power needed for the surge ahead of the boat was put in relation

	Lightship	Light Load	Half Load	Full Load
Mean draft (T) m	0.185	0.525	0.591	0.783
Displacement (Δ) t	6.900	22.67	25.98	36.38
Waterline length(L.W.L.) m	17.349	18.131	18.260	18.654
Beam max on W.L. (BWL) m	3.316	3.751	3.830	4.180
Wetted Surace (AW) m^2	45.777	59.858	62.582	73.180
Waterplane Area (WPA) m^2	42.703	49.682	50.955	55.812
Prismatic coefficient (CP)	0.697	0.699	0.696	0.655
Block coefficient (CB)	0.649	0.585	0.574	0.471
Midship coefficient (CM)	0.957	0.911	0.903	0.850
Waterplane coefficient (CWP)	0.742	0.730	0.729	0.716
Long. pos. of the centre of buoyancy (LCB) m	8.920	8.683	8.660	8.156
Long. pos. of the centre of WPA (LCF) m	9.102	9.081	9.065	8.866
Vert. pos. of the centre of buoyancy (KB) m	0.100	0.283	0.319	0.440
Transv. metacentric radius (BMt) m	4.336	1.916	1.781	1.636
Long. metacentric radius BML m	102.337	39.309	35.649	28.535
Distance from keel to the transv. metacentre (KMt) m	4.437	2.198	2.100	2.074
Distance from keel to the long. metacentre (KML) m	102.437	39.589	35.965	28.957

Tab. 13.1. Loading conditions and hull parameters (Elaboration: G. Degan)

to the propulsive power of humans and animals, the only ones that permitted riverine navigation upriver against the current in ancient times.

The hull resistance has been calculated for every loading condition and at different speeds, until 9 km/h. Mathematical models and regression equations have been used, considering the resistance components that constitute the total resistance. The added resistance due to the rudder effect for the course-correction was also considered as a factor dependent on the speed. Moreover, the calculation was performed considering the effect of a current in the opposite direction.

Another important data that we must consider is the speed of the current; we do not have data from ancient times, so we have to consider the modern speed in the same area at about 1.25 m/s, which could decrease along the riverbank at around 0.6 m/s.

Data from the modern period indicate, in good conditions and without accidents, that the speed with human traction could allow distances of 15/20 km to be covered each day, but horses could allow distances of 30 km to be covered each day (De Izarra, 1993, 166; Rieth, 1998, 107; Descombes, 2007, 30). According to ethnographic sources from mariners of the Sile river, they could cover 10 km in 4 hours with human towing only in some portions of the river, with a speed of 2.5 km/h; in some points of the river with a strong current, 12 oxen were needed to tow a Burcio (Turato *et al.*, 1980, 23), the typical riverine barge of the North area of Po Valley, with a maximum displacement of about 180 t. These data could be applied to the Early Middle Ages, although it must be considered that the use of horses is rare and the conditions of the river, at that time, might have been much more difficult than in the 20th century, because of worse maintenance.

From the resistance curve, the effective power curve was calculated, as needed for the ship's surge motion. It was related to human and animal propulsive power in order to determine the amount (number) of animals or persons needed to pull the ship. The results have been plotted onto curves, as Fig. 13.7 depicts, where each curve represents the power needed (y-axis) for every speed (x-axis) at the displacement considered, with the effect of a 1 m/s river course current in the opposite direction. The requirement of animals or persons is also shown in the figure, evaluating the surge motion considering an upriver course against the current, the amount of which is assumed according to real environmental operative conditions.

Given that the towing speed can be assumed to be around 3-4 km/h, we could assume the number of oxen or people employed to move and tow this barge in correlation with the displacement of the barge in order to maintain a useful speed. The empty boat can be easily moved by two men, while at low/medium and medium cargo it is necessary to hypothesise two/four oxen to maintain a constant speed (Fig. 13.7).

The option of hoisting a sail instead of towing has been considered, whenever the environmental conditions were favourable. However, with reference to the assumed mast position on board, effective potential scenarios of sailing propulsion are limited to the downwind course. As shown from archaeological surveys, the mast was fitted in the fore part of the ship, next to the bow, in such a manner that a beam-reach sailing would have caused a force of yaw more than propulsive power.

Based on what can be seen, the functionality of the mast was to assure a coupling point for the towing lines during normal towing operations.

Carlo Beltrame

14. THE SHIP-CONSTRUCTION TECHNIQUE BY SEWING IN THE ROMAN AND EARLY MIDDLE AGE PERIODS

We have just described the method of construction used on the barge of Santa Maria in Padovetere as a sort of carvel bottom-based solution which cannot be classified among the 'shell-first' construction nor in the 'skeleton-first' construction concepts (Pomey, Kahanov and Rieth, 2012), and we have seen how the technique used to join its planking was the sewing technique, which used continuous stitching. This last technique was more often associated with boats and ships built according to the carvel 'shell-first' method. This method implies that the planking is built before the frames and that the latter do not give the shape and, instead, represent a 'simple' strengthening of the hull (Fig. 14.1). The sewing technique was largely used in the Greek Archaic period (see further) but was also probably known earlier and coexisted with the 'mortise-and-tenons' technique (Pomey and Boetto, 2019) (Fig. 14.2). Indeed, both these practices are simple technical solutions to join the planks of ships built according to the 'shell-first' or the 'bottom-based' methods. For centuries they were probably both known by the shipyards facing the Mediterranean, which chose them according to traditions and other reasons which we are still investigating.

The first evidence of the use of the 'mortise-and-tenons' technique in a ship used to sail in the Mediterranean is offered by the Uluburun (Turkey) shipwreck (Pulak, 1999) (Fig. 14.3), dated to the end of the 14th century BC, but the technique was already known, by at least the Third Millennium, in Egypt to complete the construction of riverine boats (Ward, 2000). After a period of probable coexistence, by the 6th century BC, it seems the sewing technique was preferred to the 'mortise-and-tenons' for the construction of Greek maritime vessels. According to Pomey and Boetto (2019, 22), its diffusion would have been guaranteed by the Ionian Greeks colonising the cities of the western Mediterranean while the 'mortise-and-tenons' technique would have had a Phoenician/Levantine origin, as also proposed by Cato the Elder (*De Agr.* XXI, 18, 9), who speaks of *coagmenta punica*. Although this is of course a fascinating theory, the discovery of the sewing technique on the boat of Zambratija (Istria-Croatia) (Koncani Uhac, Boetto and Uhac, 2019), dated between 1175 and 900 BC, has, as was predictable, complicated the panorama. As just seen, the first traces of the use of tenons appeared already in the Third Millennium BC, although used for riverine boats, while the first evidence of the sewing technique was seen on the Zambratija boat, in the upper Adriatic (Fig. 14.4), far from the main routes of the Ionian colonisation, and on the western Mediterranean, in the shipwreck of Mazarròn 1 (Tejedor, 2018), a possible Punic boat dated between the 7th and the 6th century BC, which presents both the mortise-and-tenons and the sewing technique.

In the sewn technique, the planks are joined with a continuous stitching along a flush seam through the channels pierced along the borders. Little pegs lock the stitches in the channels (Fig. 14.5). Wooden dowels or tenons are used to align and fix hull planks to hull planks along both edges. The dowels (and the tenons) also stopped possible movements of the planks which could stress the sewing. The holes in the planking present a characteristic tetrahedral shape in the inner face. A continuous stitching leaves an |X|X|X|X| pattern inboard (Fig. 14.6). Rope stitches held in position a wadding made of a roll of vegetable fibre caulking placed along the seams. Given that in the *baggaras* made in Iran, the function of the wadding is 'to tension the cordage, not least by swelling when wet, thus improving the watertightness of the seam beneath' and since in the same boats 'it also cushions the cordage against wear, especially at the edges of the sewing holes' (Cooper *et al.*, 2020 and references) (Fig. 14.7), we can suppose it had the same function in Greek and later boats.

The frames of these ships have the following pattern: there is a central floor timber which could be lashed (in the older phase) or could be nailed by bronze nails (in the last phase of this technique) to the planking and had no contact with the keel. The futtocks were joined to the floor timber through a flute beak junction stopped with pegs (Fig. 14.8). The section of these frames was trapezoidal, that is the base was less wide than the upper part and the sides were diagonal. The upper side had a curved shape. This profile probably allowed better tightening of the ropes joining the frames with the hull.

Leaving the complex problem of the origin of the sewing technique to other scholars, of course, we can say that its diffusion in the Archaic period, by the second quarter of the 6th century until the beginning of the 5th century BC, was widespread, since it has been recognized in shipwrecks sunk along the Iberian coast (Cala Saint Vicenç-Majorca), the Gallic coast (Bon Porté, Place Jules Verne-Marseille), the Tyrrenian sea (Isle of Giglio), the Sicilian coast (Gela) and the Ionian coast (Pabuç Burnu-Bodrum) (Pomey and Boetto, 2019 and references).

The fortune of this technique did not last so much since it was soon progressively replaced by the 'mortise-and-tenons' system as would be demonstrated by the *Jules-Verne 7* shipwreck which, already at the end of the 6th century BC, was constructed with this technique and was abandoned in

Location	Type of evidence	Dating	Technique of dating	References
Altinum (Marcon) (VE)	Section of boat	Post 1° cent. BC	Stratigraphy	Cipriano, 2011, 85-86; partially unpublished.
Aquileia (*Canale Anfora*) 1 (UD)	Section of ship	1° cent. AD?	Stratigraphy	Bertacchi, 1990; Beltrame, 2002a; Beltrame and Gaddi, 2013a.
Aquileia (*Canale Anfora*) 2 (UD)	Section of ship	End 2nd-beginning 3rd cent. AD	Stratigraphy	Beltrame and Gaddi, 2013a.
Caska 1 (Pag island-*Novalia*)	Boat	42-107 AD	AMS Radiocarbon	Boetto and Radic, 2017.
Caska 3 (Pag island-*Novalia*)	Section of boat	1st-2nd cent. AD	Stratigraphy	Boetto and Radic, 2017.
Caska 4 (Pag island-*Novalia*)	Boat (reused)	1st-2nd cent. AD	Stratigraphy	Ferreira Domìnguez *et al.*, 2021.
Corte Cavanella di Cavanella d'Adige 1 (RO)	Boat	End 1st-beginning 2nd cent. AD	Stratigraphy	Beltrame, 2002a.
Corte Cavanella di Cavanella d'Adige 2 (RO)	Boat (reused)	180-200 AD	Stratigraphy	Beltrame, 2002a.
Cervia (RA)	Fragments of boat	7° century AD or later	Associated finds	Bonino, 1968; 1971; Beltrame, 2019b.
Cervia (RA) (saltworks)	Fragments of planking	3rd cent. BC-1st cent AD	Stratigraphy/ ^{14}C	Beltrame, 2019a.
Grado (GO)	Plank of ship	243-382 AD	AMS Radiocarbon (ETH Zurich)	Unpublished.
Lagoon of Venice (VE)	Plank?	590-470 BC?	^{14}C (C.R.A.D. Udine)	Beltrame, 2002a.
Lido di Venezia 1 (Alberoni)	Fragments of ship	92-231 AD	Radiocarbon	Beltrame, 1996; 2002a.
Lido di Venezia 2 (San Nicoletto)*	Fragments of ship	1-150 AD	AMS Radiocarbon (Arizona, ICA)	Beltrame, 2002a, Willis and Capulli, 2018.
Ljubljana (Lipe)**	Ship	150-50 BC	AMS Radiocarbon	Muellner, 1892; Salemke, 1973; Gaspari, 1998; 2017.
Meolo (VE)	Frame of boat	Roman period?	Context	Beltrame, 2002a.
Motta di Cavanella d'Adige (RO)	Section of boat?	2nd-1st century BC	Stratigraphy	Tiboni, 2009.
Opitergium (TV)	Planks (reused?)	End of the 2nd century AD	Stratigraphy	Beltrame, 2002a.
Patavium	Section of planking	Beginning of the 2nd cent. AD	Stratigraphy	Beltrame, 2002a.
Pomposa (FE)	Boat	11th cent. AD?	Associated finds (common pottery)	Bonino, 1968; Beltrame, 2002a.
Pula 1	Boat	1st-250 AD	Stratigraphy	Boetto, Koncani Uhaç and Uhaç, 2017.
Pula 2	Boat	1st-250 AD	Stratigraphy	Boetto, Koncani Uhaç and Uhaç, 2017.
San Francesco del Deserto island (Lagoon of Venice)	Planks	2nd-4th century AD?	Associated finds	Capulli and Pellegrini, 2010.
Stella, river (Precenicco) (UD)	Boat	1-50 AD	Associated finds	Vitri *et al.*, 2003; Castro and Capulli, 2016.
Valle Ponti (Comacchio) (FE)	Ship	25-0 BC	Associated finds	Berti, ed., 1990.
Vrhnika 2 (Ljubljanica river)	Section of planking	2nd century BC	AMS Radiocarbon	Gaspari, 2017.
Zambratija	Boat	1175-900 BC	AMS Radiocarbon	Koncani Uhac, Boetto and Uhac, 2019.
Zaton 1 (Nin-*Aenona*)	Boat	1st century AD	Associated finds	Brusic, 1995; Brusic and Domjan, 1985.
Zaton 2 (Nin-*Aenona*)	Boat	1st century AD	Associated finds	Brusic, 1995; Brusic and Domjan, 1985.
Zaton 3 (Nin-*Aenona*)	Boat	1st century AD	Associated finds	Gluscević, 2004

* Fragments of planking with the same characteristics, of the same wood and found in the same place of the single fragment of planking published by Beltrame (2002a), have been defined by Willis and Capulli (2018) as Lido di Venezia 3. Although these discoveries happened within 12 years of each other, there is no logical reason to think that they come from two different ships. For this reason, we consider them to be the same wreck.
** This find is located far from the Adriatic, in a riverbed.

Tab. 14.1. List of ships or fragments of boats built with the sewing technique in the Adriatic area (C. Beltrame).

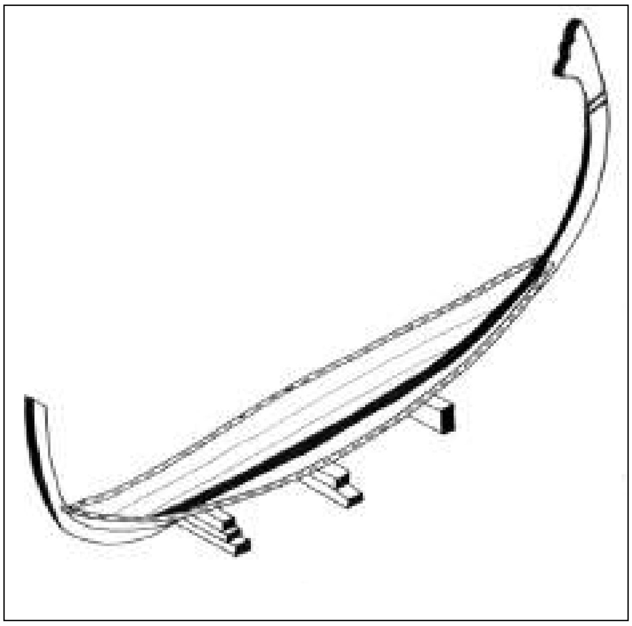


Fig. 14.1. First phase of the 'shell-first' method.

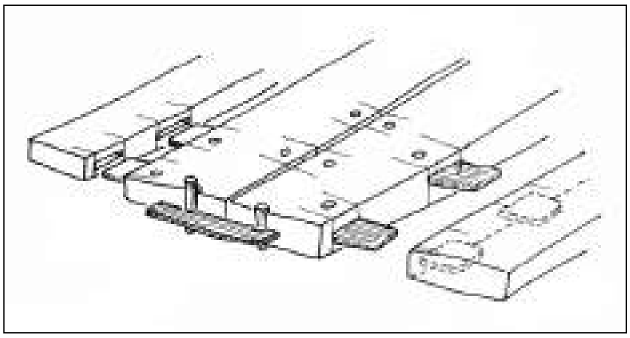


Fig. 14.2. Sketch of the mortise-and-tenons technique (Gassend, 1982).

the harbour of Massalia together with a boat (*Jules-Verne 9*) built with the sewing technique (Pomey and Boetto, 2019 and references).

It is important to underline the coexistence of the two techniques in many boats. The Pabuç Burnu and the Cala Saint Vincenç hulls present both tenons, unpegged in the

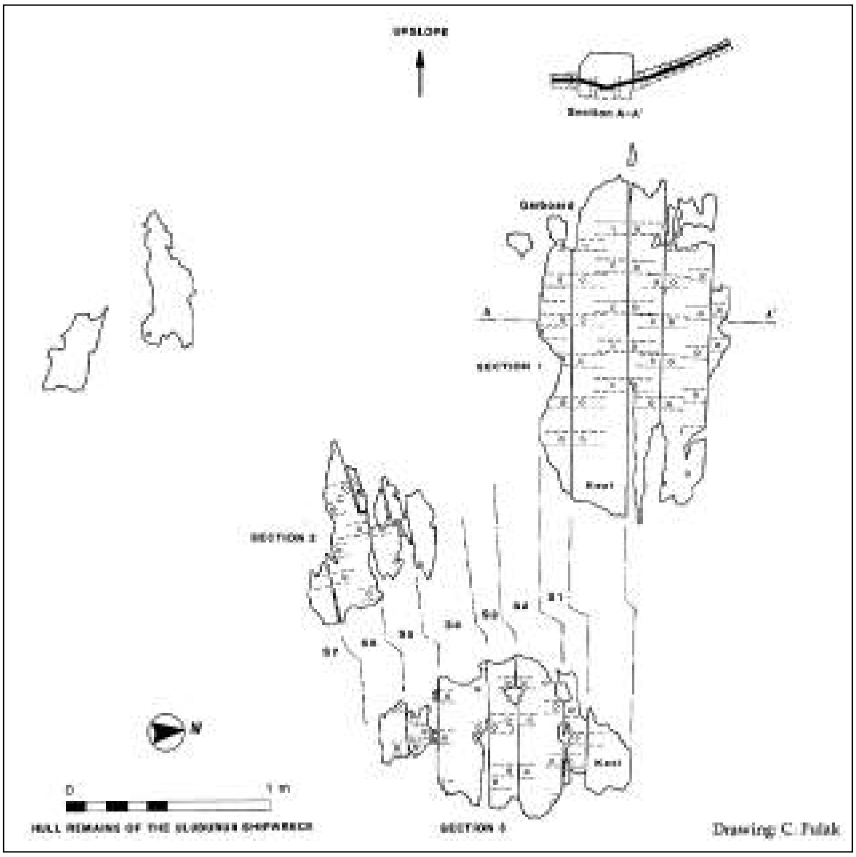


Fig. 14.3. Remains of the hull with mortise-and-tenons on the end of the 14th century BC sitewreck of Uluburun (Pulak, 1999, Fig. 1).

planking, and sewing (Fig. 14.8); in the Gela 1 wreck the sewing technique is predominant but there are traces of the use of tenons (Fig. 14.9); in the Jules-Verne 7, the ship built with tenons was repaired with the sewing technique, in the Ma'agan Mikhael boat (Kahanov, 2003), the junction of the stem and the stern-posts were made with both techniques (Fig. 14.10). The sewing technique was also used for repairing the Gela 2 hull. This last technique continued to be used in the Greek period because it was very practical for repairing and for joining difficult and critical parts of the ships, such as the curved extremities.

After the aforementioned testimonies of the use of this technique in specific parts of the ships, but not in the junction of the planking, it seems the Mediterranean shipyard opted to use only the 'mortise-and-tenons' technique while abandoning the sewing one. Despite the abandonment of the sewing technique in the entire Mediterranean, the Northern Adriatic shipyards, where the first evidence of this technique is documented, maintained this tradition for unknown reasons. The evidence of the use of the sewing technique in this limited area of the Roman Empire is very widespread and is shown by hulls which almost always can be classified as local, that is, built in this region, from Cervia to Aquileia, along the western coast, and from Nin (Zaton) to Porec, along the Eastern coast (Tab. 14.1). This local attribution is possible either thanks to the limited size of many of these boats, which could not have been built much far from the place of abandonment or sinking, and because of their discovery in inland waters. The Santa Maria in Padovetere barge was not the only one found inside an old river since the planks reused from *Patavium* and the single small floor-timber from Meolo (Fig. 14.11) were found in silted rivers while the barge of Lipe, the planking of Vrhnika and the small barge of the Stella were found inside still active rivers. Two different sections of ships were found inside the silted Canale Anfora at Aquileia (Figs. 14.12), the two small boats of the possible *mansio*, at Corte Cavanella, were excavated one inside a *cavana* (a dock covered by a roof) connected with a channel and one in reused conditions (Fig. 14.13), while the section of boat found north-west of *Altinum* lay inside an old channel connected with the Zero river (see further).

Although the Grado plank and the Lido di Venezia 1, Lido di Venezia 2 and the Valle Ponti ships were found along shores (the latter along an old shore), it is reasonable to suppose that they were trying to enter the inland waters. The Lido di Venezia 1 and Lido di Venezia 2 finds testify possible attempts to enter into lagoons, the Valle Ponti ship possibly was exiting or entering an old river while the plank of Grado was perhaps already into the lagoon of Grado (see below).

The regional placement of the sewing ships is also inferable through the wood species used since most of them were built with species which are compatible with the forests present in the Roman period close to the place of discovery. To be more precise, the Roman shipyards building these ships were much more selective than the shipyards working with the 'mortise-and-tenons' technique. Indeed, the use of elm for the plank, a hardwood, was very regular and applied to the entire planking (an exception was the boat 2 of Corte Cavanella, made with softwood), at least along the western

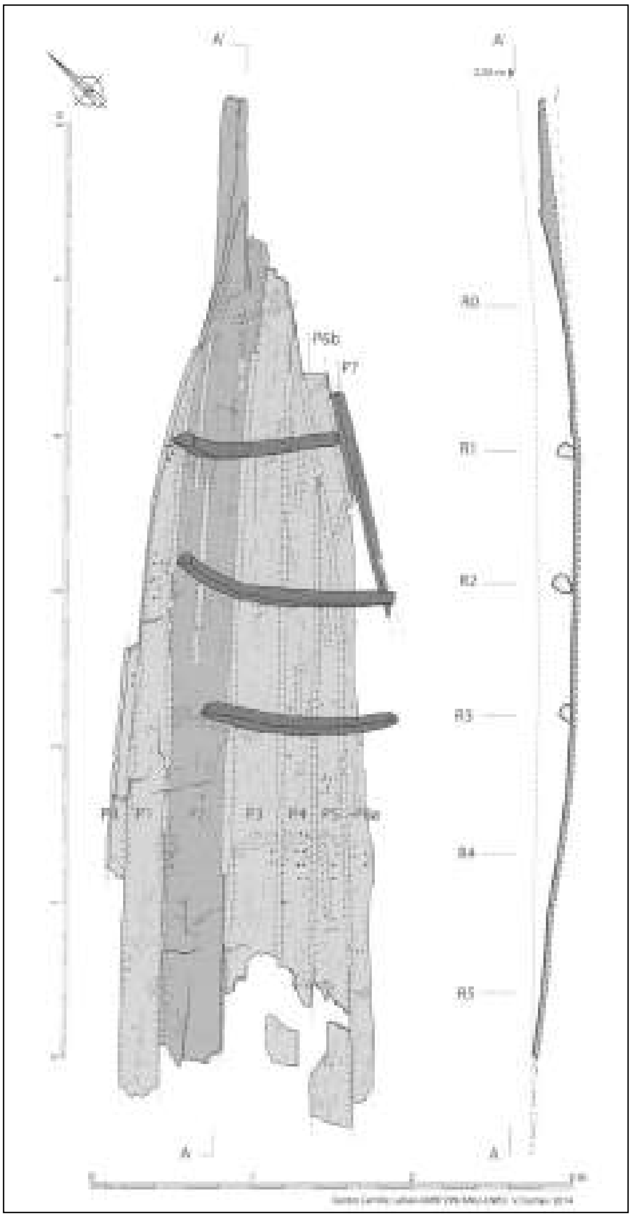


Fig. 14.4. The sewn Bronze Age hull of Zambratija (Koncani Uhac, Boetto and Uhac, 2019, Fig. 8.2).

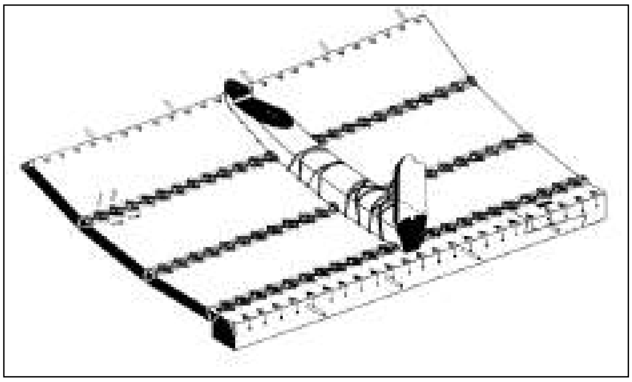


Fig. 14.5. Technique of sewing of the 6th century BC hull *Place Jules Verne 9* (Pomey and Boetto, 2019, fig. 23).

Fig. 14.6. Cast of the stitching on the hull of Gela 1 (490 BC *circa*) (photo: C. Beltrame).

Fig. 14.7. Wadding along the seam of a Baggaras boat (courtesy: J.P. Cooper).

littoral. The same homogeneity was applied to the frames which were mainly made with *Quercus robur*. Oak was very common along the Northern Adriatic coasts while elm was abundant along the coasts of the Italian Northeast.

It is still too early to say if this request for homogeneity in the use of wood and this use of elm and oak is a prerogative either of the sewing technique or of the local shipyards. To answer this question, we would need to find more boats built with 'mortise-and-tenons' in this area, a technique which is not completely absent along these coasts. The planks with 'mortise-and-tenons' reused in the saltworks of Cervia, for example, are of elm (Beltrame, 2019a), while the planks from the same site with traces of stitching are of pine. The presumed local boat found at Monfalcone, close to a *villa*, built with 'mortise-and-tenons', was made of *Abies* for the planking, and walnut for the frames (Scheda didattica del Museo Archeologico Nazionale di Aquileia).

The characteristic choice of elm for the planking of the sewing boats was not always applied along the Eastern littoral where (Pula 2, Caska 1, 3, 4) they selected the much

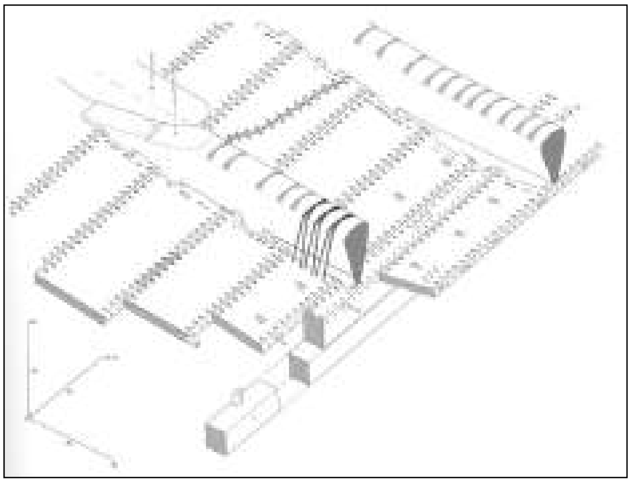


Fig. 14.8. Axonometry of the hull of Cala Saint Vincenç (520-500 BC) (Nieto and Santos, 2008, fig. 53).

Fig. 14.9. Details of a plank of the *Gela 1* hull with both sewing channels and a tenon (490 BC *circa*) (photo: C. Beltrame).

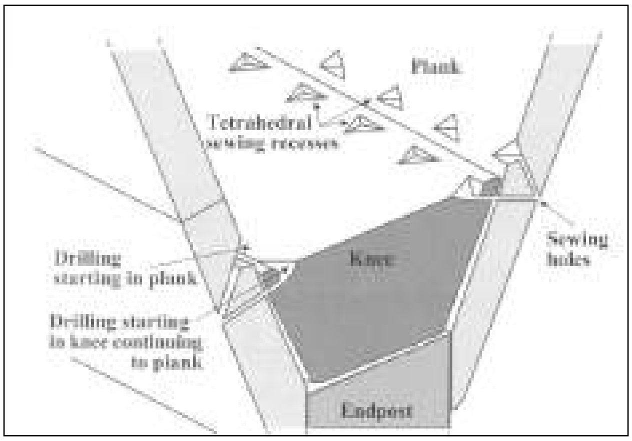


Fig. 14.10. Sewing channels in the knee and strakes of the mortise-and-tenons hull of Ma'agan Mikhael (400 BC) (Kahanov and Linder, 2004, fig. 10).

less resistant beech wood perhaps because of its availability in the close mountains (Ferreira Dominguez *et al.*, 2021).

As for the 'mortise-and-tenon' technique, it is possible the sewing system was used not only for shipbuilding but also for general carpentry. Indeed, we have evidence of the use of planks, joined with the sewing technique, in a watermill at *Opitergium* (Beltrame, 2002a) and in a river bank at Motta di Cavanella d'Adige (Tiboni, 2009). In both cases, it is possible that the manufacts were reused elements of boats like the two planks found in a submerged bank close to the island of San Francesco del Deserto, in the Venetian lagoon (Capulli and Pellegrini, 2010) (Fig. 14.14). A situation of reuse has also been found in the saltworks of Cervia where fragments of planking, both of sewn boats and of boats assembled by mortise-and-tenons, dated in the Republican period, had been used to build the tanks of the *salina* (Beltrame, 2019a) (Figs. 14.15, 14.16). The boat of Porec was used under stone foundations (ISBSA Zadar 2021).

The find of Motta di Cavanella d'Adige is one of the more ancient Roman traces of the use of this technique in the Adriatic area (considering that the barge of Ljubljana and the section of planking from the Ljubljanica were far from the coast). Indeed, the stratigraphical excavation would have dated its deposition in the 2^{nd}-1^{st} century BC. The two fragments of planks reused in the saltworks of Cervia could have been older since other timbers used in the same wooden structure were dated, by ^{14}C, between the 3^{rd} century BC and the 1^{st} century AD (Guarnieri, 2019, 118).

The use of this technique in this macro region is particularly well attested in the first three centuries after Christ, but it continued in the Late Roman period, as attested by the barge of Santa Maria in Padovetere, possibly until the 7^{th} century AD, or a little later, as documented by the not precisely dated fragments of a boat from Cervia (Beltrame, 2019b). This continuity of use is also testified by various Latin authors which call these boats *sutiles naves* and which began to quote this technique at the end of the 2^{nd} century BC (Varro in Aulo Gellio, XVII, 3,4 and Pacuvius, quoted by Verrio Flacco in Festo, 508, 33), although it is always described as archaic, belonging to the past (Casson, 1963)[1]; their quotations reach the 5^{th} century AD when St Jerome (*Epistolae* CXXVIII, 3) compared the fragility of virginity with this sewing technique. Varro and Pacuvius would also confirm the diffusion of this technique among the Illyrian (presumably according to a geographical and not an ethnic notion of this word: Pomey and Boetto, 2019, 6) and Istrian populations, which is so well documented by the archaeological evidence.

The sewing technique of the Roman period presents important differences in comparison to that of the Greek period. The planking loses the characteristic tetrahedral inner holes, but it acquires typical trapezoidal grooves along the sides (Figs. 14.17, 14.18). This design, which became characteristic of the Roman and Late Roman periods and which was used to better protect the stitching as it did not have to protrude from the hull, is present only on planking thicker than 3.5 cm. Thinner planks have simple circular grooves, as in the Greek ships. The transversal dowels and the tenons among the planks disappear almost completely, although sometimes single dowels appear in certain parts of some boats (Grado, Lido Alberoni and Aquileia) (Fig. 14.19). This structural weakening is balanced by the reduction of the space between the frames which passes from about one

[1] Read also Homer (Iliad, 135), Aeschylus (Suppliants, 134-135), Virgil (Aeneid, 6, 413-414), Strabo (7, 4, 1) and Pliny (N. H., XXIV, 65).

Fig. 14.11. Small flat floor-timber of Roman sewn boat from Meolo (Venezia) (photo: C. Beltrame).

Fig. 14.12. Section of Roman sewn ship 2 from the Canale Anfora at Aquileia (photo: D. Gaddi).

Fig. 14.13. Roman sewn boat n. 2 reused in the *mansio* of Corte Cavanella (Rovigo) (photo: C. Beltrame).

metre to 25-45 cm. Also, the design of the frames changes drastically. In the Roman period, they were much simpler, with almost rectangular sections. The floor-timbers are no longer joined to the futtocks; the frames are composed of single elements which are not in contact with each other. They are no longer jointed to the hull by bronze nails; they can be connected to the planking through wooden pegs and they can also be lashed to the hull, as in the Zambratija, Caska 4 and Valle Ponti watercrafts, with a solution which recalls very well the boats made in the Indian Ocean (Cooper *et al.,* 2020). In general, we can say that the Roman technique is less refined than that of the Greek period.

In certain points, especially on the diagonal junctions of the planks, the Roman techniques use few, sporadic, iron nails (San Francesco del Deserto, Cervia boat, Cervia saltworks, Santa Maria in Padovetere, Valle Ponti) (Fig. 14.20). This is a detail which we can also observe in the *baggarā*s made in the Indian Ocean (Cooper *et al.,* 2020).

The sewing technique of the Roman age produced boats of very different shapes and sizes. We have evidence of very small boats with a flat bottom (Corte Cavanella 1, 2, *Altinum,* Meolo) for inland waters, flat-bottom barges which could sail or be towed only along inland waters (Santa Maria in Padovetere, Stella river, Ljubljana river) and boats and medium size ships able to sail along the coast. Of course, at the moment, we have no clear evidence of big ships or ships with bottleneck sections, such as the Madrague de Giens ship, although the thickness of the planks found at Grado and Lido Alberoni suggest that they might come from larger ships.

It is probable that this technique had some limitations in construction in terms of size and complexity of the

Fig. 14.14. Sewn plank from San Francesco del Deserto (photo: C. Beltrame).

Fig. 14.16. Detail of a fragment of sewn plank 159a from the Roman saltworks of Cervia (photo: C. Beltrame).

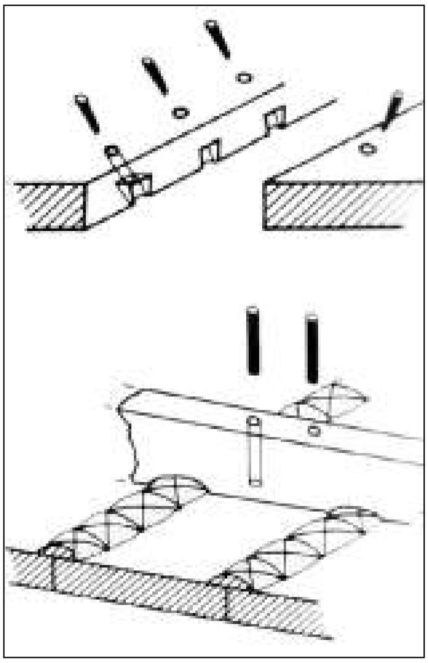


Fig. 14.17. Axonometry of the sewing system of the Roman ships.

Fig. 14.15. Fragment of sewn plank 159a from the Roman saltworks of Cervia (photo: C. Beltrame).

Fig. 14.18. Detail of the trapezoidal channels in a plank from the Alberoni beach (photo: C. Beltrame).

Fig. 14.19. Wooden dowel along the edge of the plank of Roman period found on the shore at Grado (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, du plication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 14.20. Iron nail along the edge of plank 159a found in the saltworks of Cervia (photo: C. Beltrame).

shape. This is also evident looking at the characteristics of the boats built with this technique in India and in the Gulf, now conserved in Qatar, which do not exceed the 12 m in length and present relatively simple shapes (Cooper *et al.,* 2020) (Fig. 14.21). For this reason, it is possible that we will never find this kind of ship far from the North Adriatic. Ethnography also tells us that this technique requires a demanding maintenance with an almost annual total renovation of the stitching (Chittick, 1980, 298). On the contrary, this technique makes repairing the brakes in the planking much easier than with the 'mortise-and-tenons' technique since it simply requires sewing the fracture without removing the planks.

The sewing pattern with cross-stitched 'X' or banded-X (Fig. 14.22), which is very similar to that used in the Greek period, is considered by G. Boetto *et al.* (2012) to be an element of distinction between the techniques used along the western and the eastern coasts of the Adriatic. Along the eastern coast, indeed, they used a simple loop diagonal sewing pattern (/// or I/I/I) (Fig. 14.23). These authors think that another element of distinction between these two ship-building traditions is the ship-shape: small coasters with round hulls and small keels along the eastern coast, and flat-bottom boats with at most a thickened keel along the western coast. If the distinction based on the sewing pattern seems to recur, we cannot agree with the distinction based on the ship-shape and the shape of the keel. The ship of Valle Ponti, for example, can be considered a coastal ship, of medium tonnage, since its length (23 m) and its shape could allow it to move in the Adriatic. Among the numerous fragments of ships found along the western coast there are also traces of other maritime ships of possible quite big size (for example Lido 1 Alberoni, Lido 2 San Nicoletto, Cervia and Grado), perhaps even the Valle Ponti ship.

We are not able to see an element of evident distinction among the ships found along the two coasts of the Adriatic, neither in the type of wood used, since it might depend greatly on the availability close to the shipyards. Indeed, in the planking of the Pula 1 boat, elm was used as in any western Adriatic boat. There are no distinct solutions either in the frames, since both on the western and on the eastern coasts feature frames joined to the hull with both wooden pegs and lashes. Otherwise, Pomey and Boetto (2019, 11) admit that the ships of the eastern coast are very heterogeneous since they have 'significant differences in terms of dimensions, shape, propulsion systems, and the selection of wood species used'.

To conclude we think that the sewing pattern could really be a signature to distinguish the provenance of a boat from one or the other side of the Adriatic, but that a definition of two different ship-building traditions still lacks sufficient arguments since there are no other distinct elements between them and the types of ships along both sides are very heterogeneous.

The idea of two distinct northern and north-western Adriatic traditions is less convincing than another opinion of the same authors, that the barges of Lipe and of Vrhnika, in the Ljubljanica river, should be classified as belonging to a building tradition with strong connections not only with the Adriatic but also with the Danube river (Pomey and Boetto, 2019, 17-18).

A question remains open: why was this technique only used in the Roman period in this limited area? Can we merely attribute this phenomenon to tradition or is there any practical reason for its use?

The author initially proposed a sort of environmental explanation (Beltrame, 2002a) which was, subsequently, theorised by S. Marlier (2002) and, more recently, was proposed again by Pomey and Boetto (2019, 19). Since the first discoveries were represented mainly by boats with flat bottoms or hulls with a modest draft, it seemed possible there was a connection between the ship-shapes and the

Fig. 14.21. Baggaras boat in the Qatar Museum (Courtesy A. Ghidoni).

Fig. 14.22. Caulking and traces of stitching showing the sewing pattern from the fragment of Roman ship 2 found in the Canale Anfora at Aquileia (photo: D. Gaddi).

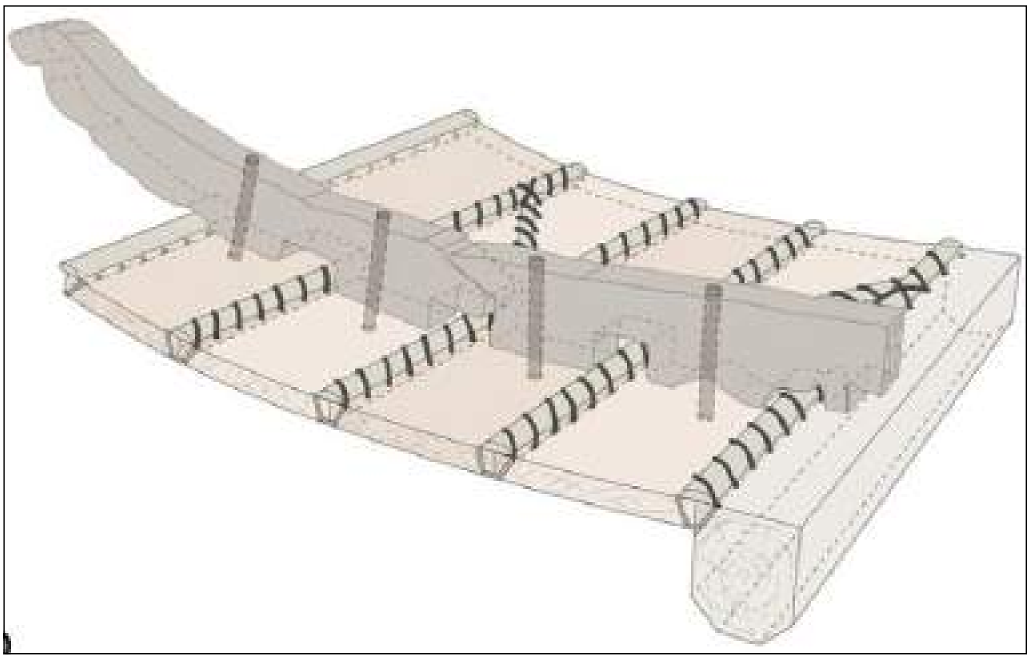


Fig. 14.23. Axonometry of the sewing system of the Roman *Caska 1* hull (Pomey and Boetto, 2019, fig. 6b).

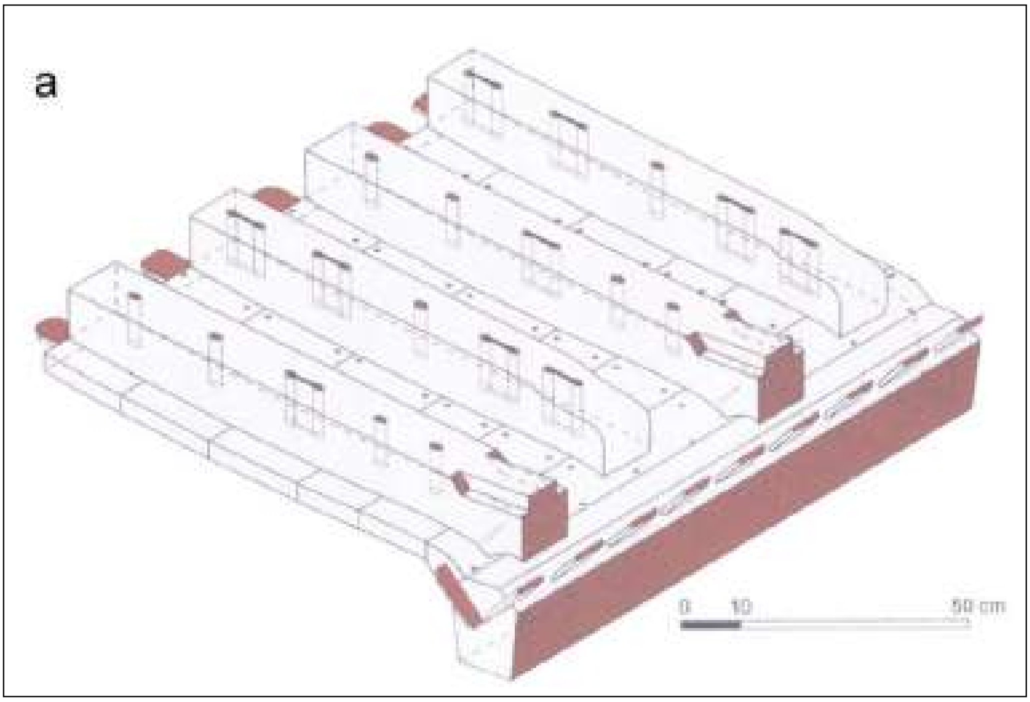


Fig. 14.24. Axonometry of the frame assembly system by internal lashing and treenails on the Cavaliere Roman shipwreck (Marlier, 2006, Fig. 7.4).

shallows navigated by these boats. Now this 'processual' explanation has become fragile because the more recent discoveries demonstrate that these boats and ships can be found in the most varied of environments: channels, rivers, lagoons, but also the sea, as represented both by the shallow shores of the western Adriatic and by the archipelagos of the Eastern Adriatic. So, the use of this technique to join the planking with a nautical environmental reason cannot be justified easily.

It is possible perhaps to suggest a more cognitive factor to explain this behaviour. It could be one of the increasingly numerous forms of conservatism of a local indigenous ship-building tradition which have emerged from archaeological research: one such tradition is lashing the frames to the planking in hulls that have been built with 'mortise-and-tenons', a technique recognized, between the middle of the 3rd century BC and the middle of the 2nd century AD, in 18 shipwrecks located only along the coasts of Provence and Catalonia and, for this reason, defined as a north-western Mediterranean tradition (Pomey and Boetto, 2019, 36-43) (Fig. 14.24), which has not still received any convincing practical/environmental explanation. These technical traditions produced forms of cultural identities which could be easily identified among the sailing communities, but we do not know if they were really done on purpose, especially considering the cultural *koiné* of the Adriatic, and in general of the Mediterranean, during the Roman Empire.

OTHER RECENT FINDS OF SEWN BOATS

Carlo Beltrame

15. RECENT FINDS OF PLANKING OF A SEWN SHIP OF ROMAN PERIOD ALONG THE SHORE OF ALBERONI, AT THE LIDO DI VENEZIA

In June 2022, Mr. Gianluca Busetto, walking along the sandy shore of the Alberoni, in the Lido di Venezia, 260 m north from the pier (Fig. 15.1), discovered two fragments and two smaller pieces of planking with evident traces of a sewing technique of the Roman period.

The wood was very dehydrated, because it had been left in the sun, so the dimensions must be considered with precaution. The fragment of plank n. 1 is 115 cm long, and 27 cm wide (Fig. 15.2). The length of the pegs (7.5 cm), still conserved in the channels, indicates the original thickness of the plank which now is reduced to only 5-6 cm (Fig. 15.3). The channels have an ellipsoidal shape and the following dimensions: 2.6×1.6 cm (Fig. 15.4). On the edge of the external side, the channel is inside a notch of about 2.5-3.5 cm and the hole is about 2 cm. The distance between the centre of each channel is about 8-11.5 cm.

There are two channels with a diameter of 2.4 cm hosting treenails which joined the frames at 62 cm of distance between them. On the inner side, there are a couple of signs made with a chisel of unknown nature. The plank was radially cut from the tree.

The fragment of plank n. 2 is 65 cm long, and 25 cm wide (Fig. 15.2). The length of 8 cm of the pegs, still conserved in the channels, indicates the original thickness of the plank which now varies from 5 to 6.8 cm. The channels have an ellipsoidal shape and the following dimensions: 2.5×2.9 cm. The distance between the centre of each channel is about 7.8-11 cm. On the edge of the external side, the channel is inside a notch of about 2.8-3.5 cm and the hole is about 2 cm. There is a hole with a pentagonal shape of 2 cm wide hosting a treenail which joined the frames (Fig. 15.5). Close to this treenail, on the inner side of the plank, there are a

Fig. 15.1. Site of discovery in 2022 of the Roman planks of Alberoni (entrance of Malamocco).

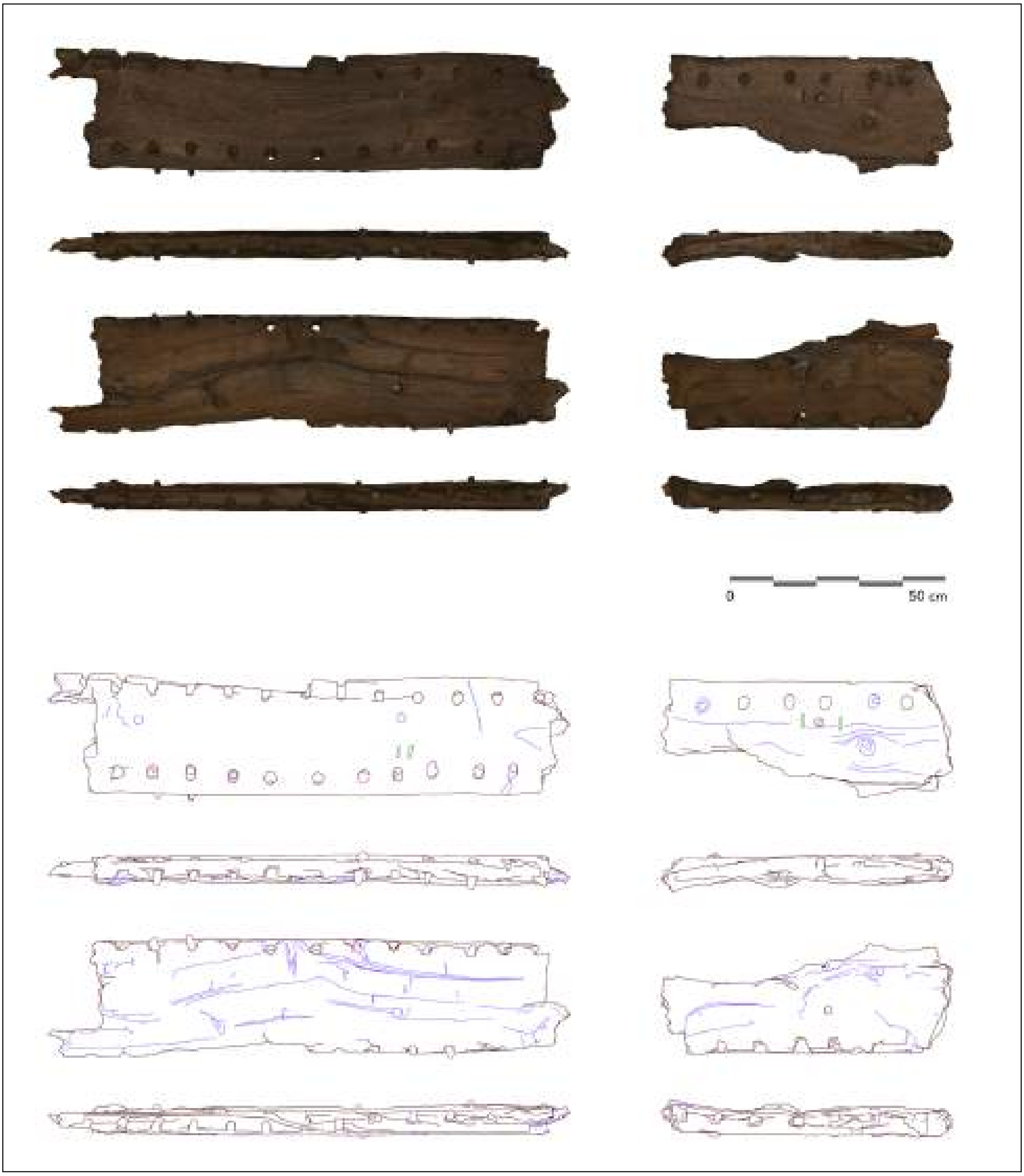


Fig. 15.2. Fragments of planking 2022 (photogrammetry: E. Costa) (authorised by the Ministero della Cultura, duplication forbidden).

couple of signs made with a chisel of unknown nature, 9 cm distant between them. Along an edge, there is a transversal treenail with a diameter of 2.7 cm.

Both the planks were made with elm while all the pegs and treenails are of boxwood (see below). Two more small pieces of planks have characteristics not different to those of the two main planks fragments.

An AMS radiocarbon analysis on a peg (made at the ETH of Zurich) indicates the calibrated date about 95-231 CE (Fig. 15.6).

In January 2003, along the same shore, Mr Marcello Rossani found another fragment of sewn plank (88 cm long), which has never been published (Fig. 15.7). The plank was 22 cm wide and 6.8 cm thick. The channels

Fig. 15.3. Peg in the channel of a dehydrated plank 2022 (photo: E. Costa) (authorised by the Ministero della Cultura, duplication forbidden).

Fig. 15.4. Channels for sewing in a plank 2022 (photo: E. Costa) (authorised by the Ministero della Cultura, duplication forbidden).

Fig. 15.5. Hole with pentagonal shape and signs made with a chisel on the inner face of plank 2/2022 (photo: E. Costa) (authorised by the Ministero della Cultura, duplication forbidden).

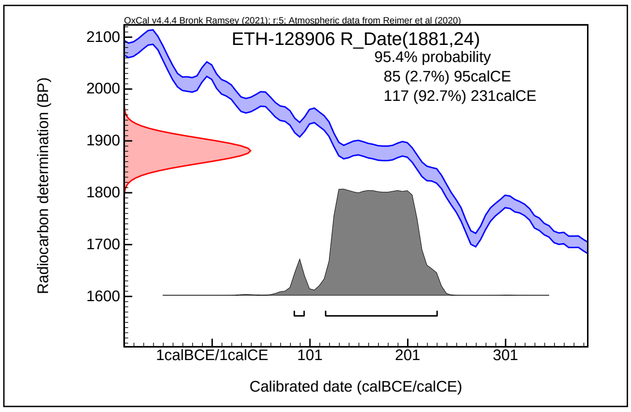


Fig. 15.6. AMS dating of a wooden peg from the fragments of planking 2022 (ETH).

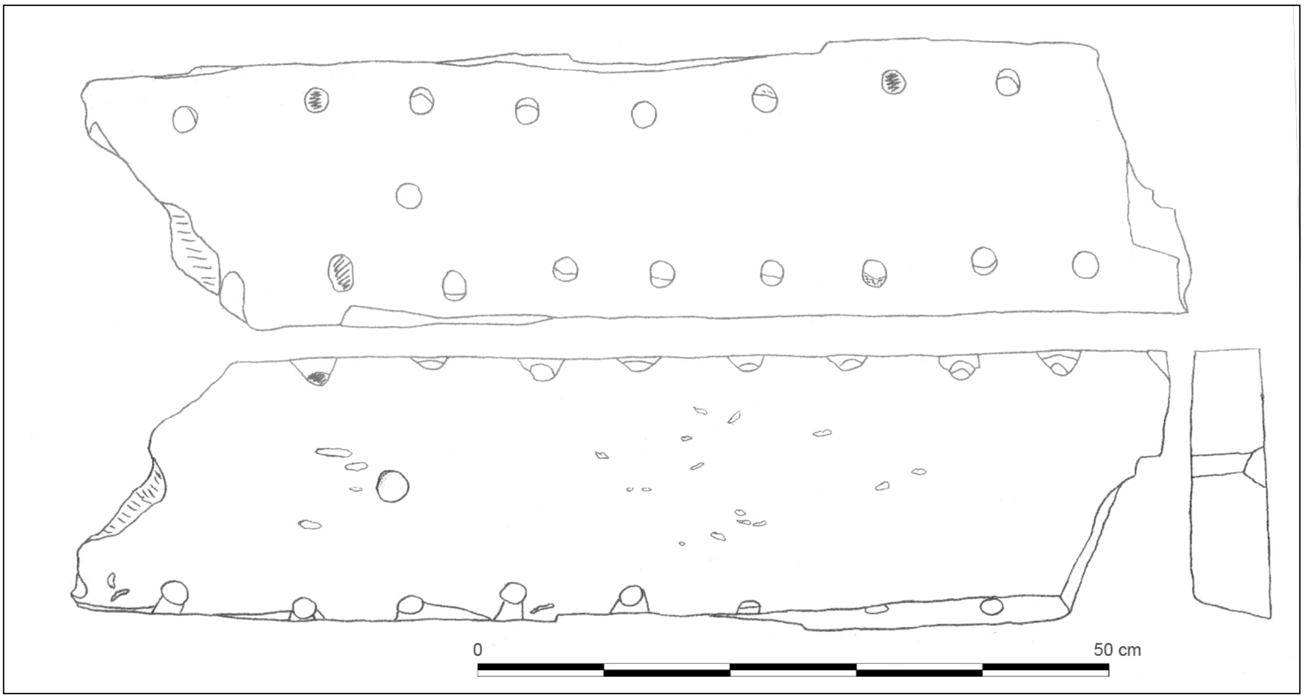


Fig. 15.7. Drawing of the plank found in 2003.

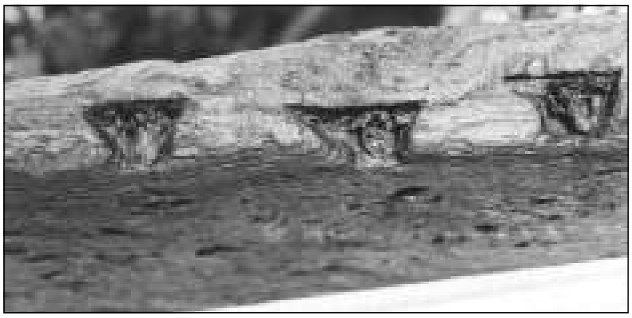


Fig. 15.8. Channel with trapezoidal shape along the edge of planks 2003 (photo: C. Beltrame).

Fig. 15.9. Flute beak shape peg extracted from a channel in 2003 (photo: C. Beltrame).

had a diameter of 2.2 cm and were 17 cm distant from each other. Along the edge, the channels had the typical trapezoidal shape (Fig. 15.8). A treenail to join a frame had a diameter of 2.5 cm and was inserted from the external side. This was 57 cm distant from a second channel for another treenail that has not been conserved. A typical flute beak shape peg, extracted from a channel, still conserved traces of rope (Fig. 15.9).

The location of the discovery of the pieces recovered in 2022 is exactly the same as some of the planks found between 1993 and 1997 by the Sub San Marco diving club and published by the author (Beltrame, 1996; 2002a) (and known as *Lido 1*). For this reason, and because of the thickness of the planking, we can say that these elements come from the same shipwreck. Considering the thickness of the planking, we are convinced that, as suggested in past publications, the ship had to be quite long, of course, more than 20 m long.

It is clear that, not far from the shore of Alberoni, probably only a couple of hundred metres away considering the lack of traces of consumption on the edges of the planks, there is a sewn ship of the Roman period. Considering the lack of any element of the cargo, it is probable that there is only an empty hull. As already discussed, the position of the discovery, close to the entrance of Malamocco, which, before the building of the piers, was much more dangerous than today, suggests that the ship was probably trying to enter the lagoon. Indeed, according to Strabo (V, 1, 7 C213), from the entrance of Malamocco the ships could take the Brenta river to reach *Patavium*.

It is interesting to note that fragments of this ship have come to light with a timelapse of many years, although we cannot exclude the possibility that other elements approached the shore but were not signalled to the authorities.

This shipwreck probably uncovers for very short periods, otherwise, after so many years, the *teredo* might have eaten the wood, and someone would have seen it since the beach of Alberoni is very populated during the summer period. Its conservation is also probably guaranteed by a thick layer of sand that possibly sometimes moves, for a very short period, and releases some pieces of wood which reach the shore. But since no storm happened in the days before the last discovery, perhaps we have to look for another explanation for this phenomenon, other than the movement of the sand. We might hypothesise that the occasional passage of *turbosoffianti*, that is, the powerful trawling metal boxes used to fish clams in the upper Adriatic, impact the shipwreck under the sand and tear off some elements which the sea pushes to the shore. Indeed, although the use of *turbosoffianti* close to the shore is forbidden, it is practised illegally during the night anyway. This would explain why, after so many years, the ship is still present and continues to release parts of planking.

Elisa Costa, Dario Gaddi

16. A recent find of a plank of a sewn ship of Late Roman period at Grado (GO)

16.1 *The plank*

In March 2021, along the shore of the bathhouse G.I.T. of Grado (GO) (Fig. 16.1), a plank (8.35 m long) was discovered by chance (Fig. 16.2). The same item was unofficially reported one year earlier in the same place.

The plank is well conserved since it presents an extremity with a fingernail shape, broken on the point, and sharp edges while the second extremity is broken (Fig. 16.3). Length and good conditions suggest that the plank comes from a shipwreck which is probably not too far. Moving on to the seabed, the plank would indeed have broken and would have smoothed the edges. The width varies from 30 to 34 cm, and the thickness from 5.5 to 7.5 cm. The fingernail is 140 cm long.

Along the edges, on the external surface, there are the typical channels for the stitching (Fig. 16.4). They have a notch on the edge of about 2.1-3.6 cm and a round hole that is 0.7-1 cm distant from the edge with a diameter of 1.8-2.2 cm; their centres are distant one from another by about 6-11 cm. On the inner surface, the pegs holes have a diameter of about 2.2-2.5 cm, they are 2.7-3.8 cm distant from the edge. The channels host pegs with a typical flute beak shape.

18 couples of channels with treenails inside the plank joined the frames which are not present (Fig. 16.5). Their distance is from 23 cm to 73 cm, with an average of about 41 cm. Between the biggest distances (62-63.5-73 cm), there are little rectangular notches that are 2 cm long and 0.7 cm transversal to the plank on the inner surface, most likely made with a chisel.

Along the edges there are horizontal treenails which probably helped the construction of the hull (Fig. 16.6). They have a diameter of about 2.5 cm, they are three on the longest edge (at 52, 183, 404 cm from the pointed end) and two on the shortest one (at 87 and 457 cm from the fingernail); on this last edge there are also traces of corrosion of iron, probably produced by the original presence of nails (at 27 cm and 236 cm from the fingernail) (Fig. 16.7). The inner face presents evident traces of fire which could testify to the cause of the sinking of the ship (Fig. 16.8).

AMS undertaken at the ETH of Zurich offers the following calibrated dating for the cutting of the wood: 243-382 CE (Fig. 16.9).

Fig. 16.1. Site of discovery of the Roman plank at Grado.

Fig. 16.2. The Roman plank at Grado, along the beach (photo: D. Gaddi) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Xilotomical analyses indicate that the plank is of *Ulmus*, the treenail of the frames of *Cornus sp*, *Buxus, Populus/Salix*, the horizontal treenail of *Buxus*, while the pegs for the stitching are mainly of *Populus/Salix*, but also of *Carpinus betulus* and *Cornus sp*. (see further). The choice of the hard *Buxus* for the treenails and the soft *Populus* for the pegs is logical since the joint of the frames to the hull requested a hardwood, able to sustain the stress, while the pegs for the stitching only had to close the channels and stop the rope inside the hole.

We can suppose that this long plank, which is also quite thick, had to belong to a quite big ship, more than 20 m long, which perhaps sunk because of a fire, close to the place of the discovery between the half of the 3th and the end of the 4th century AD.

The plank was documented with the hand-held structured light 3D laser scanner Artec Eva to obtain a 3D model (Fig. 16.10). This technology was compared with the digital photogrammetric survey to ensure the most valuable documentation of the object and was used to obtain a scaled 3D model with an accuracy up to 0.1 mm that could be deeply analysed and studied, both from the geometric and texturing point of view (Fig. 16.3).

E.C.

2.2 *The historical and environmental context*

Many decades of studies and research, both in archaeological and geological fields, allowed the reconstruction of a sufficiently accurate image of the geomorphological structure (Marocco and Gatto, 1991; Antonioli *et al.*, 2007; Fontana *et al.*, 2018) and the population of the area currently occupied by Grado and its lagoon (Gaddi, 2001; Auriemma *et al.*, 2013). In 181 BC, at the time of the foundation of Aquileia, the lagoon had a similar extension to the current one, but the emerging lands occupied a wider area. The great river, the *Natiso cum Turro*, along which Roman people built the harbour at the east of the city, flowed into the sea with a large delta characterised by the presence of various navigable branches (Arnaud-Fassetta *et al.*, 2003). The average sea level was about 1.5-2 m lower than the current time and consequently, the coastline was about 1 km more advanced than today (Fontana *et al.,* 2018, 344) (Fig. 16.11).

The city of Grado was not an island facing the open sea, but only one of the raised areas and perhaps the largest which was always sheltered from the continuous changes in the delta environment, subjected to floods (Marocco, 1991, 223-232).

Starting from the middle of the 1st century BC, in the area of the present lagoon, about twenty settlements of both residential and productive typology are attested and were probably connected with the function of the coastal-lagoon area, such as Aquileia's outer harbour. Archaeological investigations allow the identification of both numerous *villas*, equipped with rooms with mosaics and spaces for productive activities; and some necropolises located along the two roads connecting Aquileia with the sea. The first road runs along the current course of the *Natissa* river and, passing through the islands of Montaron and Morgo, headed southwest; the second road descends directly south from the southern gate of Aquileia and runs to Grado along the current road, arriving in the lagoon with a route located a few hundred metres west of what is now Mosconi street (Gaddi, 2001, 262-265). The connection between the sea and Aquileia was also guaranteed by river routes, as evidenced by the discovery of the wreck of a cargo ship, probably of large tonnage, almost 30 m long, near the current island of Villa Nova (Fig. 16.12) (Gaddi, 2001, 265-266). It is not clear if there was a real sea harbour, but the large, submerged structure (about 800 m long) currently known as "*piere de Sant'Agata*", which faces the seafront of Grado more than 500 m from the shore and is 2 m below the surface of the water, could represent the wall that offered protection from the Sirocco winds and a large landing place west of Grado (Cainer, 1993-94).

Over the centuries the situation continued to evolve and the gradual rise of the sea level, combined with the loss of water flow of the *Natiso cum Turro*, created a completely new situation between the 5th and 7th centuries AD: the coastline retreated in several places, the tidal floods began to prevail over the islands and sandbanks, Grado became a real island on which the bishops of Aquileia found a shelter escaping the invasion of Huns of Attila in 452 AD and the Lombards

Fig. 16.3. The Roman plank of Grado (photogrammetry: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 16.4. Stitching channels on the external face of the Roman plank of Grado (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 16.5. Treenails, connecting the frames, on the external face of the Roman plank of Grado (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 16.6. Hole, along an edge of the Roman plank of Grado, for horizontal treenail connecting the planking (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 16.7. Iron nail along an edge of the Roman plank of Grado (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

Fig. 16.8. Internal face burned by fire on the Roman plank of Grado (photo: E. Costa) (authorised by the Soprintendenza ABAP FVG-MIC, duplication forbidden art. 108, co.3 del D. Lgs 42/2004 s.m.i.).

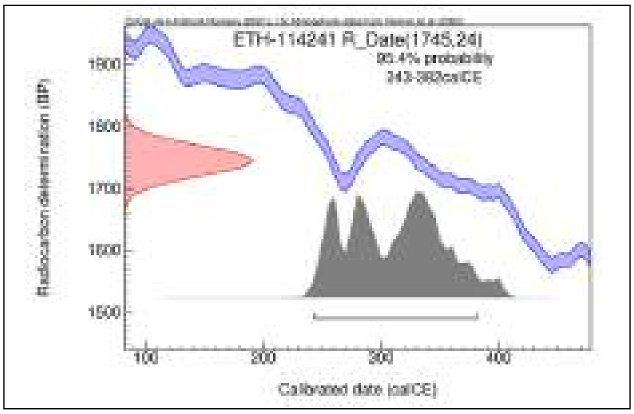


Fig. 16.9. AMS dating of a wooden fragment from the plank of Grado (ETH).

Fig. 16.10. 3D laser scanning of the Roman plank of Grado (photo: C. Beltrame).

Fig. 16.11. Archaeological map of the Lagoon of Grado and Marano (processed by D. Gaddi).

Fig. 16.12. Keel of ship of the 1st century AD (Island of *Villa Nova*) (photo: D. Gaddi).

Fig. 16.13. A.S.V., Savi ed esecutori alle acque, Relazioni b77, dis 3. (da De Grassi, ed., 2004, 164-165).

of Alboino in 568 AD. The road across the lagoon resisted for at least another century, until, in 663 AD, it was crossed by the Lombard cavalry of Duke Lupo who sacked the island (De Laurenzi, Gaddi and Novello, 2014).

2.3 *The chronological context*

The archaeological sites closest to the area of the discovery of the sewn boat plank are the sanctuary island of Santa Maria di Barbana (site 1) and Le Cove area (site 2) (Fig. 16.11). Material of a residential context that can be dated no later than the end of the 1st century AD came from the latter site (Gaddi, 2001, 263). On the island of Santa Maria di Barbana, a series of sacred and funerary inscriptions are preserved, and their original provenance has been the subject of much discussion (Gaddi, 2001, 263), but which are dated beyond the 2nd-3rd century AD. During the Early Middle Age, a papal bull of Pope Gregory III to the patriarch Callisto confirmed, in 734, the building on the island of a Benedictine abbey (Paschini, 1934, 133). The hypothesis of a continuous frequentation of the island of Barbana in the Late Imperial period is plausible, but there are no pertinent data.

From a chronological point of view, therefore, the plank of the sewn boat belongs to a period in which the evidence of the frequentation of the lagoon area is quite scarce and, where it exists, is only connected to settlements a few kilometres away, such as the area of the future Byzantine *castrum* or some sites of the western area of the lagoon (Gaddi, 2001, 266).

2.4 *The finding's area*

The sewn plank, due to its size and state of conservation, suggests that the original position of the shipwreck was a few tens metres from the place of discovery. The area corresponds to a stretch of open sea with shallow waters where

Fig. 16.14. A.S.V. Provveditori alla Sanità, b. 1, 1713.

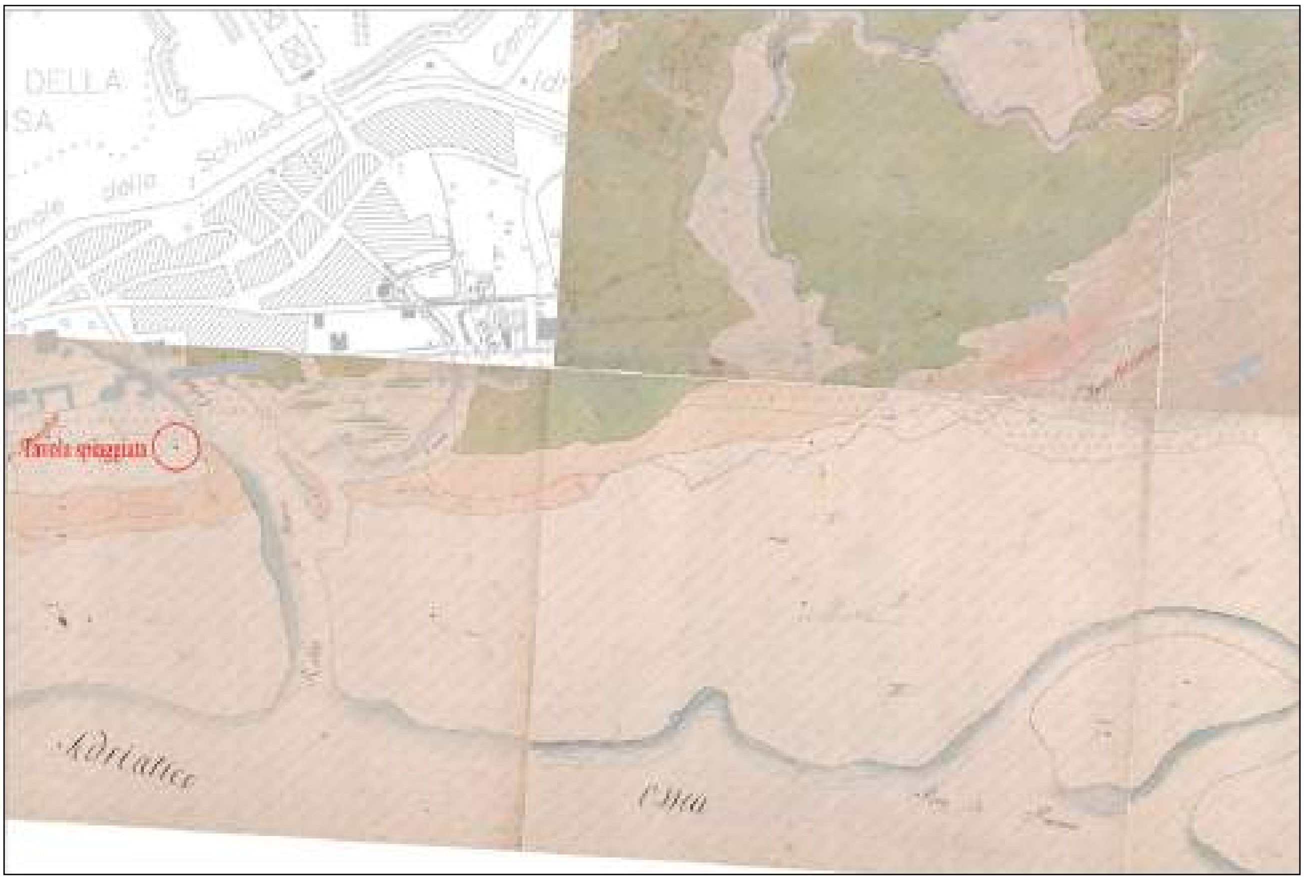


Fig. 16.15. Overlap, in 1:10000 scale, of the C.T.R. on georeferenced photomosaic of the sheets ns. CXIII, CXIV e CXVI – CXXI from A.S.G. Grado, Fascicolo I, Mappe originali, Dipartimento di Passariano ora Adriatico, Territorio Comunale di Grado, Cantone di Aquileia, Distretto di Portogruaro.

the bathymetric line of -2.5 m is located about 600 m from the current shore.

A superficial analysis of the above data could suggest that the boat was sailing in the open sea but very close to the coast; conversely, the study of historical cartography and archaeological data allows us to hypothesise a different and more complex scenario. Ancient maps (Figs. 16.13, 16.14) show, more or less clearly, that the coastline south of Grado went much further than the current one as confirmed by the geomorphological studies mentioned above. Of particular interest is the positioning of the finding on the Napoleonic cadastral map of 1811 (Fig. 16.15); the shipwreck is located along the edge of a large lagoon channel which flowed into the sea after passing the coastal dunes with a real harbour mouth, called Rotta de Moreri. The name clearly reveals what appears from the study of the previous cartography: it is a recently formed mouth of a lagoon that interrupts the sandbar of dunes documented in 18th century maps.

A further consideration is provided by the comparison with the 18th century map of the lagoon and maritime areas surrounding the city of Grado with the sea protections (Fig. 16.13), where it shows the Rotta de Moreri in correspondence with the south meander of Canal Maggiore, which runs along the entire southern lagoon, from the west at Grado Harbour towards the east and towards the sanctuary island of Barbana.

Furthermore, all the above-mentioned cartography shows the Primero Harbour further at the east (Fig. 16.14) as a narrow channel which allowed, with a SW-NE direction, the entrance to the eastern area of the lagoon, remaining sheltered from a long strip of shallow waters and sandbanks, called Ponta, which protected the navigation from the dangers of the open sea.

On cartographic comparisons of the 18th and 19th centuries and on the geomorphological data about the sea level in ancient times, it is possible to hypothesise, for the sinking area of the sewn boat, dated between 243 and 382 AD, a lagoon landscape placed perhaps immediately behind the line of coastal dunes.

D.G.

Alessandra Forti

17. XYLOTOMIC ANALYSIS OF THE WOODEN SEWN PLANKS OF ROMAN PERIOD FOUND AT GRADO AND ALBERONI

We present wood analysis from planks of two different sewn shipwrecks, one from Grado (GO) and two found washed up on the shore of Alberoni (Lido di Venezia) (see above).

The sampling strategy was carried out by taking wood fragments and storing them in fresh water to prevent decay while maintaining the submerged state. The wood was identified according to the anatomic features observed under low power STM (10x, 20x, 50x) in the three fracture planes and with the support of reference Atlas (Schweingruber, 1990) and reference collections.

Preservation of the wood of the sewn shipwreck of Grado was good, and it allowed the samples to be determined. Five wooden taxa were identified: *Ulmus* spp., *Buxus sempervirens L.*, *Carpinus betulus L.*, *Cornus* sp., *Populus/ Salix* (Fig. 17.1).

The plank was partially charred and was made of elm wood (*Ulmus* spp.). For the two horizontal treenails, boxwood (*Buxus sempervirens*) was used, while for vertical treenails, three species of wood were used: boxwood (*Buxus sempervirens*), dogwood (*Cornus* spp.) and poplar/ willow (*Populus/Salix*). Pegs were made mainly of poplar/ willow, one of dogwood (*Cornus* spp.) and one of hornbeam (*Carpinus betulus L.*) (Fig. 17.1).

The items from Alberoni were two main fragments and two very small fragments of sewn planking in a poor state of conservation, so the sample of the fourth fragment could not be determined. Two wood species were identified: *Ulmus* sp. and *Buxus sempervirens*. Elm for the plank and boxwood for the pegs (Fig. 17.1).

We note that the planks of both the shipwrecks were made of elm wood, a wood that is very resistant to mechanical action, water, and impact. (Rival, 1991). Indeed, it is well documented in the literature (Beltrame, 2002a; Beltrame and Gaddi, 2013a) that elm wood is not a novelty, as it was often used in the construction of sewn ships on the coasts of the Adriatic area: usually elm for the planking and *Quercus* for the frames. Even in the Comacchio barge, in fact, the elm was used for the bottom planking (Beltrame *et al.*, 2021), while in the Roman vessel of Caska 2, it was used for planking repairs (Ferreira Dominguez *et al.*2021). Elm was used also in the Roman hulls of Pisa, Portus and Neapolis, built with the mortise-and-tenons technique (Sadori *et al.*, 2015). Regarding the use of woods, a further comparison comes from the sewn ships of Zambratija and Pula. The prehistoric sewn ship (12^{th}-10^{th} BC) from Zambratija shows the use of elm for the planking and poplar for the pegs, as in the Grado plank. According to the authors (Boetto, Konkani and Uhac, 2017), the choice of poplar wood could be due to its flexibility. A further similarity can be found in the planking of the ship of Pola 1, also made of elm wood. (Pomey and Boetto, 2019).

According to the record of our planks, different types of wood, both hard and soft, were used for the treenails and pegs. In the Grado plank, hardwoods include boxwood, dogwood, and hornbeam, while softwoods include poplar/ willow.

In the Alberoni planking, boxwood is the only wood used for pegs. It is not a new wood for shipbuilding and was usually only used for pegs since it is not impact-resistant and therefore not suitable for shipbuilding. (Rival, 1991).

Regarding the presence of Hornbeam (*Carpinus b.*) used as a peg in the Grado plank, we should note that, although it is a hardwood, it is very vulnerable to wet environments. Despite this characteristic, *Carpinus b.* is also found as a peg in Caska 4 together with spruce and beech (Rossi and Boetto, 2020).

The taxonomic resolution *Populus/Salix* is indicated in this way because *Populus* spp. and *Salix* spp. have many similarities at an anatomical level such that they cannot always be distinguished with certainty. They also share many similarities from an environmental and mechanical point of view. In fact, both woods are soft and easy to work with, which is the reason why they are often used for tools or handles. However, since these woods are sensitive to damp conditions, they are not preferred in shipbuilding in most cases, and the presence of poplars/willows, as well as hornbeams, could be associated with repair work (Akkemik and Kocabas, 2014).

Regarding dogwood (*Cornus* spp.), used for a peg and a vertical treenail, we need to point out that it is a very durable wood and commonly considered the hardest wood in Europe. It is a wood that is particularly suitable for woodturning work and objects intended to undergo considerable stress. This wood is also present in the ship of Valle Ponti (Comacchio), where it was used for a peg just as in the case of the Grado plank. Probably due to its robustness and workability, it must have been intended for purposes related to these features.

To conclude, the analysis of the wood species from these planks belonging to two ships can provide some insight into the environment area and the choice of species, which is closely linked to the technology of the wood itself. The taxa identified suggest that the catchment area for timbers was a deciduous mesophilous mixed wood (*Ulmus* spp.), with hygrophilous component (*Populus/Salix*), but there

Fig. 17.1. Wood distribution of the remains of the sewn ships from Grado and Lido-Alberoni.

must have been also a few stands of Mediterranean evergreen oak (*Buxus sempervirens L.*). Regarding the choice of wood for the construction of the ships, in both cases, the planking was made of elm, which can be considered a standard and well-documented practice in the construction of sewn ships during the Roman period in northern Italy and, according to the Zambratjia ship, perhaps even in prehistoric times. Elm wood offered several advantages to shipbuilding: timber durability and the opportunity to provide wide planks that were extremely suitable for boat building. For pegs and treenails, *Buxus s*. is the most used species together with *Populus/Salix,* and in a few cases dogwood or hornbeam; their presence could be evidence of repairs.

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18. A SEWN BOAT OF ROMAN PERIOD NEAR *ALTINUM* (MARCON)

In 1999, in the ploughed fields of the Zuccarello property, 1 km west of the Roman city of *Altinum*, 200 m south of the present Zero river (Fig. 18.1), an excavation carried out by F. Cafiero under the direction of M. Tirelli, past director of the Museo Archeologico Nazionale di Altino, exposed the remains of a section of a sewn boat (Fig. 18.2). This laidside of a bank, made of oak poles supporting horizontal planks, which, according to S. Cipriano (2011, 85-86), could have been a *via helciaria*, that is, an elevated road running alongside a river or a channel and used to tow the boats. The boat has been exposed for a length of only 170 cm but it continues under a layer of clay. The planks were sewn together by stitching which is still preserved. This last one shows the typical IXIXI pattern over the caulking roll (Fig. 18.3). The channels have a diameter of 2 cm and are 6/7 cm from each other. Although the documentation is not clear, we can say that there are three frames *in situ*, about 7-8 cm wide, which have a distance from each other of about 12/15 cm. Other than the frames, there is a fragment of possible inner planking. The dating is uncertain since the pottery has not been studied and the wood was not sampled for ^{14}C analysis. According to Cafiero's report, it had to be abandoned after the 1st century BC.

Fig. 18.1. Position of the Roman sewn boat found close *Altinum*.

Fig. 18.2. Section of Roman sewn boat of *Altinum* (photo: F. Cafiero) (authorised by the Ministero della Cultura, duplication forbidden).

Fig. 18.3. Detail of the stitching of the Roman sewn boat of *Altinum* (photo: F. Cafiero) (authorised by the Ministero della Cultura, duplication forbidden).

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19. FINAL OBSERVATIONS

Around the middle of the 5th century AD, a barge (23 m long and 5 m wide) was navigating along a branch of the *Padus* river, possibly carrying caprines (sheep?) with their forage, and perhaps free cargo of brassicaceae and rye transported scattered on the boat or inside bags and some amphoras with flat bottoms filled with wine. It was probably towed from the riverbank against the current, but it was able to sail with a small sail when it was descending. During the towing, the speed could reach 3-4 km/h if the barge was moved by two-four oxen.

The barge connected the harbours located along the Padus and could reach the harbours on the mouths of the rivers where it had to stop since it was not able to navigate on the sea. It was not new and it had to come back in a boatyard at least one time to repair the bottom planking by sewing.

The hull had been built with the local elms, for the planks, and the local oaks, for the frames, sewing the planks together according to a technique which was traditionally used in the shipyards of the northern Adriatic coast perhaps from the Republican period but perhaps earlier. The sequence and method of construction of this type of barges imposed the building of the bottom of planking before the insertion of the frames which reinforced the shell made of planks joined by stitching.

On the upper part of the sides, lapstrakes were used saving time and protecting the sides during contacts with riverbanks and docks. Its ship-shape, with a flat bottom and a box section, was perfectly suitable for riverine navigation and the transportation of big cargos, up to 30 ton, in calm waters. The caulking was realised with the hemp cultivated in the Po Valley from the Imperial period. Probably, a long stern rudder was fixed on a high stern-post which gave this barge a very characteristic shape represented on Roman sculptures of Central Europe. Indeed, from this stern, the pilot had an excellent view and could manoeuvre the barge easily.

This watercraft was swamped by a strong flood, probably while it was moored along the side of the river not far from where it sank on its side on the riverbank. During this event, or more likely later due to the continuous water flow on the exposed part of the boat, it lost the deck, the beams and most of the ceiling. During the flood, two logboats were also swamped and remained above the barge. The narrowing of the riverbed and the movement of the north riverside permitted the covering of the hull in an anoxic environment because of the high level of the aquifer. This situation permitted the excellent conservation of the starboard side and of the stern-post of the barge, collapsed on the right, while the left side was completely degraded leaving only a small section still joined to the stern-post and collapsed with it.

As we have seen, thanks to good excavation carried out by private companies contracted by the Soprintendenza, and thanks to the scientific analysis made both on the hull and on the environmental context, we have learnt a lot about this barge, about its construction and its use, but some aspects merit deeper reflection. For example, we would like to better understand if the use of the lapstrakes was an influence of central European technology or if it was a local use. The same consideration could be made for the shape of the stern, which we can admire on sculptures beyond the Alps and not of the Mediterranean. What were the relationships between the barges of central Europe and the barges of Northern Italy?

It would also be important to reflect further on the singular similarities between the ships of Valle Ponti and this barge. In particular, the absence of stitching on a small portion of the bottom and the use of tenons on the upper parts of the hull are very intriguing. These two aspects, but especially the first one, are very curious, since although the ships could have been built in shipyards a few kilometres far, they have been built with a temporal distance of at least four centuries.

Future discoveries of boats or parts of boats built with the sewn technique, such as the items presented for the first time in this book, will be very important both to answering the questions proposed here and, in general, to a better understanding of this very peculiar technique of ship-construction and of its relationships with the Adriatic cultural and natural environment.

REFERENCES

Accorsi, C. A., Bandini Mazzanti, M. and Forlani, L., 1978, *Modello di schede palinologiche di Pini italiani (Pinus cembra L., Pinus pinea L., Pinus silvestris L. subsp. silvestris L. ecotipo emiliano)*, Archivio Botanico e Biogeografico Italiano, 54 (3/4), 64-101.

Accorsi, C. A., Bandini Mazzanti, M., Forlani, L. Mercuri, A. M. and Trevisan Grandi, G.,1999, *An Overview of Holocene Forest Pollen Flora/Vegetation of the Emilia Romagna Region-Northern Italy*, Archivio Geobotanico, 5.1-2, 3-27.

Akkemik, Ü. and Kocabaş, U., 2014, Woods of byzantine trade ships of Yenikapi (Istanbul) and changes in wood use from 6th to 11th century, *Mediterranean Archaeology and Archaeometry,* 14. 2, 317-327.

Alfieri, N., 1966, La chiesa di Santa Maria in Padovetere e la zona archeologica di Spina, in *Atti del I convegno nazionale di studi bizantini, Ravenna 1965*, 3-35, Faenza.

Allevato, E., Russo Ermolli, E. Boetto, G. and Di Pasquale, G., 2010, *Pollen-wood Analysis at the Neapolis Harbour Site (1st-3rd Century AD, Southern Italy) and its Archaeobotanical Implications*, Journal of Archaeological Science, 37.9, 2365-2375.

Andrieu-Ponel, V., 2019, Pollen analysis of protection pitch, in Koncani Uhac, I., Boetto, G. and Uhac, M., 2019, *Zambratija Prehistoric Sewn Boat. Results of the Archaeological Research, Analysis and Study*,140-147, Arheoloski muzej Istre, Pula.

Andrieu-Ponel, V., Belkacem, D., and Ponel, P., 2014, L'apport de l'étude du contenu en pollen et en spores de champignons coprophiles des materiaux d'étancheite du chaland d'Arles-Rhone 3, in S., Marlier, ed., *Arles-Rhône 3, un chaland gallo-romain du ier siècle après Jésus-Christ* (Archaeonautica 18), 130-136, CNRS Ed., Paris.

Antonioli, F., Anzidei, M., Lambeck, K., Auriemma, R., Gaddi, D., Furlani, S., Orrù, P., Solinas, E., Gaspari, A., Karinja, S., Kovačić, V. and Surace, L., 2007*, Sea level change during Holophologcene from Sardinia and northeastern Adriatic (Central Mediterranean sea) from archaeological and geomorical data*, Quaternary Science Reviews*,* 26.19-21, 2463-2486.

Arnaud, P., 2016, Entre mer et rivière: les ports fluvio-maritimes de Méditerranée ancienne. Modèles et solutions, in C., Sanchez and M.-P., Jézégou, eds., *Les ports dans l'espace Méditerranéen antique. Narbonne et les systèmes portuaires fluvio-lagunaires. Actes du colloque international tenu à Montpellier 2014*, 139-156, Ed. de l'Association de la Revue archéologique de Narbonnaise, Montpellier-Lattes.

Arnaud-Fassetta, G., Carre, M.-B., Marocco, R., Maselli Scotti, F., Pugliese, N., Zaccaria, C., Bandelli, A., Bresson, V., Manzoni, G., Montenegro, M. E., Morhange, C., Pipan, M., Marocco, R., Prizzon, A. and Siché, I., 2003, *The site of Aquileia (Northeastern Italy): example of fluvial geoarchaeology in the Mediterranean deltaic plain,* Géomorphologie: relief, processus, environnement, 4, 227-246.

Arnold, B., 1998, Embarcations romano-celtiques et construction sur sole, in E., Rieth, ed., *Concevoir et construire les navires. De la trière au picoteux*, 73-90, TIP, Université de Provence, Aix-en-Provence.

Arnold, B., 1999, *Altaripa. Archéologie expérimentale et architecture navale gallo-romaine*, Musée cantonal d'archéologie, Neuchâtel.

Arobba, D., Bulgarelli, F. Caramiello, R. and Dell'Amico, P., 2014, *Studio archeobotanico e revisione critica dei reperti archeologici recuperati dalla "Nave romana di Albenga."*, Archaeologia maritima mediterranea, 11, 79-106.

Asta, A., 2015, Le imbarcazioni monossili italiane: stato degli studi e prospettive di ricerca per un catalogo Nazionale, in D., Leone, G., Volpe and M., Turchiano, eds., A*tti del III Convegno Nazionale di Archeologia Subacquea (Manfredonia 2007),* 84-85, Edipuglia, Bari.

Auriemma, R. and Quiri, E., 2007, La circolazione delle anfore in Adriatico tra V e VIII sec. d.C., in S., Gelichi and C., Negrelli, eds., *La circolazione delle ceramiche nell'Adriatico tra tarda antichità e altomedioevo, III Incontro di Studi CER.AM.IS.,* SAP ed.*,* Mantova, 31-64.

Auriemma, R., Degrassi, V. and Quiri, E., 2015, Eastern amphora imports in the Adriatic Sea: evidence from terrestrial and underwater contexts of the Roman Imperial age, in Demesticha, S., ed., *Per Terram, Per Mare: Seaborne Trade and the Distribution of Roman Amphorae in the Eastern and Central Mediterranean*, Åström ed., Uppsala, 139-160.

Auriemma, R. *et al.,* 2013*, Alle porte del mare. La laguna di Marano in età romana*, Antichità AltoAdriatiche, 76, 93-121.

Balista, C. and Berti, F., 2016-2017, *Carotaggi geoarcheologici e scavo nei pressi della Chiesa di Santa Maria in Padovetere, anni 2006 e 2008*, Atti dell'Accademia delle Scienze di Ferrara, 94, 93-133.

Balista, C., Bonfatti, L. and Calzolari, M., 2007, Il paesaggio naturale e antropico delle Valli tra Spina e Comacchio e le sue trasformazioni dall'Età etrusca all'Alto Medioevo, in F., Berti, M., Bollini, S., Gelichi and J., Ortalli, eds., *Genti del delta da Spina a Comacchio: uomini, territorio e culto dall'antichità all'alto Medioevo (catalogue of the exhibition)*, 19-31, Corbo ed., Ferrara.

Barkai, O. and Kahanov, Y., 2016, *The Tantura F Shipwreck: Hull Remains and Fonds-Final Report*, The International Journal of Nautical Archaeology, 45.1, 6-28.

Batchvarov, K. N., 2012, Design and construction of a Black Sea Ottoman ship, in Gunsenin, N., ed., *Between continents Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009*, 175-181, Yayinlari, Istanbul.

Beaudouin, F., 1985, *Bateaux des fleuves de France*, Editions de l'Estran, Douarnenez.

Beltrame, C., 1996, La *sutilis navis* del Lido di Venezia. Nuova testimonianza dell'antica tecnica cantieristica "a cucitura" nell'alto Adriatico, in F., Ciciliot, ed., *Navalia. Archeologia e storia*, 31-53, Propeller Club, Savona.

Beltrame, C., 2002a, *Le* sutiles naves r*omane lungo il litorale alto Adriatico. Nuove testimonianze e considerazioni tecnologiche*, Archeologia subacquea, studi, ricerche e documenti, 3, 353-379.

Beltrame, C., 2002b, *Anche in Italia finalmente (ri)nasce l'archeologia navale?,* L'Archeologo Subacqueo, 23, 15-18.

Beltrame, C., 2009, *A New View of the Interpretation of the Presumed Medieval Po Delta Wreck, Italy*, The International Journal of Nautical Archaeology, 38.2, 412-417.

Beltrame, C., 2017, Documentare in archeologia navale, in Gandolfi, D., ed., A*rcheologia subacquea. Storia, organizzazione, tecnica e ricerche, Quaderni della Scuola Interdisciplinare delle Metodologie Archeologiche, 3,* 159-174, Istituto Internazionale di Studi Liguri, Bordighera.

Beltrame, C., 2019a, Gli elementi navali reimpiegati nella salina romana di Cervia, in C., Guarnieri, ed., *La salina romana e il territorio di Cervia. Aspetti ambientali e infrastrutture storiche*, 177-180, Ante Quem srl, Bologna.

Beltrame, C., 2019b, Il relitto bizantino del Savio meglio noto come "di Cervia", in C., Guarnieri, ed., *La salina romana e il territorio di Cervia. Aspetti ambientali e infrastrutture storiche*, 227-234, Ante Quem srl, Bologna.

Beltrame, C. and Costa E., 2016, *A 5^{th}-Century-AD Sewn-Plank River Barge at St Maria in Padovetere (Comacchio, FE), Italy: an interim report*, The International Journal of Nautical Archaeology, 45.2, 253-266.

Beltrame, C. and Gaddi, D., 2007, *Preliminary Analysis of the Hull of the Roman Ship from Grado, Gorizia, Italy,* The International Journal of Nautical Archaeology, 36.1, 138-147.

Beltrame, C., and Gaddi, D., 2013a, *Fragments of Boats from Canale Anfora of Aquileia (Italy) and Comparisons of Sewn-Plank Ships in the Roman Era*, The International Journal of Nautical Archaeology, 42.2, 296-304.

Beltrame, C. and Gaddi, D., 2013b, *Lo studio ricostruttivo della nave romana di Grado,* L'archeologo subacqueo, 14. 3, 12-15.

Beltrame, C., Mozzi, P., Forti, A., Maritan, M., Rucco, A. A., Vavasori, A. and Miola, A., 2021, *The Fifth-Century AD Riverine Barge of Santa Maria in Padovetere (Ferrara, Italy): A Multidisciplinary Approach to its Environment and Shipbuilding Techniques,* Environmental Archaeology, 26:1, 29-50.

Ben-Zeev, A., Kahanov, Y., Tresman, J. and Artzy, M., 2009, *The Ma'agan Mikhael ship. Volume III: a reconstruction of the hull,* A.G. Leventis Foundation, Nicosia.

Benvenuti, M., Mariotti Lippi, M., Pallecchi P. and Sagri, M., 2006, *Late Holocene Catastrophic Floods in the Terminal Arno River (Pisa, Central Italy) From the Story of a Roman Riverine Harbour*, The Holocene, 16.6, 863-876.

Bergfjord, C. and Holst, B., 2010, *A Procedure for Identifying Textile Bast Fibres Using Microscopy: Flax, Nettle/Ramie, Hemp and Jute*, Ultramicroscopy,110, 1192-1197.

Bertacchi, L., 1988, *L'imbarcazione romana di Monfalcone*, Arti Grafiche Friulane, Udine.

Berti, F., ed., 1990, Fortuna Maris. *La nave romana di Comacchio,* Nuova Alfa Editoriale, Ferrara.

Berti, F., 2017, La nave di Valle Ponti, in Gandolfi, D., ed., *Archeologia subacquea. Storia, organizzazione, tecnica e ricerche*, Scuola Interdisciplinare delle Metodologie Archeologiche 3, 207-214.

Bianchini, M., 2008, *Manuale di rilievo e di documentazione digitale in archeologia,* Aracne ed., Rome.

Black, E., 1999, Fibers and textiles used in the construction of ship's hulls, in H., Tzalas, ed., *Proceedings 5^{th} International Symposium on Ship Construction in Antiquity, Nauplia 1993*, 53-64, Hellenic Institute for the Preservation of Nautical Tradition, Athens.

Blom, E. and Vos, W. K., 2008, De 'Woerden 7': Een Romeinse platbodem, in E., Blom and W. K., Vos, eds, *Woerden-Hoochwoert. De opgravingen 2002-2004 in het Romeinse castellum Laurium, de vicus en van het schip de 'Woerden 7' (ADC Rapport 910),* 349-401, ADC ArcheoProjecten, Amersfoort.

Böcking, W., 1996, Caudicaria—*Roemische Lastkähne. Neue Schiffsfunde im Xantener Raum*, Antike Welt, 27, 209-215.

Bockius, R., 2002, *Die Römerzeitlichen Schiffsfunde von Oberstimm in Bayern,* Verlag des römisch-germanischen Zentralmuseums, Mainz.

Boetto, G., 2008, *L'épave de l'Antiquité tardive Fiumicino 1: analyse de la structure et étude fonctionnelle*, Archaeonautica, 15, 31-64.

Boetto, G., Pomey, P., Tchernia, A., eds., 2011, *Batellerie Gallo-Romaine – Pratiques régionales et influences maritimes Méditerranéennes*, Ed. Errance, Paris.

Boetto, G., Koncani Uhaç, I. and Uhaç, M., 2017, Sewn Ships from Istria (Croatia): the Shipwrecks of Zambratija and Pula, in J., Litwin, ed., *Baltic and Beyond. Change and Continuity in Shipbuilding. Proceedings of the Fourteenth International Symposium on Boat and Ship Archaeology Gdansk 2015*, 189-198, National Maritime Museum, Gdansk.

Boetto, G. and Radic Rossi, I., 2017, Ancient Ships from the Bay of Caska (Island of Pag, Croatia), in J., Litwin, ed., *Baltic and Beyond. Change and Continuity in Shipbuilding. Proceedings of the Fourteenth International Symposium on Boat and Ship Archaeology Gdansk 2015*, 279-288, National Maritime Museum, Gdansk.

Boetto, G. and Rousse, C., 2012, *Traditions régionales d'architecture navale en Adriatique à l'époque romaine*, Histria antiqua, 21, 427-441.

Boetto, G., Radić Rossi, I., Marlier, S., Brusić, Z., Huguet, C., Capelli, C., Guibal, F., Greck, S., Cenzon Salvayre, C. and Andrieu-Ponel, V., 2012, *L'épave de Pakoštane, Croatie (fin IVe-début Ve siècle apr. J.-C.). Résultats d'un projet de recherche franco-croat,* Archaeonautica, 17, 105-151.

Boetto, G., Zazzaro, C. and Poveda, P., 2021, Final report on the remains of four vessels recently found in the ancient harbour of Naples, Italy (late 2° century BCE – late 3° century CE), in S., Demestica, L., Blue *et al.*, eds., *Under the Mediterranean I. Studies in Maritime Archaeology*, 59-74, Sidestone Press, Leiden.

Bondesan, M., 1990, L'area deltizia padana: caratteri geografici e geomorfologici, in Bondesan, M., ed., *L'ambiente come risorsa. Il territorio e i suoi sistemi naturali*, 9-48, Spazio Libri Editori, Ferrara.

Bondesan, M., 2001, L'evoluzione idrografica e ambientale della pianura ferrarese negli ultimi 3000 anni, in Broglio, A. and Bondesan, M., eds, *Storia di Ferrara I*, 227-263, Cassa di Risparmio di Ferrara – Corbo Editore, Ferrara.

Bondesan, M., Dal Cin, R. and Monari, R., 1990, L'ambiente in cui si arenò la nave romana di Comacchio. Possibili modalità del suo naufragio e seppellimento, in F., Berti, ed., Fortuna Maris. *La nave romana di Comacchio*, 13-23, Nuova Alfa Editoriale, Ferrara.

Bondesan, M., and Giovannini, A., 1994, *Evoluzione geomorfologica della pianura costiera fra Codigoro e Comacchio (Ferrara)*, Annali dell'Università di Ferrara (Sezione Scienze della Terra) 5.3, 27-38.

Bonifay, M., 2004, *Etudes sur la céramiques romaine tardive d'Afrique*, Archaeopress ed., Oxford.

Bonino, M., 1968, Tecniche costruttive navali insolite nei reperti di Cervia, Pomposa e Pontelagoscuro, *Atti del Convegno Internazionale di Studi sulle Antichità di Classe, Ravenna 1967*, 209-217, Longo ed., Ravenna.

Bonino, M., 1971, Ricerche sulla nave romana di Cervia, in *Atti del III Congresso Internazionale di Archeologia Sottomarina, Barcellona 1961*, 316-325, Istituto di Studi Liguri, Bordighera.

Bonino, M., 2015, *Navi mercantili e barche di età romana*, L'Erma di Bretschneider, Rome.

Boppert, W., 1992/93, *Der Blussustein – Das Grabmal eines einheimischen Aufsteigers, Mainzer Zeitschrift 87/88*, Mainz.

Bosi, G., Mercuri, A. M., Bandini Mazzanti, M., Florenzano, A. Montecchi, M. C., Torri, P., Labate, D., and Rinaldi, R., 2015, *The Evolution of Roman Urban Environments Through the Archaeobotanical Remains in Modena – Northern Italy,* Journal of Archaeological Science, 53, 19-31.

Brogiolo, G.P. and Gelichi, S., 1992, *La ceramica invetriata tardoantica e medioevale nel nord Italia,* in L., Paroli, ed., *La ceramica invetriata tardoantica e altomedievale in Italia*, All'Insegna del Giglio ed., Firenze, 23-32.

Bronk Ramsey, C., 2009, *Bayesian Analysis of Radiocarbon Dates*, Radiocarbon 51.1, 337-360.

Bruseth, J.E., Turner, T.S. and Feherenbach, T.R., 2006, *From a watery grave: the discovery and excavation of La Salle's shipwreck, La Belle*, Texas A&M University Press, College Station.

Brusic, Z., 1995, Serilia liburnica, Radovi Zavoda za povijesne znanosti HAZU u Zadru 37, 39-59.

Brusic, Z. and Domjan, M., 1985, Liburnian boats – their construction and form, in S., McGrail and E., Kentley eds., *Sewn Plank Boats. Archaeological and Ethnographic Papers Based on Those Presented to a Conference at Greenwich in Novembre 1984,* 67-85, BAR Int. Series 276, Oxford.

Bucci, G., 2020, Il Progetto ASAI, Archeologia Subacquea delle Acque Interne: dieci anni di ricerche subacquee nel Lago Tramonto, Gambulaga (FE), in G., Bucci, ed., *Il fiume nel lago. Dieci anni di ricerche archeologiche subacquee nel Lago Tramonto a Gambulaga (FE)*, Accademia delle Scienze di Ferrara ed., Ferrara, 17-68.

Cainer, *S*., 1993-94, *Indagine sulle praterie di Posidonia oceanica nel Golfo di Trieste*, Tesi di laurea in Scienze Naturali, Università degli studi di Trieste.

Calzolari, M., 1989, *Il Po tra geografia e storia: l'età romana*, Diabasis, Modena.

Calzolari, M., 2007, Il Delta padano in Età romana: idrografia, viabilità, insediamenti in F., Berti, ed., *Genti del delta da Spina a Comacchio: uomini, territorio e culto dall'antichità all'alto Medioevo (catalogue of the exhibition)*, 153-172, Corbo ed., Ferrara.

Cannarozzo, R., Cucchiarini, L. and Meschieri, W., 2012, *Misure, rilievo, progetto*, Zanichelli ed., Bologna, 1-96.

Camilli, A., 2004, *Il Cantiere delle Navi Antiche di Pisa Note sull'ambiente e sulla periodizzazione del deposito*, Archaeologia Maritima Mediterranea, 1, 53-75.

Camilli, A. and Setari, E., eds., 2005, *Le navi antiche di Pisa. Guida Archeologica*, Pacini ed., Pisa.

Capelot, J. and Rieth, E., 2005, Navigation et ports fluviaux dans la moyenne Charente, de l'Antiquité tardive au XIe siècle d'après l'archéologie et les textes, in *Ports maritime et ports fluviaux au Moyen Age, XXXV Congrès de la SHMES (La Rochelle 2004)*, 195-284, Ed. de la Sorbonne, Paris.

Cappers, R.T., Mook-Kamps, E., Bottema, S., Van Zanten, B.O, 2000 and Vlierman, K., 2000, *The Analysis of Caulking Material in the study of Shipbuilding Technology*, Palaeohistoria, 39.40, 577-590.

Cappers, R. T. J., Bekker R. M., and Jans J. E. A., 2006, *Digitale Zadenatlas van Nederland*, Barkhuis Publishing & Groningen University Library, Groningen.

Capulli, M., 2017, The Precenicco shipwreck: an 11th-13th century vessel from the river Stella, in Litwin, J., ed., *Baltic and beyond – Change and continuity in shipbuilding: Proceedings of the fourteenth international symposium on boat and ship archaeology,* 131-134, National Maritime Museum, Gdansk.

Capulli, M. and Pellegrini, M., 2010, Tavole cucite dall'Isola di San Francesco del Deserto (Venezia), in S., Medas, M., D'Agostino and G., Caniato, eds., *Archeologia, Storia, Etnologia Navale, Atti del I Convegno nazionale, Cesenatico 2008*, 263-266, Edipuglia, Bari.

Carandini, A., 2000, *Storie dalla terra. Manuale di scavo archeologico,* Einaudi Ed., Torino.

Casson, L., 1963, *Sewn Boats*, The Classical Review, 13.3, 257-259.

Castelletti, L., Maspero, A., Motella, S. and Rottoli, M., 1990, Le corde e gli intrecci di fibra vegetale, in F. Berti, ed., *Fortuna Maris. La nave romana di Comacchio,* 154-156, Nuova Alfa Ed., Ferrara.

Castiglioni, G.B., Biancotti, A., Bondesan, M., Cortemiglia, G.C., Elmi, C., Favero, V., Gasperi, G., Marchetti, G., Orombelli, G., Pellegrini, G.B. and Tellini, C., 1999, *Geomorphological map of the Po Plain at scale 1:250,000*, S.EL.CA, Florence.

Castro, F.V., 2005, *The Pepper Wreck: a Portuguese Indiaman at the mouth of the Tag river,* Texas A&M University Press, College Station.

Castro, F., Fonseca, N., Vacas, T. and Sauer, A., 2010, *Numerical models and the dynamic interpretation and reconstruction of medieval and early modern shipwrecks,* CMAC News and Reports, 2/1, 1-3.

Castro, F. and Capulli, M., 2016, *A Preliminary Report of Recording the Stella 1 Roman River Barge, Italy,* The International Journal of Nautical Archaeology, 45.1, 29-41.

Catling, D. and Grayson, J., 1982, *Hemp, Identification of vegetal fibres,* 18-23, Chapman and All, New York.

Cavalazzi, M. and Fabbri, E., 2010, Cooking ware from the excavation of a 5th-7th century context in Classe (Ravenna, Italy), in S., Menchelli, S., Santoro, M., Pasquinucci and G., Guiducci, eds., *LRCW 3. Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean. Archaeology and archaeometry. Comparison between western and eastern Mediterranean*, voll. I-II, Archaeopress ed., Oxford, 623-633.

Cesarano, M. and Corti, C., 2017, Sacro e profano. Le recenti ricerche nell'area archeologica di Santa Maria in Padovetere a Comacchio (IV-IX secolo), in C., Ebanista, M., Rotili, eds., *Atti del Convegno Internazionale di Studi, Oriente e Occidente fra tarda antichità e medioevo: popoli e culture dalle steppe al Mediterraneo, Cimitile e Santa Maria Capua Vetere 2016*, Guida Ed., Naple, 352-369.

Charlin, G., Gassend, J-M. and Lequément, R, 1978, *L'épave antique de la baie de Cavalière (Le Lavandou, Var),* Archaeonautica, 2, 9-94.

Chevalier, Y. and Santamaria, C., 1972, *L`épave de l'Anse Gerbal 'a Port-Vendres (Pyrenees-Orientales),* Rivista di Studi Liguri 37, 7-32.

Chittick, N., 1980, *Sewn Boats in the Western Indian Ocean, and a Survival in Somalia,* The International Journal of Nautical Archaeology, 9.4, 297-309.

Cipolato, A., 2018, Anfore italiche, egeo-orientali e galliche, in L., Sperti, M. Tirelli and S., Cipriano, eds., *Prima dello scavo. Il survey 2012 ad Altino*, Edizioni Ca' Foscari, Venice, 142-153.

Cipriano, S., 2011, La suddivisione agraria del territorio altinate: primi dati archeologici, in G., Cresci Marrone and M., Tirelli, eds, *Altino dal cielo: la città telerivelata. Lineamenti di Forma Urbis. Atti del convegno, Venezia 2009*, 81-94, Ed. Quasar, Rome.

Coarelli, F., 1999, *La colonna traiana*, Colombo Ed., Rome.

Cooper, J.P, Ghidoni, A. Zazzaro, C. and Ombrato, L., 2020, *Sewn boats in the Qatar Museum collection, Doha: baggāras and kettuvallams as records of western Indian Ocean technological tradition,* The International Journal of Nautical Archaeology, 49.2, 371-405.

Corti, C., 2007a, Santa Maria in Padovetere: la chiesa, la necropoli e l'insediamento circostante, in F., Berti, M., Bollini, S., Gelichi and J., Ortalli, eds., *Genti del delta da Spina a Comacchio: uomini, territorio e culto dall'antichità all'alto Medioevo (catalogue of the exhibition)*, 531-552, Corbo ed., Ferrara.

Corti, C., 2007b, La frequentazione nell'area di Santa Maria in Padovetere: materiali dalla chiesa e dall'insediamento circostante, in F., Berti, M., Bollini, S., Gelichi and J., Ortalli, eds., *Genti del delta da Spina a Comacchio: uomini, territorio e culto dall'antichità all'alto Medioevo (catalogue of the exhibition)*, 569-589, Corbo ed., Ferrara.

Corti, C., 2018, Traffici nel Delta e lungo il corso del Po. Alcune osservazioni sulla circolazione di ceramiche ad impasto grezzo e anfore, in M., Cesarano, M.C., Vallicelli and L., Zamboni, eds., *Antichi Romani e romanità nelle terre del Delta del Po. Nuovi studi e prospettive di ricerca*, Ante Quem ed., Bologna, 205-216.

Costa, E. and Beltrame, C., 2021, The 5^{th}-century AD riverine boat of Santa Maria in Padovetere: 3D reconstruction of its shape and context, in G., Boetto, P. Pomey and P., Poveda, eds., *Open Sea – Closed Sea. Local and Inter-Regional Traditions in Shipbuilding (15^{th} International Symposium on Boat and Ship Archaeology, Marseille) (Archaeonautica, 21),* 303-308, CNRS ed., Paris.

Cremonini, S., 1993, *Alcuni dettagli fotografici per le ricostruzioni paleogeoambientali nella Pianura Padana*, in Civiltà padana. Archeologia e storia del territorio, 4, 145-171, Aedes Muratoriana, Modena.

Cremonini, S., Labate, D. and Curina, R., 2013, *The Late – Antiquity Environmental Crisis in Emilia Region (Po River Plain, Northern Italy): Geoarchaeological Evidence and Paleoclimatic Considerations*, Quaternary International, 316, 162-178.

Crumlin-Pedersen, O. and Olsen, O., 2002, *The Skuldelev Ships I, Ships and boats of the north, 4.1,* Viking Ship Museum/National Museum of Denmark, Roskilde.

Crumlin-Pedersen, O., 2003, *Ten golden years for maritime archaeology in Denmark, 1993-2003,* Maritime Archaeology. Newsletter from Roskilde, 20, 4-43.

Deforce, K, Allemeersch, L, Stieperaere, H. and Haneca, K., 2014, *Tracking ancient ship routes through the analysis of caulking material from shipwrecks? The case study of two 14^{th} century cogs from Doel (northern Belgium)*, Journal of Archaeological Science, 43, 299-314.

Degrassi, ed., 2004, *La Laguna di Grado,* Edizioni della Laguna, Mariano del Friuli (GO).

De Groot, T. and Morel, J.-M. A.W., eds, 2007, *Het schip uit de Romeinse tijd De Meern 4 nabij boerderij de Balije, Leidsche Rijn, gemeente Utrecht: waardestellend onderzoek naar de kwaliteit van het schip en het conserverend vermogen van het bodem milieu*, Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten, Amersfoort.

De Izarra, F., 1993, *Le fleuve et les hommes en Gaule romaine,* Ed. Errance, Paris.

De Laurenzi, A, Gaddi, D., and Novello, M., 2014, *Grado.Un restauro per la storia. Vivere a Grado tra l'altomedioevo e l'età moderna,* S.A.B.A.P. F.V.G., Trieste.

Descombes, R., 2007, *Chevaux et gens de l'eau: sur les chemins de halage*, Cheminements, Coudray-Macouard.

Deydier, M., 1912, *Un monument romain à Cabrières-d'Aigues (Vaucluse)*, Bulletin archéologique du Comité des travaux historiques et scientifiques, 87-93.

Dinka, M., Ágoston-Szabó, E. and Tóth., I., 2004, *Changes in Nutrient and Fibre Content of Decomposing Phragmites Australis Litter*, International Review of Hydrobiology, 89.5-6, 519-535.

Dobreva, D. and Riccato, A., 2016, Cibi e ceramiche nei fondi Cossar ad Aquileia nella tarda antichità. Un contributo alla ricostruzione della dieta, delle batterie da cucina e dei servizi da mensa nella tarda antichità, in G., Cuscito, ed., *L'alimentazione nella tarda antichità*, Antichità Altoadriatiche, LXXXIV, 433-454.

D'Oriano, R., 2002, Relitti di storia: lo scavo del porto di Olbia, in *L'Africa romana: atti del 14° Convegno di studio, 7-10 dicembre 2000, Sassari,* 1249-1262, Carocci ed., Rome.

Dostal, C.M., 2017, *Laser scanning as a methodology for the 3D digitization of the archaeological ship timbers: a case study using the World Trade Center shipwreck, Doctoral dissertation*, Texas A & M University, College Station.

Essert, S, Koncani-Uhač, M., Uhač, M. and R. Šoštarić, R., 2018, *Plant remains and Amphorae from the Roman Harbour Under Flacius Street in Pula (Istria, Croatia)*, Archaeological and anthropological Sciences, 10.4, 955-971.

Evershed, R. P., 2008, *Organic Residue Analysis in Archaeology: the Archaeological Biomarker Revolution*, Archaeometry, 50, 895-924.

Fady, B., Fineschi, S. and Vendramin, G. G, 2004, EUFORGEN *Technical Guidelines for Genetic Conservation and Use for Italian Stone Pine (Pinus Pinea)*, Rome: International Plant Genetic Resource Institute.

Fangi, G., 1997, *Note di fotogrammetria*, CLUA, Ancona.

Felici, E., 2016, Nos flumina arcemus, derigimus, avertimus. *Canali, lagune, spiagge e porti nel Mediterraneo antico,* Edipuglia, Bari.

Ferreira Dominguez, A., Guibal, F., Boetto, G. and Radic, I., 2021, *Preliminary results of the wood analyses of the Roman vessels of Caska, island of Pag, Croatia,* Archaeonautica, 21, 251-256.

Filgueiras, O.L., 1989, *Barco Rabelo – Um Retrato de Família (The Rabelo Boat)*, Cálem, Porto.

Fontana, A., Vinci, G., Tasca, G., Mozzi, P., Vacchi, M., Bivi, G., Salvador, S., Rossato, S., Antonioli, F., Asioli, A., Bresolin, M., Di Mario, F. and Hajdas, I., 2018, Terra-mare: insediamenti lagunari e livello marino relativo durante l'età del bronzo in A., Vigoni, ed., Adriatico nord-occidentale, *Percorsi nel passato, Miscellanea di studi per i 35 anni del G.R.A.V.O. e i 25 anni della Fondazione Colluto*, 325-348, Fondazione A. Colluto, Portogruaro.

Fozzati, ed., 2002-3, *La galea ritrovata. Origine delle cose di Venezia*, Marsilio ed., Venice.

Franconi, T. V., 2016, Climatic influences on the riverine transport on the Roman Rhine, in C., Schaefer, ed., *Connecting the Ancient World. Mediterranean Shipping, Maritime Networks and their Impact,* 27-44, Verlag Marie Leidorf GmbH Geschäftsführer, Rahden/Westf.

Gaddi, D., 2001, *Approdi nella Laguna di Grado*, Antichità Altoadriatiche, 46, 261-276.

Ganzarolli, G., 2017, Le anfore dallo scavo presso il battistero e il commercio tardoantico a Padova, in A., Chavarria Arnau, ed., *Ricerche sul centro episcopale di Padova. Scavi 2011-2012*, SAP ed., Mantova, 195-207.

Garcia-Jaldon, C., Dupeyre, D. and Vignon, M.R., 1998, *Fibres from Semi-Retted Hemp Bundles by Steam Explosion Treatment*, Biomass and Bioenergy, 14.3.

Gaspari, A., 1998, <<Pontonium>> *iz Lip na Ljubljanskem barju*, Arheološki vestnik, 49, 187-224.

Gaspari, A., 2009, A cargo ship of Mediterranean sewn construction from Lipe, in P., Turk, J., Istenic, T., Knific and T., Nabergoj, eds, *The Ljubljanica-a River and its Past, Ljubljana*, 116-119, Narodni muzej, Ljubljana.

Gaspari, A., 2017, *The Late 2^{nd} Century BC Logboat from the Ljubljanica River at Vrhnika, Study on the Ships and Boats of Preroman and Roman Nauportus with the Outline of the Navigation on the Ljubljana Marshes between Prehistory and* *the Early Modern Period/Deblak s konca 2. stoletja pr. n. št. iz Ljubljanice na Vrhniki, Študija o ladjah in čolnih predrimskega in rimskega Navporta z orisom plovbe na Ljubljanskem barju med prazgodovino in novim vekom,* Ljubljana.

Gassend, J.-M., 1982, *Le Navire Antique du Lacydon, Musée d'histoire de Marseille*, Marseille.

Gassend, J.-M., Liou, B. and Ximénès, S., 1984, *L'épave 2 de l'anse des Laurons (Martigue, Bouches-du-Rhône),* Archaeonautica, 4, CNRS Ed., Paris, 75-106.

Geel van, B. and Aptroot, A., 2006, *Fossil Ascomycetes in Quaternary Deposits*, Nova Hedwigia, 82. 3-4, 313-329.

Gelichi, S., 2021, Oltre gli empori e il 'mare corrotto': Comacchio e l'Adriatico tra VIII e XI secolo, in Gelichi, S., Negrelli, C. and Grandi, E., eds., 2021, *Un emporio e la sua Cattedrale. Gli scavi di piazza XX Settembre e Villaggio San Francesco a Comacchio,* All'Insegna del Giglio, Florence, 641-739.

Gelichi, S. and Maioli, M.G., 1992, *La ceramica invetriata tardoantica e altomedievale dall'Emilia-Romagn*a, in L., Paroli ed., *La ceramica invetriata tardoantica e altomedievale in Italia*, All'Insegna del Giglio ed., Firenze, 215-278.

Gelichi, S., Negrelli, C. and Grandi, E., eds., 2021, *Un emporio e la sua Cattedrale. Gli scavi di piazza XX Settembre e Villaggio San Francesco a Comacchio,* All'Insegna del Giglio, Florence.

Giachi, G., Lazzeri, S., Mariotti Lippi, M., Macchioni, N. and Paci, S., 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, 4.4, 269-283.

Giachi, G., Capretti, C., Lazzeri, S., Sozzi, L., Paci, S., Mariotti Lippi, M. and Macchioni, N., 2017, *Identification of Wood from Roman Ships Found in the Docking Site of Pisa (Italy)*, Journal of Cultural Heritage, 23, 176-184.

Giovagnetti, C. and Negrelli, C., in press, *Materiali dallo scavo. Il quotidiano nelle stanze del chirurgo*, in J., Ortalli, ed., Ars medica.

Gluscevic, S., 2004, *Hydroarchaeological excavation and the discovery of the third 'sewn' Liburnian ship* – seriliae – *in the roman port of Zaton near Zadar*, Archaeologia Maritima Mediterranea, 1, 41-52.

Gonizzi Barsanti, S., Remondino, F. and Visintini, D., 2013, *3D surveying and modelling of archaeological sites – some critical issues*, Annals of the Photogrammetry, Remote Sensing and Spatial Information Science, II-5/W1, 145-166.

Grandi, E., 2015, *Un delta in movimento. Il caso di Comacchio tra tarda antichità e alto medioevo*, Reti Medievali Rivista, 16.2, 231-261.

Grandi, E. and Negrelli, C., 2021, Lo scavo di Villaggio San Francesco e i saggi nella zona dell'Ex Zuccherificio: la sequenza insediativa, in Gelichi, S., Negrelli, C. and Grandi, E., eds., *Un emporio e la sua cattedrale. Gli scavi di piazza XX Settembre Villaggio San Francesco a Comacchio*, All'Insegna del Giglio, Florence, 129-157.

Greck, S. and Guibal, F., 2011, Etude dendrologique de l'èpave Arles-Rhone *3*, in G., Boetto, P., Pomey and A., Tchernia, eds., *Batellerie Gallo-Romaine. Pratiques Régionales et Influences Maritimes Méditerranéennes*, 155-163, E. Errance, Paris.

Guarnieri, C., 2019, Lo scavo: scoperta, rinvenimenti, interpretazione e periodizzazione, in C., Guarnieri, ed., *La salina romana e il territorio di Cervia. Aspetti ambientali e infrastrutture storiche*, 109-128, Ante Quem srl, Bologna.

Guarnieri, C., Medas, S. and Pizzarello, U., 2010, Il relitto di barca fluviale del XV secolo rinvenuto nel centro storico di Ferrara, in S., Medas, M., D'Agostino and G., Caniato, eds., *Archeologia, Storia, Etnologia navale, Atti del I Convegno Nazionale (Cesenatico, 2008),* 89-100, Edipuglia, Bari.

Guibal, F., Ferreira Domínguez, A., Boetto, G., Shindo, L., Greck, S. and Pomey, P., 2021, *An overview of three decades of dendrochronology applied to ancient Mediterranean shipwrecks in southeastern France*, Archaeonautica, 21, 245-250.

Guidi, G., Russo M. and Beraldin, J-A., 2010, Acquisizione 3D e modellazione poligonale, McGraw-Hill Education ed., New York.

Guyon, M., 2010, *Méthodologie d'une fouille d'épaves en milieu terrestre*, Archaeonautica, 16, CNRS Éd., Paris, 25-34.

Guyon, M. and Rieth, E., 2011, Les chalands gallo-romains du Parc Saint-Georges, in G., Boetto, P., Pomey and A., Tchernia, eds., *Batellerie Gallo-Romaine. Pratiques Régionales et Influences Maritimes Méditerranéennes*, 91-101, Ed. Errance, Paris.

Haalebos, J. K., 1987, Een Romeins schip te Woerden, Lelystad, Rijksdienst voor de Ijsselmeerpolders, in Reinders, H. R., ed, *Flevobericht 280*, 25-28, Ministerie van verkeer en waterstaat, Rijksdienst voor de ijsselmeerpolders, Lelystad.

Haugan, E. and Holst B., 2013, *Determining the Fibrillar Orientation of Bast Fibre with Polarized KLight Microscopy: the Modified Herzog Test (red Plate Test) Explained,* Journal of Microscopy, 252.2, 159-168.

Holger-Egger, O., 1878, Liber Pontificalis Ecclesiae Ravennatis, in MGH, *Scriptores Rerum Langobardicarum et Italicarum Saec*, VI-IX, Hannover.

Holk, A., 2011, Recent research on Roman ship finds from the Netherlands, in G., Boetto, P., Pomey and A., Tchernia, eds., *Batellerie Gallo-Romaine. Pratiques Régionales et Influences Maritimes Méditerranéennes*, 33-43, Ed. Errance, Paris.

Ilvessalo-Pfäffli, 1995, *Fiber Atlas: Identification of Papermaking Fibers*, Springer Science & Business Media, Berlin.

Jézégou, M.-P., Andersch-Goodfellow, P., Labussière, J. and Sanchez, C., 2020, *Port antique: l'épave Madirac 1*, Bilan Scientifique du DRASSM 2014, 146-149.

Jones, T., Nayling, N. and Tanner, P., 2013, Digitally reconstructing the Newport Medieval Ship: 3D designs and dynamic visualizations for recreating the original hull form, loading factors, displacement, and sailing characteristics, in Breen, C. and Forsythe, W., *ACUA Underwater archaeology proceedings*, 123-130.

Jory, F., 2009, *L'ultimo dei barcari. Riccardo Cappellozza, una vita sul fiume,* Ed. Biblioteca dell'immagine, Pordenone.

Kahanov, J. and Linder, E., 2004, *The Ma'agan Mikhael Ship. The Recovery of a 2400-Year-Old Merchantman, final report, vol. 2*, Israel Exploration Society and University of Haifa, Haifa.

Kahanov, J., 2003, The hull, in E. Linder and Y. Kahanov, eds., *The Ma'Agan Mikhael Ship. The Recovery of a 2400-Year-Old Merchantman, Final Report, Vol. 1*, Israel Exploration Society and University of Haifa, Haifa.

Katz, N.J., Katz S. V. and Kipiani, M.G., 1965, *Atlas and Keys of fruits and Seeds Occurring in the Quaternary Deposits of the USSR, Nauka, 365* (In Russian).

Katz, N.J., Katz S. V. and Skobeyeva E.I., 1977, *Atlas of Plant Remains in Peat Soil*, Nedra (in Russian).

Kocabas, U., 2012, *The "Old Ships" of the "New Gate" / Yenikapi'nin Eski Gemileri -1,* Ege Yayinlari ed, Istanbul.

Koncani Uhac, I., Boetto, G. and Uhac, M., 2019, *Zambratija Prehistoric Sewn Boat. Results of the Archaeological Research, Analysis and Study*, Arheoloski muzej Istre, Pula.

Körber-Grohne, U., 1964, *Bestimmungsschlüssel für subfossile Juncus-samen und Gramineen-Früchte*, Ildesheim, Lax.

Krzywinski, K., Faegri K., Iversen J. and Kaland P.E., 2000, *Textbook of pollen analysis*, John Wiley and sons, Chichester.

Lavier, C., 2001, Apport de la dendrochronologie à l'étude de l'épave de Port-Berteau II, in E., Rieth, C., Carrière-Desbois, V. and Serna, V., *L'épave de Port Berteau II (Documents d'Archéologie Francaise)*, 129-132, Éditions de la Maison des sciences de l'homme, Paris.

Lazzari, G., Merloni, N. and Saiani, D., 2010, *Flora delle Pinete storiche di Ravenna, San Vitale, Classe, Cervia, Parco Delta del Po-Emilia Romagna*, Quaderni dell'IBIS, 4.63, 1-63.

Le Gall, J., 1944, *I bassorilievi della statua del Tevere,* Revue archéologique, Jul-Dec., 38-55.

Lemée, C., 2006, *The renaissance shipwrecks from Christianshavn, Ships and boats of the north, 6*, Viking Ship Museum/National Museum of Denmark, Roskilde.

Lucchini. A., 2020, Logboats and the river: utilisation of the Po Valley in Early Medieval times, in A., Marini, R. F., Teixeira da Conceição, J. C., Teixera, J. P., Martins Ferreira and Ferreira, L., eds., *Incipit 8. Workshop de Estudos Medievais da Universidade do Porto, 2019*, 10-22, Universidade do Porto, Porto.

Marlier, S., 2002, La question de la survivance des bateaux cousus de l'Adriatique, in L., Rivet and M., Sciallano, eds., *Vivre, produire et échanger: reflets méditerranéens. Mélanges offerts à Bernard Liou*, 21-32, Ed. Mergoil, Montagnac.

Marlier, S., 2006, An example of experimental archaeology and the construction of a full-scale research model of the Cavaliere ship's hull, in L., Blue, F., Hocker and A., Englert, eds., *Connected by the Sea. Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003*, 43-49, Oxbow Books, London.

Marlier, S. and Poveda, P., 2014, Présentation et analyse du système mécanique, in S., Marlier, ed., *Arles-Rhône 3, un chaland gallo-romain du ier siècle après Jésus-Christ* (Archaeonautica 18), 209-216, CNRS Ed., Paris.

Marlier, S., ed., 2014, *Arles-Rhone 3, un chaland gallo-romain du 1er siècle après Jésus-Christ* (Archaeonautica, 18), CNRS Ed., Paris.

Marocco, R., 1991, *Evoluzione tardo pleistocenica-olocenica del delta del fiume Tagliamento e delle lagune di Marano e Grado (Golfo di Trieste)*, AIQUA – Il Quaternario, 4 (l b), 223-232.

Marocco, R. and Gatto, F., 1991, *Caratteri morfologici e antropici della laguna di Grado (Alto Adriatico)*, Gortania, Atti del Museo Friulano di Storia Naturale, 14 (1992), 19-42.

Martin, A., 1998, La sigillata focese (Phocean red – slip / Late roman C Ware), in L., Saguì, ed., *Ceramica in Italia: VI-VII secolo*, I, All'Insegna del Giglio ed., Florence, 109-122.

Martorelli, M., Pensa, C. and Speranza, D., 2014, *Digital photogrammetry for documentation of Maritime Heritage,* Journal of Maritime Archaeology, 9, 81-93.

Marshall, J.A., 1992, The identification of Flax, Hemp, Jute and Ramie in Textile Artefacts, Unpublished MAster Thesis, University of Alberta.

Mauquoy, D. and Van Geel, B., 2007, *Plant macrofossil methods and studies: mire and peat macros*, *Encyclopedia of Quaternary Science*, 2315-2336, Elsevier Science, Amsterdam.

Medas, S., 2003, The Late-Roman "Parco di Teodorico" Wreck, Ravenna, Italy: Preliminary Remarks on the Hull and the Shipbuilding, in C., Beltrame, ed., *Boats, Ships and Shipyards. Proceedings of the 9th International Symposium on Boat and Ship Archaeology, Venice 2000*, 42-48, Oxbow Books, Oxford.

Mees, A. and Pferdehirt, B., 2002, *Römerzeitliche Schiffsfunde in der Datenbank >>Navis I<<,* Verlag des Römisch-Germanischen Zentralmuseums, Mainz.

Meier, K.S. and Willems, H., 2003, *Calcareous Dinoflagellate Cysts in Surface Sediments From the Mediterranean Sea: Distribution Patterns and Influence of Main Environmental Gradients*, Marine Micropalaeontology 48.3, 321-354.

Mercuri, A. M., Mazzanti, M., Florenzano, A., Montecchi, M.C. and Rattighieri, E., 2013, *Olea, Juglans and Castanea: the OJC Group as Pollen Evidence of the Development of Human-Induced Environments in the Italian Peninsula*, Quaternary International, 303, 24-42.

Mercuri, A. M., Accorsi, C. A. and Bandini Mazzanti, M., 2002, *The Long History of Cannabis and its Cultivation by the Romans in Central Italy, Shown by Pollen Records From Lago Albano and Lago di Nemi,* Vegetation History and Archaeobotany, 11.4, 263-276.

Mercuri, A.M., Allevato, E., Arobba, D., Bandini Mazzanti, M., Bosi, G., Caramiello, R. and Castiglioni, E., 2015, *Pollen and Macroremains from Holocene Archaeological Sites: A Dataset for the Understanding of bio-Cultural Diversity of the Italian Landscape*, Review of Palaeobotany and Palynology, 218, 250-266.

Miola, A., Favaretto, S., Sostizzo, I., Valentini, G. and Asioli, A., 2010, *Holocene Salt Marsh Plant Communities in the North Adriatic Coastal Plain (Italy) as Reflected by Pollen, non-Pollen Palynomorphs and Plant Macrofossil Analyses*, Vegetation History and Archaeobotany 19.5-6, 513-529.

Miola, A. and Valentini, G., 2004, *La via Annia a Ca' Tron: il contributo dell'analisi palinologica*, in F., Ghedini and M.S., Busana, 147-162, Grafiche Antiga, Treviso.

Moser, D., Nelle, O. and Di Pasquale, G., 2018, *Timber Economy in the Roman Age: Charcoal Data from the Key Site of Herculaneum (Naples, Italy)*, Archaeological and Anthropological Sciences, 10.4, 905-921.

Muellner, A., 1892, *Ein Schiff im Lalbascher Moore,* Argo, 1, 1-7.

Muller, S.D., 2004, *Palynological Study of Antique Shipwreck from the Western Mediterranean Sea, France,* Journal of Archeological Science, 31.3, 343-349.

Nardi Berti, R, 2006, *La struttura anatomica del legno ed il riconoscimento del dei legnami italiani di più corrente impiego*, Ivalsa, Sesto Fiorentino.

Negrelli, C., 2015, Dal VI all'VIII secolo: continuità e rotture nella circolazione dei manufatti ceramici tra Romagna e Delta padano, in E., Cirelli, F., Diosono and H., Patterson, eds., *Le forme della crisi. Produzioni ceramiche e commerci nell'Italia centrale tra Romani e Longobardi (III-VIII sec. d.C.), Atti del Convegno, Spoleto – Campello sul Clitunno, 5-7 ottobre 2012,* Ante Quem ed., Bologna, 139-152.

Negrelli, C., 2018, Jesolo tra IV e V secolo: una stazione itineraria?, in S., Gelichi, S., Cadamuro and A., Cianciosi, eds., In limine. *Storie di una comunità ai margini della laguna,* All'Insegna del Giglio ed., Firenze 2018, 28-35.

Negrelli, C., 2021, Le ceramiche tardoantiche e altomedievali in Gelichi, S., Negrelli, C. and Grandi, E., eds., 2021, *Un emporio e la sua Cattedrale. Gli scavi di piazza XX Settembre e Villaggio San Francesco a Comacchio,* All'Insegna del Giglio, Florence, 201-276.

Negrelli, C., Bracci, F. and Rucco, A.A., 2016, I materiali ceramici dalla tarda antichità alla prima età altomedievale, in M., Miari and C., Negrelli, eds., *Ritmi di transizione 2, dal Garampo al Foro Annonario: campagne 2009-2013*, All'Insegna del Giglio ed., Firenze 2016, 93-130.

Nieto, X. and Santos, M., 2008, *El vaixell Grec arcaic de Cala Sant Vicenç*, Museu d'Arqueologia de Catalunya, Barcelona.

Ossowski, W., 2010, *Przemiany w szkutnictwierzecznym w Polsce, Gdańsk,* Centralne Muzeum Morskie w Gdańsku.

Pacetti, F., 1998, La questione delle Keay LII nell'ambito della produzione anforica in Italia, in L., Sanguì, ed., *Ceramica in Italia: VI-VII secolo: atti del Convegno in onore di John W. Hayes: Roma, 11-13 maggio 1995*, 185-208, All'Insegna del Giglio, Florence.

Paschini, P., 1934, *Storia del Friuli*, Arti Grafiche Friulane, Udine.
Patitucci Uggeri, S., 1970, *Comacchio (Valle Pega). Necropoli presso l'ecclesia beatae Mariae in Padovetere*, Notizie Scavi, s. 8, 24, 69-121.
Parizzi, S. and Beltrame, C., 2020, *Calculating the Tonnage and the Dimension of the Cargoes of Marble of Roman Period*, Digital Applications in Archaeology and Cultural Heritage, 18, online.
Peruzzi, L., 2014, Un giogo dai contesti tardo-antichi del Cantiere delle Navi di Pisa, in A., Asta, G., Caniato, D., Gnola and S., Medas, eds., *Navis 5. Archeologia, Storia, Etnologia navale, Atti del II Convegno Nazionale (Cesenatico, 2012)*, 377-379, Libreriauniversitaria, Padova.
Pferdehirt, B., 2002, Das schiff 6 aus Mainz, in A., Mees and B., Pferdehirt, eds, *Römerzeitliche Schiffsfunde in der Datenbank NAVIS I*, 100-103, Römischen-Germanischen Zentralmuseums, Mainz.
Pignatti, S, 1982, *Flora d'Italia*, Edagricole, Bologna.
Pieri, D., 2005, *Le commerce du vin oriental à l'époque byzantine (V^e^ – VII^e^ siècles). Le témoignage des amphores en Gaule*, IFPO ed., Beyrouth.
Pomey, ed., 1997, *La Navigation dans l'Antiquité,* Edisud, Paris.
Pomey, P., Kahanov, Y. and Rieth, E., 2012, *Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: analysis, problems, and future research,* The International Journal of Nautical Archaeology, 41.2, 235-314.
Pomey, P. and Boetto, G., 2019, *Ancient Mediterranean Sewn-Boat Traditions,* The International Journal of Nautical Archaeology, 48.1, 5-51.
Portale, E. C. and Romeo, I., 2001, Contenitori da trasporto, in A., Di Vita, ed., *Gortina V.3. Lo scavo del Pretorio (1989-1995), vol. V.3* t.I. I materiali*, Bottega D'Erasmo, Padova, 260-410.
Poveda, P., 2012, Hypothetical Reconstruction of the Dramont E Shipwreck, in Gunsenin, N., ed., *Between continents Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009*, 331-336, Yayinlari, Istanbul.
Poveda, P., 2015, *Méthode de restitution des navires antiques: nouveaux outils et Nouvelles analyses des restitutions en archéologie navale,* Revue d'histoire maritime, 21, 157-179.
Poveda, P. and Boetto, G., 2018, Napoli A, un voilier abandonné dans le port de Neapolis à la fin du Ier siècle: architecture, fonction, restitution et espace de navigation, in Boetto, G. and Rieth, E., eds., De re navali *Pérégrinations nautiques entre Méditerranée et océan Indien* (Archaeonautica, 20), 19-56, CNRS ed, Paris.
Pulak, C., 1999, *Hull Construction of the Late Bronze Age Shipwreck at Uluburun,* INA Quarterly, 26.4, 16-21.
Pulak, C., Ingram, R. and Jones, M., 2015, E*ight Byzantine shipwrecks from the Theodosian habour excavations at Yenikapi in Istanbul, Turkey: an introduction,* The International Journal of Nautical Archaeology, 44.1, 39-73.
Radic Rossi, I., Casaban, J.L., Yamafune, K., Torres, R. and Batur, K., 2014, Systematic Photogrammetric Recording of the Gnalić Shipwreck Hull Remains and Artefacts, in McCarthy, J., Benjamin, J., Winton, T. and van Duivenvoorde, W., eds., *3D Recording and Interpretation for Maritime Archaeology. Coastal Research Library, vol 31.* Springer, Cham.
Ravn, M., 2012, Recent Advances in Post-Excavation Documentation: Roskilde Method, in Gunsenin, N., ed., *Between continents Proceedings of the Twelfth Symposium on Boat and Ship Archaeology, Istanbul 2009,* 313-317, Yayinlari, Istanbul.
Reimer, P.J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., *et al.*, 2013, IntCal13 and Marine13 Radiocarbon age Calibration Curves 0-50,000 Years cal BP, Radiocarbon 55.4, 1869-1887.
Reynolds, P., 2010, Trade networks of the East, 3^rd^ to 7^th^ centuries: the view from Beirut (Lebanon) and Butrint (Albania) (fine wares, amphorae and kitchen wares), in S., Menchelli, S., Santoro, M., Pasquinucci and G., Guiducci, eds., *LRCW 3. Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean. Archaeology and archaeometry. Comparison between western and eastern Mediterranean*, voll. I-II, Archaeopress ed., Oxford, 89-113.
Remondino, F. and Rizzi, A., 2010, *Reality-based 3D documentation of natural and cultural heritage sites – techniques, problems and examples*, Applied Geomatics, 2.3, 85-100.
Ribechini, E., 2009, Direct Mass Spectrometric Techniques: Versatile Tools to Characterise Resinous Materials, in Colombini, M. P. and Modugno, F., eds., *Organic Mass Spectrometry in Art and Archaeology*, 77-96, John Wiley & Sons, New York.
Rieth, E., 1998, *Des Bateaux et Des Fleuves. Archéologie de la batellerie du Néolithique aux Temps modernes en France*, Ed. Errance, Paris.
Rieth, E. and Guyon, M., 2010, Les épaves Gallo-Romaines, in Rieth, E., ed., *Les épaves de Saint-Georges-Lyon (Ier-XVIIIe siècles)* (Archaeonautica, 16), 35-104, CNRS, Ed. Paris.
Rigaud, P., 2004, La navigation dans le delta, in Landuré, C. and Pasqualini, M., eds., *Delta du Rhône. Camargue antique, médiévale et moderne (Bulletin Archéologique de Provence, suppl.2)*, 271-276, Ed. de l'Association Provence Archéologie, Aix-en-Provence.
Rival, M., 1991, *La charpenterie navale romaine*, Ed. du CNRS, Paris.
Robinson, N., Evershed, R. P, Higgs, W., Jerman, J., and Eglinton, K., 1987, *Proof of a Pine Wood Origin for Pitch from Tudor (Mary Rose) and Etruscan Shipwrecks: Application of Analytical Organic Chemistry in Archaeology*, The Analyst, 112, 637-644.
Rossetti, E., 2020, Anfore e terra sigillata italica dal Lago Tramonto, Gambulaga (FE), in G., Bucci, ed., *Il fiume nel lago. Dieci anni di ricerche archeologiche subacquee nel Lago Tramonto a Gambulaga (FE)*, Accademia delle Scienze di Ferrara ed., Ferrara, 109-146.
Rossi, I. R. and Boetto, G., 2020, *The Roman Scuttled Ships and Harbour Structures of Caska, Pag Island, Croatia in their Cultural and Historical Context*, The International Journal of Nautical Archaeology, 49.2, 263-290.
Rucco, A.A., 2015, *Comacchio nell'alto medioevo. Il paesaggio tra topografia e geoarcheologia*, All'Insegna del Giglio, Florence.
Rucco, A. A., Mozzi, P. and Ninello, E., 2015, Indagini nell'area di S. Maria in Padovetere in Valle Pega, in A. A. Rucco., ed., *Comacchio nell'alto Medioevo. Il paesaggio tra topografia e geoarcheologia*, 95-104, All'Insegna del Giglio, Florence.
Rucco, A. A., 2021, L'ambiente e l'uomo nell'entroterra comacchiese tra VII e X secolo d.C., in Gelichi, S. Negrelli, C. and Grandi, E., eds., *Un emporio e la sua cattedrale. Gli scavi di piazza XX Settembre Villaggio San Francesco a Comacchio*, 583-607, All'Insegna del Giglio, Firenze.
Sadori, L., Allevato, E., Bellini, C., Bertacchi, A., Boetto, G., Di Pasquale, G., Ermolli, E. R. 2015, *Archaeobotany in Italian Ancient Roman Harbours*, Review of Palaeobotany and Palynology, 218, 217-230.
Salemke, G., 1973, *Die Ausgrabung eines Binnensee Transportschiffes. Schiffsarchäologie von 1890 aus Laidbach, Österreich (jetzt Ljubljana in Jugoslavia),* Das Logbuch, 9.1, 21-24.
Schweingruber F.H., 1990, *Anatomie europäischer Hölzer. Ein Atlas zur Bestimmung europäischer Baum-, Strauch- und Zwergstrauchhölzer*, Verlag Paul Haupt, Bern und Stuttgart.
Scrinari, V. S. M., ed., 1979, *Le navi del porto di Claudio,* Ed. Viella, Rome.

Shimony, C. and Werker, E., 2003, The Plant and Lashing, in E., Black, eds., *The Ma'agan Mikhael Ship. The recovery of a 2400-Year-Old-Merchantman, Final Report, Vol 1*, Israel Exploration Society and University Haifa, Haifa.

Stefani, M. and Vincenzi, S., 2005, *The Interplay of Eustasy, Climate and Human Activity in the Late Quaternary Depositional Evolution and Sedimentary Architecture of the Po Delta System*, Marine Geology, 222-223, 19-48.

Stuart, P. and Bogaers, J.E., 2001, *Nehalennia: römische Steindenkmäler aus der Oosterschelde bei Colijnsplaat, Rijksmuseum van Oudheden*, Leiden.

Tanner, P., 2013a, *Digital reconstruction and analysis of the Newport ship, Newport Medieval Ship Archive*, Archaeological Data Service, York.

Tanner, P., 2013b, 3D *Laser Scanning for the Digital Reconstruction and Analysis of a 16th century Clinker Built Sailing Vessel,* ACUA, Underwater Archaeological Proceedings, 137-169.

Tanner, P., 2020, *The reconstruction and analysis of archaeological boats and ships,* University of Southampton, Doctoral Thesis.

Tanner, P. and Belasus, M., 2021, The Bremen-Cog: reconstructed one more time, in G., Boetto, P. Pomey and P., Poveda, eds., *Open Sea – Closed Sea. Local and Inter-Regional Traditions in Shipbuilding (15th International Symposium on Boat and Ship Archaeology, Marseille)* (Archaeonautica, 21), 315-324, CNRS ed., Paris.

Tejedor, C. C., 2018, T*he Mazarròn 1 Shipwreck: an iron-age boat with unique features from the Iberian Peninsula,* The International Journal of Nautical Archaeology, 47.2, 300-324.

Tempesta, C., 2018, Anfore da trasporto, in C., Guarnieri and G., Montevecchi, eds., *Il Genio delle Acque. Scavi nelle piazze di Ravenna*, Longo, ed., Ravenna, 131-143.

Tiboni, F., 2009, *Chioggia. Località di Motta di Cavanella d'Adige. Le operazioni di scavo e primo studio di un relitto del II-I secolo a.C.,* Quaderni di Archeologia del Veneto, 25, 82-84.

Trakadas, A., 2011, *The Skuldelev Reconstruction Project: Progress and Perspectives,* ACUA Underwater Archaeology Proceedings, 41-48.

Turato, G.F., Sandon, F., Romano, A., Assereto, A. and Pergolis, R., 1980, *Canali e burci,* La Galiverna ed., Padova.

Uggeri, G., 1990, *Aspetti archeologici della navigazione interna nella Cisalpina,* Antichità Altoadriatiche, 36, 175-196.

Viano, J., Masotti, V. and Gaydou, E. M., 1999, *Nutritional Value of Mediterranean Sheep's Burnet (Sanguisorba minor ss. Muricata)*, Journal of Agricultural and Food Chemistry, 47.11, 4645-4648.

Vitri, S, Bressan, F., Maggi, P., Dell'Amico, P., Martinelli, N., Pignatelli, O. and Rottoli, M., 2003, Il relitto romano del fiume Stella (Ud), in F. Lenzi, ed., *L'Archeologia dell'Adriatico dalla Preistoria al Medioevo, Atti del Convegno Internazionale (Ravenna, 7-8-9 giugno 2001),* 324-338, All'Insegna del Giglio, Florence.

Walker, A., 2019, *Atlante del Legno*, Unico Hoepli Editore, Milan.

Ward, C., 2000*, Sacred and Secular: Ancient Egyptian Ships and Boats,* The University Museum, Philadelphia.

Weerd de, M. D., 1977, *Römerzeitliche Transportschiffe und Einbäume aus Nigrum Pullum/Zwammerdam (Z.-H.),* Studien zu den Militärgrenzen Roms, 2, 187-198 and plates 13-19.

Weerd de, M. D. and Haalebos, J. K., 1973, *Schepen voor het opscheppen. Het scheepsarcheologisch onderzoek te Zwammerdam: inheemsen Romeinse vaartuigen in het haventerrein van het castellum Nigrum Pullum*, Spieg. Hist 8, 386-397.

Wicha, S. and Verlaque, R., 2019, Identification of waterproofing materials, in Koncani Uhac, I., Boetto, G. and Uhac, M., 2019, *Zambratija Prehistoric Sewn Boat. Results of the Archaeological Research, Analysis and Study*, 128-133, Arheoloski muzej Istre, Pula.

Willis, S., 2017, *Insights into the Manufacture of Laced Watercraft Through a Pollen Analysis of the Fibrous Materials from Roman-era Laced Boats of the Upper Adriatic, Italy*, Palynology, 41.4, 484-492.

Willis, S. and Capulli, M., 2018, *A Report on the Late 1st-2nd-Century-AD Venice Lido III Sewn Timber Assemblage,* The International Journal of Nautical Archaeology, 47.2, 343-356.

Zangheri, P., 1936, *Romagna fitogeografica: Flora e vegetazione delle pinete di Ravenna e dei territori limitrofi fra queste e il mare*, P. Valbonesi, Forlì.

INDICE

THE SHIPWRECK OF SANTA MARIA IN PADOVETERE (COMACCHIO-FERRARA)

Archaeology of a riverine barge of Late Roman period and of other recent finds of sewn boats

Insegnamento di Archeologia Medievale – Dipartimento di Studi Umanistici, Università Ca' Foscari Venezia

Con il contributo di

Dipartimento di Studi Umanistici – Università Ca' Foscari Venezia

Questo libro è stato stampato grazie al finanziamento PRIN 2017 per il progetto FOOD&S.T.O.N.E.S. (CUP H74I17000170003)

Università Ca' Foscari Venezia

The 5th century AD barge of Santa Maria in Padovetere was discovered and investigated inside an ancient river, West of Comacchio. The place, which later hosted the parish of Santa Maria in Padovetere, is considered a strategic crossroads of Late Roman waterways.

The anoxic conditions have well preserved the bottom and the entire right side. This extraordinary conservation, coupled with *in situ* digital documentation, has allowed the reconstruction in 3D of the entire shape of the shipwreck. It was a riverine flat bottom barge with a very high stern and a central long rudder according to a shipshape well documented by Central European Roman sculptures. Scientific analysis allowed to reconstruct the environment where it moved and to make hypotheses on the types of goods transported. This is a very rare example of an ancient riverine barge and an important evidence of the technique of construction by sewing. The book also presents other recent finds of this construction technique which, during the Roman period and the Early Middle Age, was used only in the Upper Adriatic.

€ 54,00

ISBN 978-88-9285-198-6

e-ISBN 978-88-9285-199-3

MONOARC-141

Carlo Beltrame and Elisa Costa

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Germano Degan, Alessandra Forti, Dario Gaddi, Antonella Miola, Paolo Mozzi, Claudio Negrelli and Alessandro Alessio Rucco, foreword by Sauro Gelichi